551

A FAWCETT BOOK

STEREO HI-FI

HANDBOOK · No. 3

75c

By JOSEPH MARSHALL

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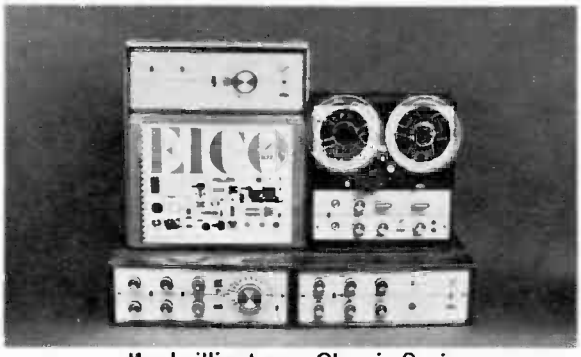

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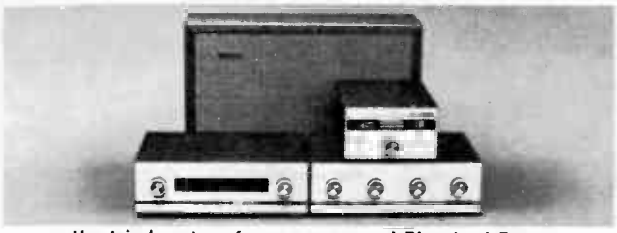

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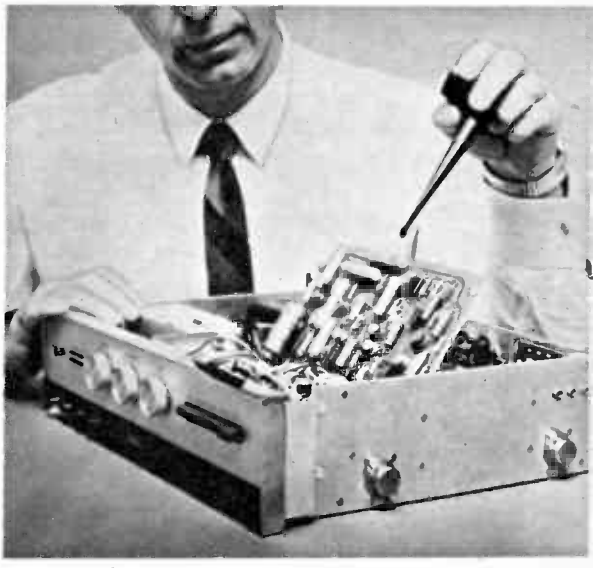

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IT ISN'T really necessary to know very much about the technical aspects of high fidelity to buy a satisfactory system or to listen to one—but it helps.

For one thing, a little knowledge at least of the meaning of the terms, will give you some protection against the seller of inferior or nonstandard products. For another, a little knowledge will enable you to determine more accurately what kind of system will serve your own particular needs best and to obtain the maximum performance from it. Finally, the ability to talk intelligently about high fidelity is often as much a measure of sophistication as the ability to talk intelligently about vintage wines.

No one can make you a high fidelity expert in three or four easy lessons. But on the other hand, the subject is by no means as mysterious or complicated as it may seem at first hearing or reading; and the fundamentals are quite simple.

Let us begin by considering the nature of sound. First of all, and this is both basic and of practical importance, sound exists only in your mind. It is an experience or an event, not a *thing*. If there were no ears and minds to hear it, a thunderstorm would be perfectly silent. The stimulus which produces sound can be measured by instrument but *sound* itself cannot be measured directly as yet; and our present indirect measurements indicate that it differs in every individual. I stress this because it points out the fundamental fact that sound is subjective, not objective. What is heard depends as much on the person who hears it as on the stimulus that produces the sensation.

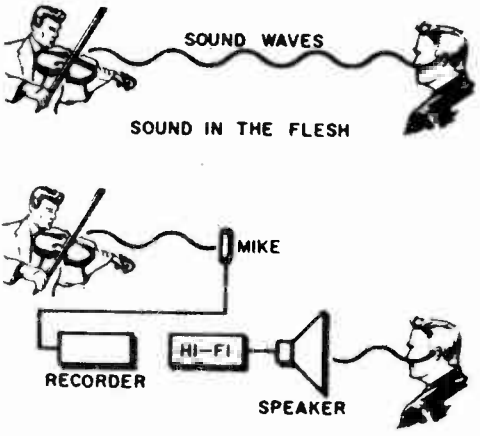
We are going to be talking about many aspects of sound in terms of measured quantities and qualities; but it is important to understand that in doing so we will *not* be talking about what you will actually hear or experience, but rather about the external stimulus that will strike your hear. This, of course, is important. You won't be able to hear, for example, a 20,000 cycle sound, assuming your ear is capable of hearing it, if the system does not deliver the necessary stimulus. But it is equally true that each of 100 or 1000 or 1 million people listening to the same hi-fi system, will hear (or not hear) something at least slightly different.

Thus, while the criterions we will be discussing will give you the means of judging what kind of *stimulus* a hi-fi system will present to your ears, only you yourself can judge the *sound* of the system. The purpose of high fidelity is to satisfy *your* ears, not instruments; and one of the great virtues of components type high fidelity is that there is a sufficient variety of difference in the characteristics of the systems available to provide satisfaction to almost any ear, as well as almost any purse.

Sound is generated in your ears by vibrations in the air. These vibrations vary the pressure on your ear and thus actuate the wonderful, and still mysterious, process in your mind that produces the sensation of sound.

We speak of the vibrations, or changes of pressure in the air, as "sound waves." No one knows whether "sound waves" as we picture them actually exist; but our picture of them does give us a good understanding of what goes on and hence we accept it as valid.

FIG. 1—HOW HI-FI WORKS



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We assume that when a fiddle plays a note, the air in front of it is formed into a series of waves very much like those produced when we throw a rock into a pool of water, or when a fish rises to take a fly. We picture these waves in cross-section with a wavy line as a Fig. 1, traveling from the violin to the ear.

Sound waves have two basic parameters or "quantities." The first is *amplitude* which is the height of the waves. The more intense the shock to the air, the higher the amplitude of the waves and the higher the amplitude of the waves, the louder the sound produced in the ear.

The second is *frequency*. Most sounds have a recurrent waveform—that is, they produce a series or train of waves. We can measure the number of these waves that pass a given spot in a second and we call this the frequency of the waveform or sound. The frequency of the waveform determines the pitch of the sound we will hear. The higher the frequency the higher the pitch of the sound; the lower the frequency the lower the pitch.

The waveforms that produce audible sound in human ears range from something under 20 cycles per second, to something over 20,000 cycles per second. This varies with the individual. Young children and young adults can usually hear sounds produced by vibrations of 20,000 cycles; but the ability to hear these waveforms decreases with age and most people over 45 experience little or no sensation of sound to waveforms above 12,000 or 15,000 cycles per second. This, however, does not mean that a hi-fi system that also stops at 12,000 or 15,000 cycles a second will be as good to these older ears as a system that goes to 20,000 cycles or higher. More of this later.

Ears differ also in their reaction to the amplitude of sound waveforms. At very loud levels—approaching what is called the "threshold of pain"—a 50-cycle wave will produce just about the same "loudness" to the ear as a 1000 cycle or 10,000 cycle wave. But at relatively low levels, the 50-cycle wave will seem very much less loud than a 1000-cycle tone of the very same amplitude. This variation in the perception of amplitude is called the "loudness contour" and differs from individual to individual.

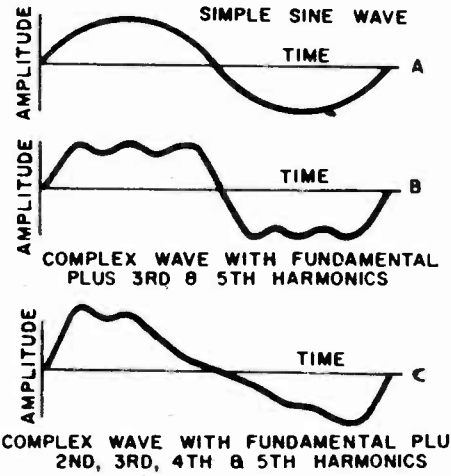
The simplest type of waveform is the "sine wave" and this is a nice smooth, snaky curve like that of A in Fig. 2. Not that it matters, but it is called a "sine" wave because it can be described mathematically in terms of the "sine" of an angle. It is rather doubtful that a pure sine wave is produced by any natural phenomenon or any musical instrument, though we can generate them very easily with electronic gadgets. Most waveforms are more complex and less smooth in form and shape.

We have found it helpful to think of complex waves as consisting of combinations of sine waves; and in any event it is possible to analyze most musical sound waves into combinations of a "fundamental" and several "harmonics." The fundamental is the component of the lowest frequency; "harmonics" are components which are multiples of the fundamental. For example, a bass tone could be analyzed into a fundamental of 100 cycles, plus harmonics 200, 300, 400, etc., cycles in frequency. The fundamental establishes the basic pitch of the sound, and the combination of harmonics establishes the "timbre" or tone quality or individuality of all musical instruments.

Every instrument produces a slightly different combination of fundamental and harmonics. Some generate only even order harmonics—that is 2nd, 4th, 6th, 8th, etc., times the fundamental; some generate only odd order harmonics, that is the 3rd, 5th, 7th, 9th, etc.; and some generate both even and odd order harmonics.

The proportion of the "mixture" of fundamental and harmonics also varies from instrument to instrument. In most cases the fundamental has the highest amplitude, and the harmonics are considerably lower. But, in some cases, the harmonics are higher in amplitude than the fundamental. For example, the most conspicuous difference in the waveform of the voice of a basso and a baritone, singing the same

FIG. 2



Sound waves are complex combinations of fundamentals and overtones. Each of the musical instruments produces a distinctly individual waveform. This partly accounts for the difference in tone.

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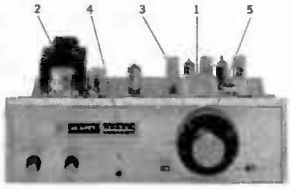

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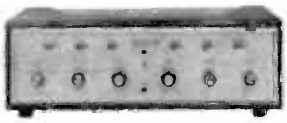

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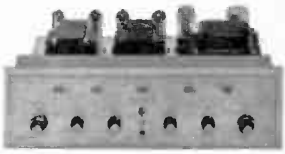

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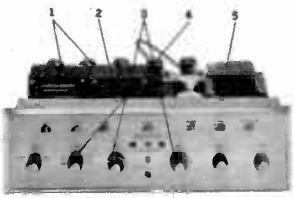

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Hum Level(db)	—80	—80	—70
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note, is that in the waveform of the basso the fundamental is stronger than any harmonic, whereas in the baritone, the harmonics tower over fundamental.

It is extremely important to note, however, that the actual waveform of any instrument is not a "bundle" of sine waves but a single complex wave. Our analysis is artificial. The waveform of B in Fig. 2 shows the actual waveform of a sound produced (or analyzable into) a combination of a wave of a given frequency, with waves 3 times and 5 times the fundamental frequency, or the 3rd and 5th harmonics of the fundamental. The waveform in C is the waveform of a fundamental plus the 2nd, 3rd, 4th and 5th harmonics. Notice that it is not readily possible from a look at these shapes to find the individual harmonics. Notice, also, how different the waveform is for these combinations.

Because, it is possible to analyze these complex waves into combinations of sine waves, it has often been assumed that any system capable of passing the individual sine waves of the combination will be able to pass the complex waveform. In other words, if we have a complex wave analyzable into a 20-cycle fundamental, plus every harmonic up to the 20th, which would be 400 cycles, it has been assumed that if the system will pass all the pure sine waves from 20 to 400 cycles it will pass the complex wave. Similarly, it has been assumed that since the most critical and acute human ear is capable of "hearing" individual sine waves from 20 to 20,000 cycles, a system capable of passing individual sine waves from 20 to 20,000 cycles will be capable of reproducing any complex waveform the ear can distinguish.

This has given us the simplest and one of the most basic measures of a hi-fi system—the "frequency response." To measure this we pass individual sine waves of exactly the same amplitude through the system and measure the output to see what variation exists at the output. If the system passes all sine waves from 20 to 20,000 cycles equally well, the curve of the response would be a straight line and we would then say the response is "flat."

You will note in all the curves, that we measure the amplitude in terms of something called a "decibel." Actually a decibel is not a measure of absolute quantity—like an inch, or a mile, or a pound. One decibel is the smallest *difference* in amplitude between two sounds that the human ear can distinguish. Of course, when we measure an amplifier we are not measuring the actual sound, but rather the voltage, current or power of the electrical current going through it. However, it has been determined that a difference between two voltages of 1.12 to 1, or two powers of 1.26 to 1 will produce a 1db difference in the sound the electric current will generate when it is translated into sound waves by the loudspeaker. Thus measuring the frequency response in terms of decibels, rather than volts or watts, gives us a more relevant idea of how the frequency response of an amplifier will affect the sound we hear. For example, in terms of power the difference between 100 and 126 is pretty sizable; but in terms of the sound the ear will hear it represents the smallest difference that even an acute ear will discern. Plotting the frequency response in terms of decibels (abbreviated "db") produces a much flatter curve than we would get if we plotted it in terms of volts or watts, but one which is actually much more representative of the effect on our ears.

Before we continue, let us digress for a moment to examine what a hi-fi system is. In essence it is simply a system that permits us to hear sounds generated at a different time and place. To do this we must have a very long chain of conversions, and gadgets to accomplish them. The original waveforms are captured by a microphone. The microphone is simply a device which translates changes in the pressure of the air into an electric current. If the microphone is perfect, the electric current it generates will vary in frequency and amplitude precisely as the waveform of the sound, and thus it will provide an electrical replica of the sound waves. This electric current is amplified and is used to drive a recorder which is a device that translates an electric current into mechanical motion. The current drives a sharp cutter over the surface of a lacquer disc and cuts into it wiggles which, if the recorder is perfect, are also facsimiles of the original sound waves. The disc can now be duplicated, stored, sold and bought by you.

In your home you put the disc on the turntable of a hi-fi system. The wiggles in the groove vibrate the needle or stylus in the pickup. The pickup translates these vibrations into an electric current that is a replica of the original waveform. This current is amplified and drives the loudspeaker. A loudspeaker is a device which translates an electric current into soundwaves. The electric current moves the diaphragm back and forth; this varies the pressure on the air, producing sound

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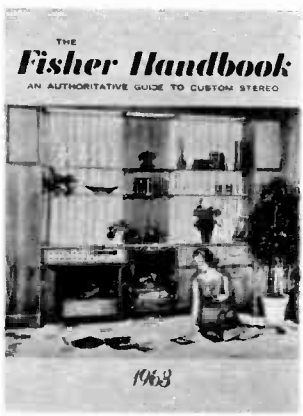

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waves which arrive at your ear; and, if the whole chain was perfect, the sound you hear in your home will be precisely the same sound you would have heard if you were on the spot where the music was played in the first place, even though this might have been years and thousands of miles away from the time you are hearing it.

Obviously, in view of the number of steps in this whole process and considering that the waveform can be modified in each of the steps, achieving complete fidelity—that is, delivering to the ear precisely the same sound that existed in the first place—is a pretty big order to fill. The remarkable thing is that it can be done—at least it can be approached so closely that most people cannot tell the difference between a recording and the actual live performance in side by side comparisons when the finest of available equipment is used. True, the highest fidelity cannot be achieved inexpensively; but a very satisfying degree of it, and a high illusion of actual presence at the original event, can be obtained at a quite moderate cost.

It is perfectly obvious that to reproduce waveforms perfectly the entire system, *from one end to the other,* must be capable of reproducing the waveforms perfectly. In the advertisements of the big brand hi-fi packages, you will usually find the sentence "the amplifier responds to all frequencies from 20 to 20,000 cycles, the complete range of human hearing," or something similar. This might, and usually does, give the impression that the entire system has this response. The fact is that the "overall" response of the entire system in these packages is seldom better than 60 to 10,000 cycles.

It is relatively easy to obtain a response from 20 to 20,000 cycles in the electronic portion of the system—the amplifiers and preamplifiers—though even here there is plenty of room for ambiguity that may make a sow's ear look like a silk purse to the casual and uninformed reader.

It is common to specify the frequency response of amplifiers in several ways: at "average levels," at "full rated power output" most recently, in terms of "power bandwidth."

"Average level" is 1 watt or less. Any bright high-school boy can produce an amplifier with a response flat from 20 to 20,000 cycles at 1 watt with parts scrounged from junked radios and TVs. Therefore, the response at average levels is a two-bit measure which merely separates infants from little boys.

The waveform of a violin tone (diagram at the left) is very different from a sine wave (diagram at the right) of the very same fundamental pitch.

It is true that most of the time the hi-fi amplifier will be delivering 1 watt or less to the loudspeakers. But some of the sounds that contribute the most to the impressiveness and awesomeness of music will require the amplifier to push 10 watts or more into the speaker during short peaks. Therefore, to reproduce a symphony orchestra faithfully, an amplifier should be able to deliver at least 10 watts over the full 20 to 20,000 cycle range.

Especially significant, because it is the most difficult and expensive to obtain, is the response in the lowest octaves from 20 to 60 cycles, and the highest octave from 10,000 to 20,000 cycles. This is where the boys are separated from the men. Only the finest amplifier will be flat from 20 to 20,000 cycles at maximum output. Page 24 gives the response of three classes of hi-fi amplifiers—the finest, good and minimum—at a level of 1 watt. You will note that the minimum amplifier is flat here from 20 to 20,000, but the finest is flat from almost zero to 100,000 cycles. In B we have the response of the same amplifiers at their maximum rated power output. You will note that the minimum amplifier is now flat only from 40 to 10,000 cycles, whereas only the finest amplifier remains flat from 20 to 20,000.

Because this *power response* is so much more indicative of performance capabilities, it is less often given in manufacturer's specifications, and almost never given in the case of the big brand package hi-fis.

To make amplifiers look somewhat better than they really are, a more recent standard called the "power bandwidth" has been established. This gives the response at *one half* the rated output power of the amplifier, and greatly favors the poor amplifier over the good one. The "power bandwidth" of the fine amplifier is exactly the same over the 20 to 20,000 range at full power as at half-power. But a poorer amplifier may have a flat response at half-power from 20 to 20,000 cycles, but only 50 to 10,000 cycles at full power.

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when we get to the transducers—the phono pickup and the loudspeaker. There are a number of pickups today flat within 2 or 3db from 20 to 20,000 cycles. The majority will be flat to 15,000 and the less expensive ones to 10,000. The drop off in response beyond the flat range is quite severe. The 15,000 cycle pickup may be as much as 10db down at 20,000 cycles.

The most difficult and expensive point at which to get a full range response is the loudspeaker. The problem here is largely at the low end. There are one or two commercial speaker systems capable of reproducing at least a portion of the lowest octave below 30 cycles; but they cost from $500 to $1000 apiece. Experience has shown that not too much is lost with a speaker response flat to 30 cycles. The average listener, more interested in music than complete fidelity, will be content with a response to 40 cycles. Speaker response is by no means as smooth as that of amplifiers or even pickups. There are usually many peaks and valleys in the response curve caused by resonances in the speaker or the room in which it is measured. The curves of D on page 24 are smoothed out curves of three classes of loudspeakers.

The "overall response" of a hi-fi system is very little if any better than that of the poorest elements in it, usually the loudspeaker and pickup. The minimum for an acceptable degree of fidelity would be something on the order of 50 to 12,000 cycles; the response of medium systems, on the order of 40 to 16,000 cycles; and of the finest systems from 30 to 20,000 cycles.

DISTORTION

To reproduce the original sound perfectly, the waveform must pass through the entire high fidelity system without being changed or deformed. But the waveform is very easily changed at every step in the process. For example, most of the elements in the chain can be generators as well as reproducers. They will generate harmonics of the waveform they are passing. In other words, if they are handling a 100 cycle tone, they will generate 200, 300, 400, etc., cycle waveforms. These are added to the waveform passing through the system and obviously change the shape of the waveform and therefore the sound that it will produce. For example, if the sine wave A of Fig. 1 is put through a system which generates odd harmonics—the 3rd, 5th, and 7th—the waveform coming out of the system might look like that of B. And if the waveform of B is passed through a system generating even order harmonics —the 2nd, 4th, 6th, etc.—it will come out of the system looking like C.

It is not possible to eliminate this kind of distortion completely, but it is possible to keep it low enough so that the change in waveform will be too slight to be audible or too small to change the character of the original sound. In either case the permissible level is very, very low.

To be inaudible or insignificant, any component of the waveform must be below the resolving ability of the ear. The human ear, like the human eye, has quite remarkable resolving power—or ability to resolve or discern very minute details in a complex sound. For instance, the difference between the loudest sound the ear senses —at the point where the sensation turns to pain—and the weakest one it can discern is of the order of one trillion times, or 220db. The resolving power for complex waves composed of sounds occurring simultaneously or in rapid succession is undoubtedly very much less. I have never seen any data on this, but experience with nearly a generation of listeners to high fidelity systems suggests the conservative statement that at the levels a hi-fi system is played in the home, any component of the sound has to be at least 60db below the peak level to be insignificant. This represents 1/10th of 1%.

To some extent the resolving power of the ear depends on the volume level of the sound presented to it — just as the ability of the eye to discern small details depends on the size of the picture. The louder the listening level, the smaller the detail in the complex wave the ear can resolve. To hear all the detail in a symphony, it is necessary to play a hi-fi loudly enough at the peaks so the small details will still be above the threshold of hearing. On the other hand, the louder the level the less distortion the sound can have and be tolerable. The situation in this respect is exactly comparable to "grain" in photography. The bigger the enlargement we want to make, the smaller the grain on the film must be.

The finest amplifiers do in fact manage to keep distortion down to this degree at any level that would be used in the home. Distortion is generated largely when amplifiers are operated at, or close to their maximum power capabilities. The easiest way to keep distortion down at any operating level, is to use an amplifier at half-power or less. This is one reason for choosing amplifiers with high power output

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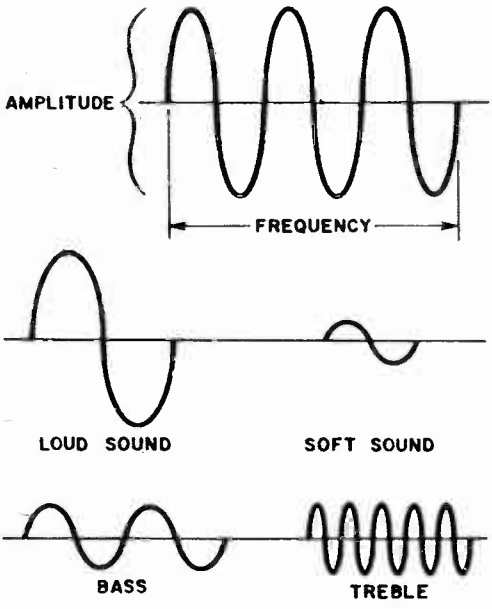
capabilities. The curves of page 24 illustrate this. In the components hi-fi industry, power output is rated at the point where the distortion is 2%. Notice that the amplifier that delivers 20 watts at the 2% point, still has around ½% below 10 watts; whereas the 45-watt amplifier gets down to 1/10% below 10 watts, and the 100-watt amplifier has practically no distortion whatever below 10 watts and is within 1/10% up to 20 or 30 watts. Granted that we may seldom, or never, exceed a power output of 10 watts in the home, the 100- and 45-watt amplifiers will be far more free of distortion at normal levels than the 20-watt amplifier.

There are several ways of measuring and specifying distortion. The most common and tolerant way is to state the distortion at 400 or 1000 cycles. This is the point at which any amplifier is flattest and puts out its maximum power output. It can result in very nice curves, like those in E of page 24, but it does not really tell us very much about the sound the amplifier will produce when it is handling musical waveforms. To provide really significant measures of performance, the harmonic distortion should be measured throughout the frequency range from 20 to 20,000 cycles. Even the finest amplifier will have more distortion at 20 and 20,000 cycles than at 1000 cycles. Indeed the amplifier with 2% distortion at 1000 cycles, could well have 10 or even 20% distortion at 20 cycles. In the best amplifiers the distortion at maximum power output will be less than 2% at any point in the range between 20 and 20,000 cycles. In the Marantz amplifiers it is less than .3 of 1% at the two extremes of 20 and 20,000 cycles. A on page 25 gives typical distortion curves for the three classes of amplifiers over the full frequency range.



Sound waves have two principal parameters. They are amplitude which determines loudness and frequency which determines pitch. Study diagrams.

Again here, as in the case of frequency response, it is the performance at the extremes of the frequency range that separates superb amplifiers from good ones. All in all, the specifications for harmonic distortion from 20 to 20,000 cycles at full rated power output provide the best single measure of performance. This follows because to achieve low distortion over the full range, an amplifier must have a very wide frequency response, very low distortion at average levels, and all the other qualities needed for faithful reproduction.

There is another type of distortion which is far less tolerable and has a more severe effect on waveforms. When two waveforms meet in a nonlinear system they will produce additional waveforms by simple addition and subtraction. Thus if we feed a 500 cycle and a 2000 cycle tone into an amplifier that is not linear, we will get at the output a waveform which includes not only the original 500 and 2000 cycle components, but also sum and difference components of 1500 and 2500 cycles. This type of distortion, called intermodulation sounds much worse to the ear than harmonic distortion. As we have noted, musical tones are combinations of fundamentals and harmonics at octave multiples of the fundamental. Harmonic distortion merely adds additional harmonics to the mixture. While this changes the timbre and character of the sound it is not necessarily grating to the ear because the distortion falls into the harmonic pattern of music. But the products of intermodulation do not follow the musical harmonic pattern. They are foreign, dissonant, and therefore grating to the ear, and indeed may be painful if they are excessive. Therefore the tolerance of the ear for intermodulation is much lower than for harmonic distortion. On the other hand, intermodulation is usually higher than harmonic distortion. To be insignificant, intermodulation should be 60db down, or 1/10th of 1% at any loudness level. This is much harder to achieve and again the easiest way to be sure of very low intermodulation distortion is to use amplifiers at a fraction of their maximum capabili-

ties. Fig B gives typical IM distortion curves for the three classes of amplifiers.

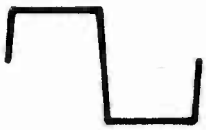
As in the case of frequency response, for perfect reproduction, the distortion should be insignificant at every point in the chain, not merely the amplifier. It is far more difficult to achieve low levels of distortion in pickups and loudspeakers than in amplifiers. Again the most difficult points are the two extremes. In the case of pickups, the highest distortion is generated at the top of the range above 10,000 cycles. Harmonic distortion here is far less serious than intermodulation, since the harmonic of frequencies above 10,000 are beyond the range of normal hearing. However, one of the IM products of, for example a 10,000 cycle and 15,000 cycle tone (5000 cycles) does fall in the hearing range. It is extremely difficult to measure either the harmonic or IM distortion of pickups and distortion specifications are seldom given. Generally, however, the flatter and smoother the curve of the pickup, and the freer of any peaks, the lower the distortion. The higher the compliance, the lower the distortion, assuming the pickup is tracking properly for the simple reason that the higher the compliance the further the pickup can be driven by a high amplitude wiggle in the groove without distorting the waveform by compression.

In the case of loudspeakers, the most difficult point is the lowest portion of the spectrum below 100 cycles. Good speaker systems will have very low distortion over the mid- and high-frequency range. The distortion characteristic of speakers are determined by their resonances, damping, the compliance of the movement, and the linearity of response in the mid-range. For example, if a speaker has a high amount of distortion at 60 cycles, and a peak at 180 or 240 cycles, the harmonics produced by the distortion will be greatly exaggerated by the peaks at 180 and 240 cycles. The finest speakers will have 3% distortion at their lowest rated frequency; good ones will not exceed 10%; poor ones may have 100% or several hundred per cent. Indeed, in automobiles and most home radios, juke boxes and most package hi-fis, the speakers have virtually no response to fundamentals below 80 cycles. However, the distortion generates high levels of harmonics which give the illusion of a deep bass. In fact, speakers with the most obvious bass usually have the highest distortion. It is not the amount of bass that counts, but the quality and naturalness of it. The low distortion speaker may seem

A.

Complex wave composed of fundamental plus the third and fifth harmonics.

B.



Square wave composed of fundamental plus all odd harmonics to infinity.

C.

Simple sine waves of fundamental only.

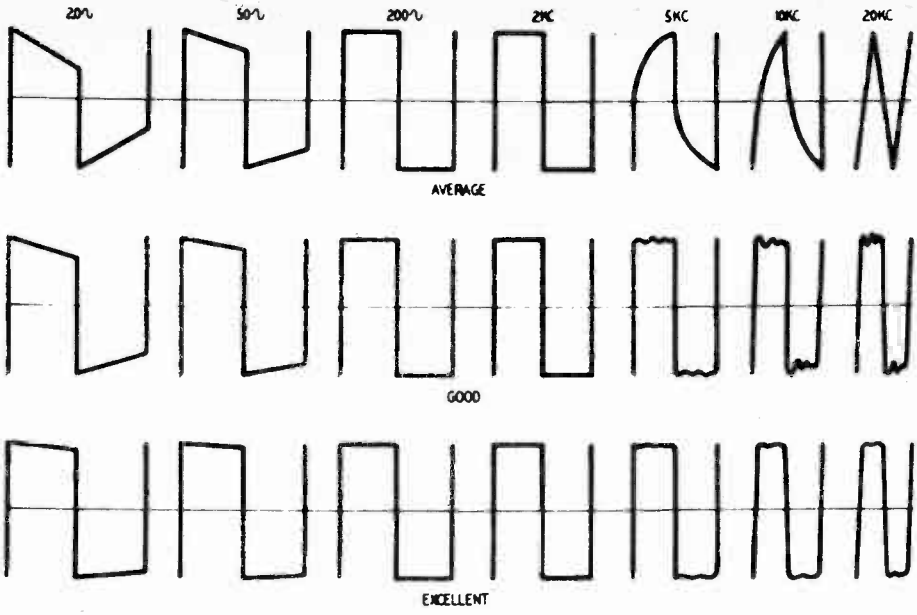
The waveforms of some actual sounds resemble square waves more closely than sine waves and hence require much wider passband in hi-fi system.

to have less bass, but careful listening will reveal that it is far more faithful to the original instrument. Page 24 gives the distortion characteristics of the three classes of good hi-fi loudspeakers. The poorest of these is very much superior to the typical radio or package hi-fi speaker.

TRANSIENT RESPONSE AND DISTORTION

I have said that *it has been assumed* that the ability to reproduce sine waves between 20 and 20,000 cycles at low distortion is a sufficient guarantee of high fidelity performance. There are engineers who stubbornly maintain this position although it is quite inconsistent with the knowledge they have, or should have, of electronic theory.

A high fidelity system does not take a complex wave apart into its individual sine waves. It either passes the entire complex wave perfectly or it deforms it. The tendency to think of sound waves as bundles of sine waves, rather than entities in themselves, is rather like looking at a crate not as an entity but a collection of boards. Take a wooden crate or box 2 feet square and 4 feet long. It is made of boards ranging in length from 2 to 4 feet, in width



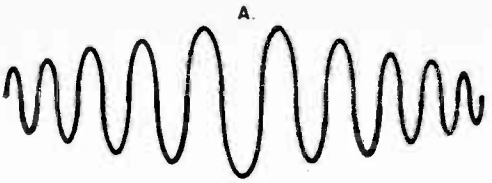
Square wave response of three classes of amplifiers is shown here. Amplifier capable of passing square waves from 20 to 20,000 cycles with little deformation will pass any musical waveform without trouble.

from 2 to 6 inches, and in thickness from ½ to 1 inch. If we take the crate apart we could pass it through the mail slot in the door, by passing the individual boards through it. But if we are going to handle the crate as it is, we'll need a door at least 2 feet wide and high to pass the crate. This is a terrific difference in passbands; and certainly the mail slot, though it is capable of passing every component part of the crate, could not possibly pass the entire crate. A similar situation applies to sound waveforms.

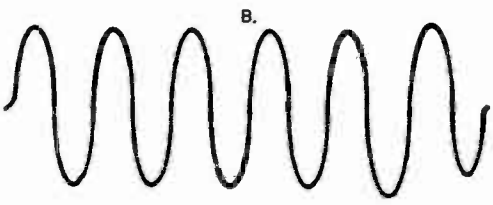
Let us go back to page 17 and look again at the waveform A. This is the waveform of a complex wave analyzable as a fundamental plus the 3rd, 5th and 7th harmonics. Any student in an elementary course in waveform theory can see at a glance that this waveform resembles a square wave much more than a sine wave. Indeed, if we continued to add odd order harmonics—the 9th, 11th, 13th, etc., ad infinitum—we would end up with the square wave of B. That very same student has also learned that to pass a square wave through any system without altering its shape, we need a pass band that extends upward at least 10 times the fundamental and *downward at least to 1/10th the fundamental.* Thus if this particular square wave had a fundamental frequency of 60 cycles, we would need a system with a response from 6 to 600 cycles to pass it without significantly deforming its shape. Here then we have a complex wave which requires a bandpass very much wider than that necessary to pass any of the components of the wave. Notably, it would need to pass sine waves for *three octaves below* the frequency of any single sine wave we can find in it.

The complex waveforms of sound seldom become real square waves, though some approach them quite closely, but they do fall into shapes that are just as close to the shape of square and sawtooth waves and pulses as they are to sine waves. Common sense indicates that they will require a pass band intermediate between that required to pass sine waves and those required to pass square and sawtooth waves without deformation. And, critical designers have always measured amplifiers, and loudspeakers for that matter, with square waves. Square wave measurement cuts all components down to a very much less impressive size. For example, the amplifier with a sine wave response from 20 to 20,000 cycles, becomes a 200 to 2000 cycle square wave amplifier. Furthermore, the amplifier will deliver less than half the continous power with square waves than it will with sine waves. To reproduce square waves over the range of 20 to 20,000 cycles at 10 watts, we need an amplifier with a sine wave response from 2 to 200,000 cycles and a sine wave power output of 20 watts. This is clearly an amplifier of another color entirely.

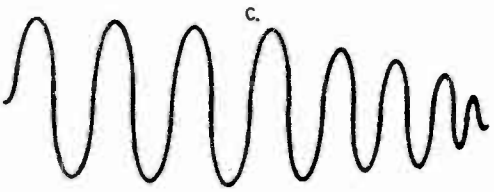
Since musical waveforms never quite reach the shape of square waves, we can



Waveform with slow attack and slow decay.



Waveform with fast attack and fast decay.



Waveform with fast attack and slow decay.

The tone quality of instruments is determined in part by the attacks and decays of the waveforms.

presumably do with a somewhat narrower bandpass — perhaps 10 to 100,000 cycles. And it is very notable that the amplifiers which deliver the best sound—even to the engineers who insist that a 20 to 20,000 cycle sine wave response is sufficient—do have bandpasses somewhere in this range at power outputs of 10 watts or less. One thing is for sure; an amplifier capable of handling square waves from 20 to 20,000 cycles will have no trouble handling any musical wave form—just as a garage big enough to take the biggest Cadillac will handle a Corvair nicely with no danger of denting the fenders.

There is another reason why a hi-fi system needs a bandpass wider than that needed to pass only sine waves from 20 to 20,000 cycles. Sound differs not only in the amplitude, frequency and harmonic composition but also in attack and decay. In other words, waveforms differ in how rapidly they rise from zero to maximum amplitude, and how slowly they decay from maximum to minimum. For example, a violin bowed has a slow attack and a slow decay. It takes the waveform a noticeable interval to rise to maximum amplitude and a noticeable interval to decay to zero. The waveform might look something like A on this page. For simplification we indicate the individual waves in the tone burst as sine waves, although, of course, they are more complex in shape. The slow attack is evidenced by the triangular shape of the front of the tone burst.

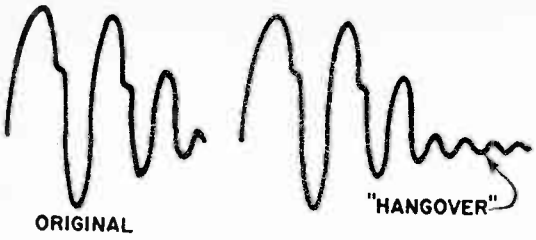
On the other hand, in percussive instruments, like the piano where the sound is produced by a sharp blow, the waveform rises very quickly and steeply to the maximum. The attack is very rapid and the tone burst looks like B, where the shape of the front of the tone burst is square.

If the piano is struck with the soft pedal on, the attack will be as sudden; and the decay will be extremely rapid — there is practically no interval between the peak and minimum at the end. The tone burst looks like B. But if we strike the same note with the loud pedal on, the decay will be slow. It will take a noticeable interval for the sound to die away and the end of the tone burst will taper away in a sort of funnel shape, as in C.

A very large part of the character of the various musical instruments is determined by the attacks and decays. In the case of the piano, the harp, harpsichord, guitar, banjo, balalaika, etc., the difference in attacks and decays accounts for the largest difference in character. And a system which does not reproduce these attacks and decays perfectly, will remove the difference between these instruments until they sound very much alike.

There is no problem reproducing slow attacks and slow decays; but it is quite difficult to reproduce fast attacks and fast decays.

To understand why, let us consider what happens when, for example, a sudden blow is applied to a drum. The sound rises from zero to maximum amplitude in a very brief interval—a few microseconds. The leading edge of the waveform is almost perpendicular. The time it takes for a waveform to rise from zero to maximum is called "rise time." All systems have a time constant. It takes a measurable interval to react to the stimulus. For instance, the cry of pain follows by a fairly considerable interval the actual prick of a pin. No system can react more rapidly than its time constant permits. The rise time of an electronic system is determined by its time constant and this has a relation to the frequency response. For example, a system with a rise time of 100 microsec-



Poor transient response results in "hangover," or a sort of artificial echo, as system keeps on sounding after the original sound has stopped.

onds will reproduce a 10,000 cycle sine wave.

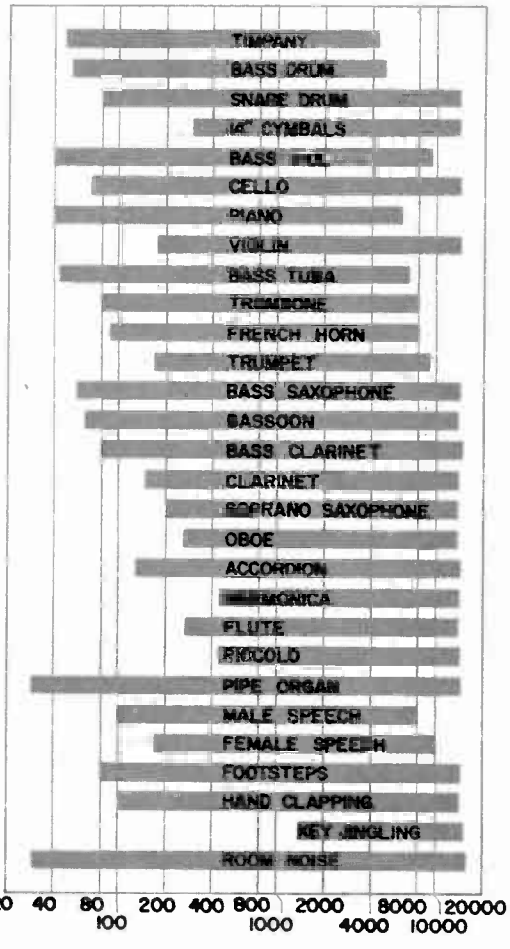
Now consider the drum note we were talking about. Its fundamental frequency may be 60 cycles, and it may have no harmonic higher than 1200 cycles. Yet, the leading edge of tone burst might well rise from nothing to its maximum in 100 microseconds. Obviously, the amplifier must be capable of responding in 100 microseconds, which is another way of saying that it must have a sine wave response at least to 10,000 cycles. Here again, we see how a complex wave may require a bandpass much wider than that of any significant sine wave component into which it can be analyzed. In this instance, the highest significant since wave component is 1200 cycles, and yet we need a response nearly ten times wider to reproduce the waveform perfectly.

Some of the musical sounds with the steepest wavefronts have relatively high fundamental frequencies—the trap drums, temple bells, blocks, high octaves of the piano, harp, banjo, etc. To reproduce these steep attacks faithfully we need rise times as short as 10 microseconds, or shorter, which would require a response up to 100,000 cycles.

It is argued that because the ear cannot hear above 20,000 cycles, it is not capable of distinguishing rise times shorter than, say 50 microseconds. If human senses actually behave like electrical and mechanical devices, this will be true; but the analogy is by no means complete. For example, a near-sighted person has a naturally "blurred" vision — in other words, his visual system distorts the visual waves it receives. If the engineer's assumption were valid, then if we presented the eye with a waveform already distorted the same way as the eye distorts it, the mind should not be aware of it. And yet, a near-sighted person is, if anything, far more sensitive to the blurring of a dirty or wet windshield than a person with "normal" eyesight.

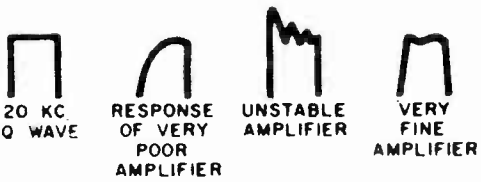
Whether the ear can in fact distinguish rise times higher than 50 microseconds, it does seem to be true that it can tell the difference between wave forms that possess higher rise times and those that do not. In any event, it does not at all follow that it cannot tell the difference between an amplifier that stops at 20,000 cycles and one that goes up to 100,000 or 200,000 cycles. Very probably this is related to the ability of amplifiers — and other components—to reproduce rapid decays.

To reproduce a waveform with rapid decay, the reproducing system must stop producing a sound immediately the waveform stops stimulating it. This is not at all easy to accomplish. Any system, electrical or mechanical, acquires momentum when it is energized, particularly when it is



Frequency range of instruments, other sounds in cycles per second. Ear is sensitive to sounds with vibration periods that run from 20 to 20,000 cps.

FIG. 6



Square wave response is one of best measures of amplifier performance. The flatter the wave at the top of 20 cycles and 20 kc, the finer is amplifier.

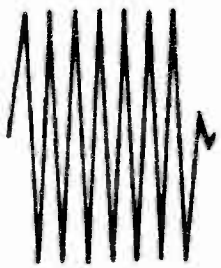
energized at a high level. Like the billiard ball which keeps rolling long after the cue has stopped delivering energy to it, reproducing systems want to keep on vibrating after the stimulating waveform has stopped, producing a sort of echo or "hangover" of the original sound.

The tendency to hangover is exaggerated if the system has resonances, and such resonances are inescapable in any electrical or mechanical system. Indeed even individual atoms have resonances and as a matter of fact can be identified by the frequency of the radiations they emit—this is the fundamental basis of spectrography. At any rate if the resonant peaks in a reproducing system are excited the system will vibrate at its own resonant frequency and carry along with it the waveform of the sound being reproduced. A resonant system stores up a tremendous amount of energy and keeps releasing it for a considerable period after the stimulus stops. Pluck the string of a violin or guitar. The stimulus may last only a few microseconds, but the sound continues for many seconds.

There are two ways of dealing with resonances so they will not markedly affect the waveforms passing through a system, and thus produce hangover or ringing. One way is to keep the resonant points out of reach of any possible stimulus. A resonant peak is most easily excited by a stimulus whose frequency is close to the resonant frequency. Obviously in a system that is going to be handling waveforms in the range from 20 to 20,000 cycles, we must be sure that there are no resonances within this range. Actually, we must make sure there are no resonances for a considerable range above and below because a resonant point can also be excited by harmonics or sub-harmonics of its resonant frequency. Strike middle C on the piano hard with the loud pedal depressed, and if you move your fingers along the strings you will feel the other C strings vibrating also, and the sound produced is not that of middle C only but actually the sum of all the Cs in the other octaves.

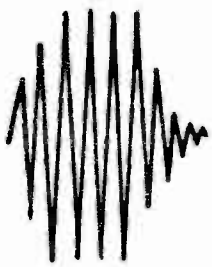
The tendency to produce resonant peaks is increased in amplifiers by the use of "feedback" to reduce distortion. Only with large amounts of feedback is it possible to reduce amplifier distortion to the insignificant amounts we have been discussing. But feedback exaggerates any peaks in the response and, after a point, triggers them into oscillation. In practice then, it is necessary to design amplifier to be flat to 100,000 cycles or more at the high end,

A.



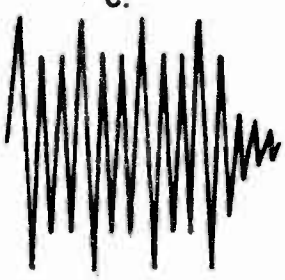
Waveform of tone burst has fast attack and decay.

B.



Tone burst after passing through system with poor transient response.

C.



Tone burst after passing through system with distortion and poor transient response.

Tone bursts are test of loudspeakers. Few speakers reproduce bursts perfectly over full audio range.

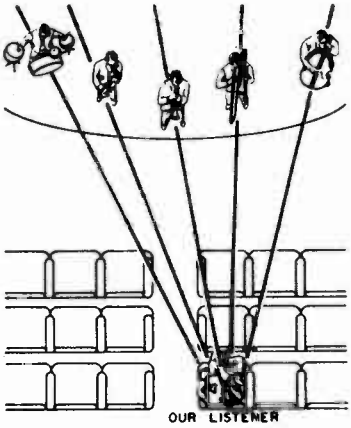
and well below 10 cycles at the low end to minimize the possibility of ringing and hangover.

Therefore, partly to make sure of having a rise time short enough to handle fast attacks, and partly to make sure that it will be able to handle fast decays without hangover and ringing, a hi-fi amplifier needs, and the best ones will have, a response flat from less than 10 cycles to more than 100,000 cycles at any normal level. That is why high powered amplifiers whose response at 10 or 20 watts is flat to well below and well above audibility produce so much more natural sound than amplifiers whose response at the same levels cuts off at 20 and 20,000 cycles.

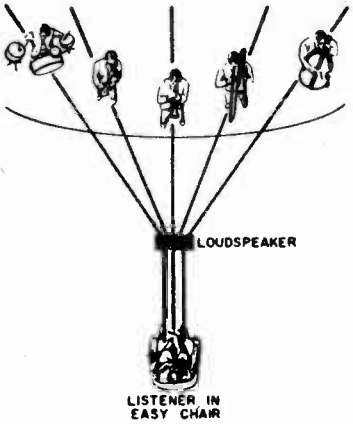
The same thing is true, or would be true of loudspeakers, but unfortunately it is far more difficult and, indeed, at the moment impractical to obtain such bandwidths in speaker systems. Furthermore, loudspeakers have mechanical resonances and acquire mechanical momentum and they are much harder to deal with than electrical ones. This is complicated by the fact that in most practical speaker systems the response at the bottom of the range is obtained by resonating the speaker. In practically all speaker systems we will find, if we measure the response, one or two resonant peaks somewhere between 20 and 100 cycles. Since a resonant system stores high energy, the system produces a louder sound at these resonant peaks, than at other portions in its range, and thus if the resonant peaks are carefully controlled they can make up for what would otherwise be a drop in response and thus widen and flatten the response. On the other hand, if the peaks are not carefully controlled, the speaker will not so much reproduce a bass as generate a bass at the resonant frequency. In other words it will become not a mere reproducer but a musical instrument adding its own tone to the music passing through it or substituting its own bass for the bass in the original waveform. Instead of the sound of the original drum or double-bass viol you hear the sound generated by the speaker resonance. In fact, this is precisely the device used in juke boxes and most package hi-fis to produce a big bass sound. The fact that the bass doesn't have much resemblance to either the drum or double-bass does not bother most people.

When resonances are unavoidable, as they are in any practical speaker—or any musical instrument—the only way to deal with them is to "damp" them, or in some way absorb the energy stored in the resonant system, so that it will no longer be available to vibrate the system. In the piano this is done by the felt pads which fall on the strings as soon as the key is released, and absorb the energy stored in

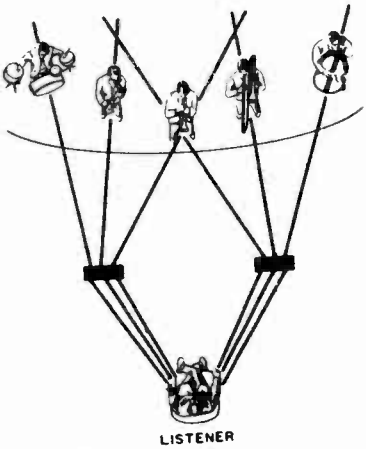
Fine Arts quartet listens to itself at recording session through fine hi-fi system, using AR speakers. Hi-fi systems are used similarly by orchestras and by individual artists to hear how they're doing.



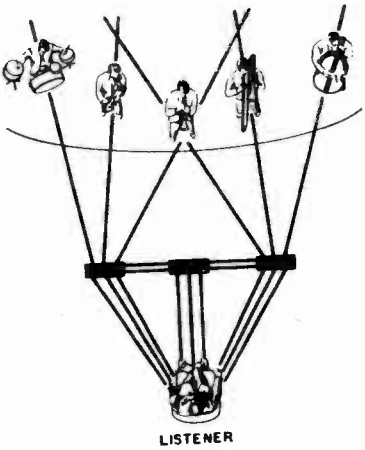
In auditorium, sounds from individual instruments reach ears separately and are combined in mind to create tonal picture in panoramic sound.



When listening to a monophonic recording, the sound from all instruments comes from same spot. It's like hearing music through an open door.



Two-channel stereo divides band into two parts. If speakers are too far apart, a very discernible "hole-in-the-middle" effect is noticed.



When "phantom" or third middle channel is added, filled hole produces a curtain of sound that corresponds to original instruments on the stage.

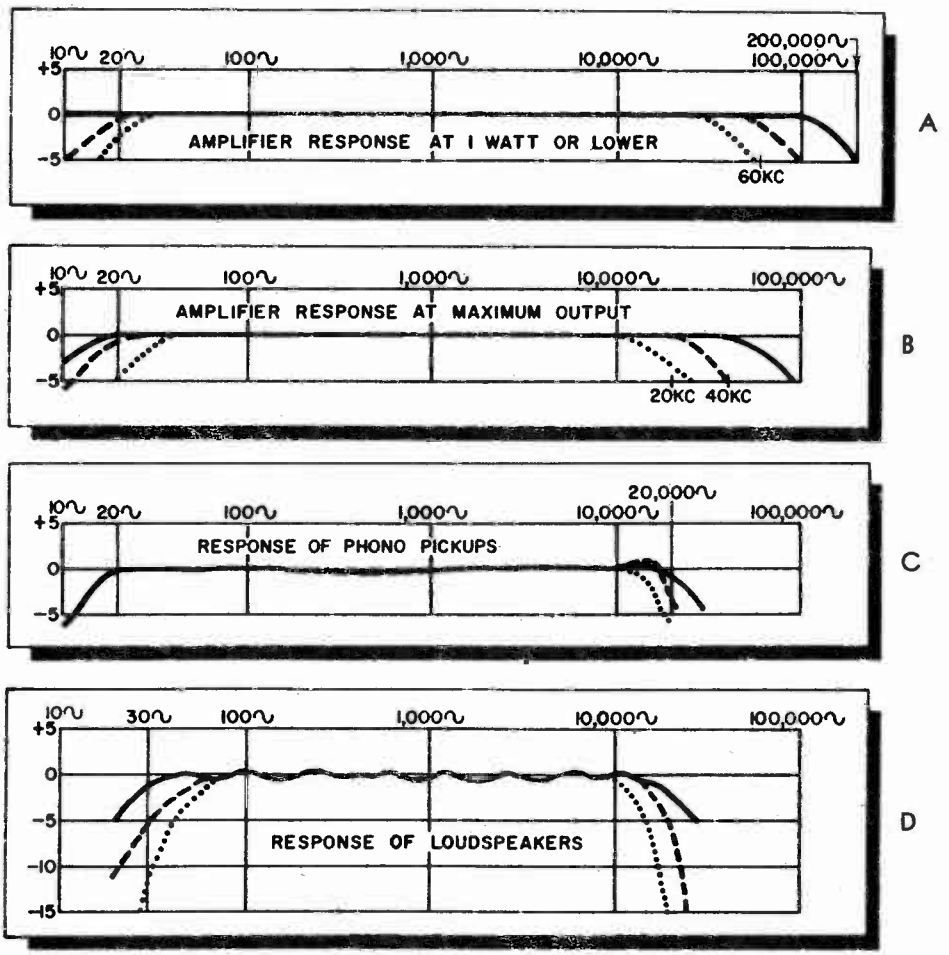
the string. A similar damping action is produced in the violin by the fingers of the left hand which not only key the strings but also absorb the stored energy. A drummer damps the drums by putting his hand on the diaphragm or, as in some jazz bands, by fastening pillows to one of the diaphragms. Damping is necessary for a speaker system not only to prevent it from generating a tone at its own resonant frequency, but to minimize hangover of the waveforms passing through it. Once a mechanical device like a speaker is put into motion it tends to continue in motion after the stimulus has stopped. A high amount of damping is therefore necessary for a speaker to reproduce fast decays faithfully.

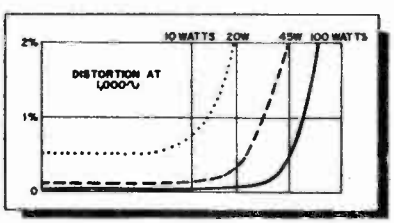
Loudspeaker systems can be damped in several ways—by the enclosure, by the magnetic field produced when its voice coil moves in the magnetic flux of the magnet, and by the amplifier. An amplifier damps loudspeakers by presenting a very low resistance which then absorbs the stored energy very much like the felt pads absorb the energy of piano strings. A high amount of amplifier damping will flatten out peaks in a speaker system; on the other hand, by reducing the amplifier damping the resonant peaks in a speaker system can be accentuated and hangover exaggerated. A few years ago amplifiers had "damping controls" to control the amount of damping. Today, most amplifiers have fixed damping. Since the damping factor will vary from amplifier to amplifier, the same

speaker may sound quite different with different amplifiers.

The highly damped speaker, in which the tendency to self-oscillation and hangover is almost completely suppressed, has the finest transient response and produces the most faithful reproduction of the waveforms fed into it. This type of speaker is preferred by critical listeners and people who want the highest possible fidelity and resolution of detail. Many people, however, find the sound they produce a little on the "dry" or dull side. Hence, most speaker systems are designed with more or less hangover to yield a bright and reverberant sound.

HIGH-FIDELITY STANDARDS



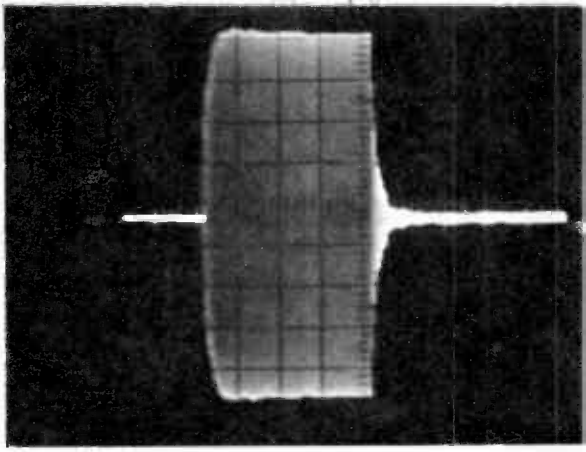


These diagrams show various hi-fi frequency responses and power outputs.

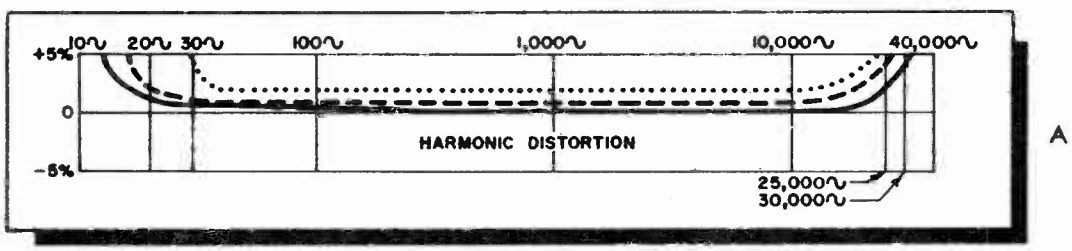
To insure completely faithful reproduction without hangover ringing or false bass, a speaker system, like an amplifier, ought to have a response well below and well above audibility. The response can be extended above audibility quite easily. There are several tweeters whose response extends to 30,000 cycles or higher. The low end is another story. Presumably it would be possible to put together a system of speakers with resonances below 10 cycles in some type of infinite baffle with no resonances of its own, and thus to obtain a response to 10 cycles or lower. But such a nonresonant system would be quite bulky and expensive and nothing resembling it is available commercially.

Nevertheless it is quite true that the wider the bandwidth of the speaker system, particularly the farther down it goes, the better it reproduces fast attacks and decays and the more faithful the bass to the original. The trouble is that you have to pay through the nose for every additional few cycles of response at the low end. Speakers with a reasonably flat response to 40 cycles are available for around $100. Each extension of 10 cycles will more than double the cost. Systems with response to 30 cycles run to around $200 apiece and anything that approaches 20 cycles will cost more than $400.

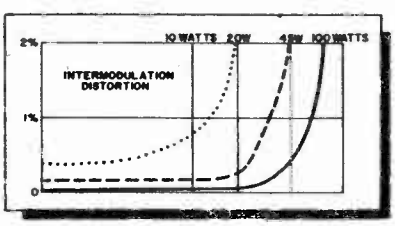
The ability to reproduce fast attacks and fast decays faithfully is called "transient response." Unfortunately, there is no simple and infallible way to measure transient response. In amplifiers, square wave response is an excellent measure since square waves have extremely fast attacks and decays, and also because they will energize resonances far above and far below their own fundamental frequency. Thus an amplifier which reproduces square waves faithfully between 20 and 20,000 cycles will be able to handle just about any attack or decay characteristic in musical waveforms or any natural sound. There are a few amplifiers which come very close to doing this. The oscilloscope traces of page 18 show the square wave response of the three grades of high fidelity amplifiers.



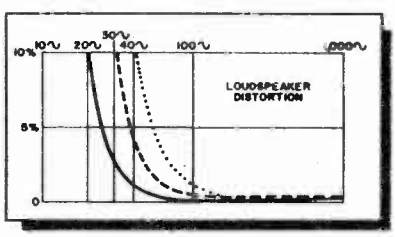
This actual photograph of oscilloscope trace shows the almost perfect reproduction of the tone burst by the Jensen flat-piston loudspeaker system.



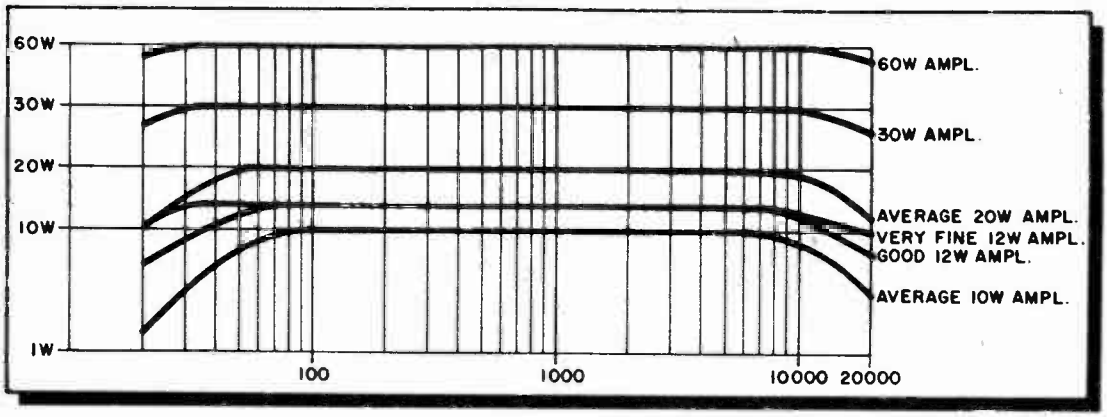
A



B



C



Power response of representative amplifiers.

The best measure of loudspeaker transient response is testing with "tone burst" signals. A tone burst consists of several cycles of a sine wave keyed to produce an extremely fast attack and fast decay. It looks like A on page 21. The tone burst is fed to the loudspeaker through a fine amplifier, the output of the speaker is picked up by a microphone, amplified and then displayed on the screen of an oscilloscope. The modifications produced by the system are evidenced by changes in the shape of the burst. The perfect system would reproduce the burst perfectly. If the system has inadequate rise time, the leading edge of the burst will be triangular instead of square. If the system has hangover, the closing edge will taper into a triangle instead of cutting off sharply. If there are any resonances in the system, peaks will appear in the tone burst. As in the case of sine wave or square wave testing, tone burst testing should be carried out with tone bursts at various portions of the audible range from 20 to 20,000 cycles. No speaker system yet produced approaches the ideal in this respect over the full audio range.

There is a very simple test of transient response which anyone can make without instruments. Simply take the arm of the record player and place it gently on the record. The contact with the disc produces a very low frequency transient which in terms of excitation is only a few cycles long, with an extremely sharp attack and decay. It should produce in the speakers a single, very low frequency, very dull "thump." If there is more than one thump, or if the thump lasts an appreciable length of time, or has a bright reverberant sound, the transient response is poor. If the thump is fuzzy and has high frequency components, as well as the fundamental very bassy one, the system is distorting severely or resonating at some high frequency. As a matter of fact, an expert can obtain a pretty accurate idea of the characteristics of the entire system with this one simple test.

POWER OUTPUT

To duplicate the loudness of a symphony orchestra with all the power generated by the blowing, bowing and pounding of from 50 to 100 men, the hi-fi system must have enough power to drive the loudspeaker to the desired level. If a system does not have enough power, two things happen. First, the waveform of very loud sounds is squashed down or compressed. This, of course, means that the dynamic range of the original sound is not reproduced faithfully. Far more serious, however, is that at this point, where the system stops to amplify and starts to compress, high levels of distortion are generated. Therefore, a good high-fidelity system should have enough power to reproduce the loudest sound at the loudest level we desire in the listening room and some to spare, so that it never reaches the point of overload and the accompanying high levels of distortion.

It is possible to duplicate the full volume of a symphony orchestra in the normal living room, with between ¼ and 1 *acoustic* watts. However, loudspeakers are very inefficient devices. The Klipschorn, which is the most efficient of available speakers, has an efficiency of about 30 per cent; and one or two other horns approach this figure also. But most speaker systems have efficiencies ranging between 1 and 7 per cent. So that, depending on the size of the room

and the listening level desired, it takes anywhere from 1 to 50 watts of amplifier power to drive a loudspeaker to the natural volume level of a symphony orchestra.

Not everybody wants to listen to records or radio at the original level of an orchestra; and indeed in most places trying to do it would certainly irritate the neighbors and might even call out the cops. Still it takes considerable power to produce even moderate levels cleanly and without distortion. With most speakers, 10 watts is the minimum and this leaves little reserve. A power output of between 20 and 35 watts per channel is far better and an output of 35 to 70 watts per channel provides insurance against audible distortion at any level likely in the home.

Producing amplifiers with high power output is expensive and results in bulky and heavy units. Therefore, there has been an unfortunate, if natural, tendency on the part of some manufacturers to exaggerate the power output of amplifiers by stating it in terms which, though quite true, tend to give the impression that the power output is greater than it actually is.

A few years ago power output was rated simply in terms of the output the amplifier would deliver at a given distortion level with sine waves. While sine waves are not really representative of musical waveforms, in this respect they are more severe tests because their *average* power level is much higher than that of musical waveforms. Thus the power output with sine wave is a good indication of the "continuous" power the amplifier can deliver.

The first step toward exaggerating the power output, was to state it in terms of "peak power output" rather than "continuous power output." We note from the shape of sound waves that actually the power will vary from zero to the peak produced by the top of the waveform and back to zero. The sine wave output is the average power delivered for a continuous train of sine waves. Actually, during the short interval represented by the peak of each sine wave, the amplifier will be delivering twice the average power. Thus any amplifier capable of delivering 10 watts of continuous sine wave power will actually deliver 20 watts during the short period occupied by one of the peaks. It can honestly be said that such an amplifier has a "peak output power" of 20 watts. This makes an amplifier sound twice as good to somebody who doesn't know what is actually involved.

The use of peak power was justified by the explanation that musical waveforms are not sine waves but complex waves with peaks of very short duration; and therefore that any amplifier capable of developing 10 watts with continuous sine waves would be capable of developing 20 watts with musical peaks. Actually, this is not entirely true. Some of the highest peaks occur with instruments in the bass range, the organ for instance, which produce a train of waves which lasts a considerable interval and which, therefore, require not peak but continuous power output. But even though it makes some sense the fact is that "peak power" is not measured with musical waveforms but determined by a simple multiplication of the sine wave power. It is, thus, purely a "paper" measure.

Not content with this somebody came up with a rating called "music power output." This sounds good, and if there were some way of measuring it accurately, it might make sense. But the means used to measure it are not only extremely artificial but of a type which makes poor amplifiers look very much better than they are and fine amplifiers no better than they are. Briefly, it involves replacing the power supply in the amplifier under test, with a more ideal power supply. In most amplifiers the power output is limited by the fact that after a point the power supply does not deliver additional power. An amplifier with an imperfect power supply will therefore deliver more power when that power supply is replaced with a nearly ideal one. This is like measuring the speed of automobiles by replacing the engine they come with, with a more nearly ideal engine. Under such a test a Falcon will give vastly more improved performance than a Jaguar or Ferrari which already have the closest approximation of the ideal engine. This procedure is justified, as in the case of "peak" power on the assumption that the power peaks in musical waveforms are of very short duration, and therefore the imperfect power supply will be able to deliver about the same power during a short peak, as the nearly ideal power supply would continuously. Aside from the fact that this assumption is not completely justified, the "music power" rating favors the poor over the good amplifier. The "music power output" of a fine amplifier is little if any more than the continuous sine wave power output. But in poor amplifiers it can be more than twice the continuous sine wave power output. So, it does not provide a good relative measure of amplifier performance and the pur-

chaser of a hi-fi amplifier is advised to disregard the "music power" rating entirely and make the comparison on continuous sine wave power or, far better, the power output over the full audio range.

Actually, continuous sine wave power output does not tell us much about an amplifier. It is usually measured at one frequency only—400 or 1000 cycles—the point at which amplifiers are flattest and most easily deliver power. As in the case of distortion it is important to know what the power output is over the full audio range of 20 to 20,000 cycles. Only the finest amplifiers will deliver their full rated power output over this full range. Most amplifiers will deliver less than half their rated power output at 20 and 20,000 cycles. The most significant measure of power output capabilities is the curve for power output with sine waves from 20 to 20,000 cycles at 2% distortion. This will be quite similar to the curve for distortion at full power output over the same range.

The manufacturer of fine amplifiers gains nothing whatever by using "peak power," music power or half power bandwidth ratings. Therefore, he usually states his power output in terms of "continuous sine wave," and indeed he usually gives the power output over the full range as for example "35 watts with less than 2% distortion from 20 to 20,000 cycles."

In all of this discussion you may have noted that in practically all cases the "tell tales" are the low and high end performance. The better the performance of the system below 50 and above 10,000 cycles the better the system in just about every characteristic. Therefore, in judging relative performance from specifications, concentrate on these two ends. It is the performance here that makes the big difference between good, better and superb systems—as well as the price you pay for them.

So far we've been talking only about reproducing the tone quality of sound. We can reproduce tone quality perfectly and yet not have the illusion of hearing the sound exactly as we would have heard it at the moment it occurred. The reason is that our perception of sound has direction and spread as well as of frequency, waveform and amplitude.

Unfortunately, when we reproduce the orchestra with a single loudspeaker we lose a sense of direction and the spread of the sound. Even with the best single speaker system the sound comes from a single spot—a few feet wide at most. We hear the orchestra as if through a window, door or the small end of a megaphone as shown on page 23. The instruments may sound natural, but the illusion of being on the spot in the concert hall listening to a performance is simply not there.

We can restore this directional effect and therefore the illusion of presence with stereophonic or "stereo" hi-fi systems, which use two or more channels and speaker systems. The ideal way would be to use a separate speaker for each of the instruments of a band or orchestra and space them in the living room the same way the instruments are spaced on the concert stage or bandstand. Like most ideals this is impossible. It might be cheaper to hire a full-time orchestra and keep it in the living room. However, we have found it possible to get a good illusion of presence with only two speakers by cleverly manipulating the recording process.

To understand this let us look at page 23. Here we have a five-piece band spread on the stage. By using two microphones spread apart by a good distance, we divide the band into two parts. One microphone responds largely to the players on the left, the other microphone responds largely to the players on the right. We can now feed the output of each microphone into a separate recording and eventually a separate hi-fi system, so that in the living room the sound will come out of two speakers. The drum and the sax will seem to be to the left of the listener sitting in his chair in the living room and the double bass and trombone to the right. If the speakers are arranged some ten feet apart, the two pairs of instruments will appear to be ten feet apart.

There is one problem. If the two channels are sharply isolated and the left-right directionality is too sharp, you get the effect of an orchestra divided into two parts—one way out in left field, the other way out in right field, with nothing (but rumble) in the infield. In other words, this arrangement leaves a hole in the middle, and the listener is rather in the position of the audience on the sideline, and right at the net, of a tennis game, snapping its collective head to follow the ball from one count to the other.

Of course, this two-channel hole-in-the-middle effect is highly dramatic. You can tell immediately that here is something very different from the sound of a monophonic or ordinary hi-fi. And lots of people are enchanted by it. Unfortunately, it is also very different from what one hears in a concert hall—unless one is standing beside the conductor.

FILLING THE HOLE

We now have several ways of filling the hole-in-the-middle. The most obvious way is to use a third speaker in the middle. Of course, since we can only have two channels on a disc record or radio broadcast, we could not feed this middle channel with a third independent signal. We could, however, take portions of the signal from the right and left channels, blend them together and feed the blended signal to the middle speaker. By adjusting the volume level of the middle speaker we could have it radiate just enough sound to fill in the hole-in-the-middle, and to provide a single curtain of sound across the whole room.

Actually, we do not need a third speaker at all. When the same sound reaches both ears at the same time and with equal loudness and the same phase the ear places the sound straight ahead. Thus if we radiate exactly the same sound from two spaced speakers the ear will imagine that it comes from a third speaker halfway between the two. Using this effect we can create a phantom middle channel to fill in the hole in the middle and to spread the sound out uniformly from one speaker to the other.

Look at the diagrams on page 23. If the trumpet player is standing right in the middle his sound will be picked up by both the right and the left microphones in equal volume, because the patterns of the mikes overlap the middle. When this sound comes out of the loudspeakers it will be identical in amplitude and phase on each side; therefore, the trumpet will appear to be in the middle between the two speakers.

This, however, is a tricky process and most recordings made today use another and more controllable method of doing the same thing. Most original stereo recordings today are first recorded with three microphones. There are the normal left and right microphones, but in addition there is a third microphone in the middle. The output of each of these microphones is recorded separately on tape. In the process of editing, the sound from the middle microphone and channel is added in varying amounts to the left and right channels. Each channel then carries not only the sound picked up by its own microphone, but some of the sound picked up by the middle microphone. When this is radiated by the two loudspeakers in the home, the middle component, being identical in each channel, will appear to come from a point between the two speakers—or through a

High fidelity often demands extreme watchmaker's type precision in manufacturing, as photo shows.

phantom third speaker. Indeed, by skillful blending of the three channels of the original recordings in the process of editing, it is possible to fill in the hole-in-the-middle with a number of phantom speakers so that we can have a continuous line of sound, and the instruments can seem to be placed all along that line instead of merely at two or three points.

The finest stereo recordings made today no longer have only left and right directionality, but present the sound all along the line between the two speakers and also in depth. The illusion of listening to an actual orchestra with all its spread and depth can be very fine indeed.

It is pretty obvious from this discussion that reproducing the sound so perfectly that the listener enjoys the illusion of being present in person at the time and in the place where the sound was originally created, is not easily or cheaply achieved. The wonder is that it can be achieved at all. But with the right components, it can be achieved for about $2000.

Few people can afford such a price for this experience. Nor is it necessary to have a complete illusion of presence to enjoy music fully and completely. An investment between $500 and $1000 will bring music to your ears so nearly like the original that the difference will not matter to most people.

As a matter of fact, a gratifying effect and acceptable reproduction of music can be obtained today for as little as $125. Something between this minimum and $500 will buy a system that will satisfy most ears and most musical tastes, and produce an entertaining degree of presence. •

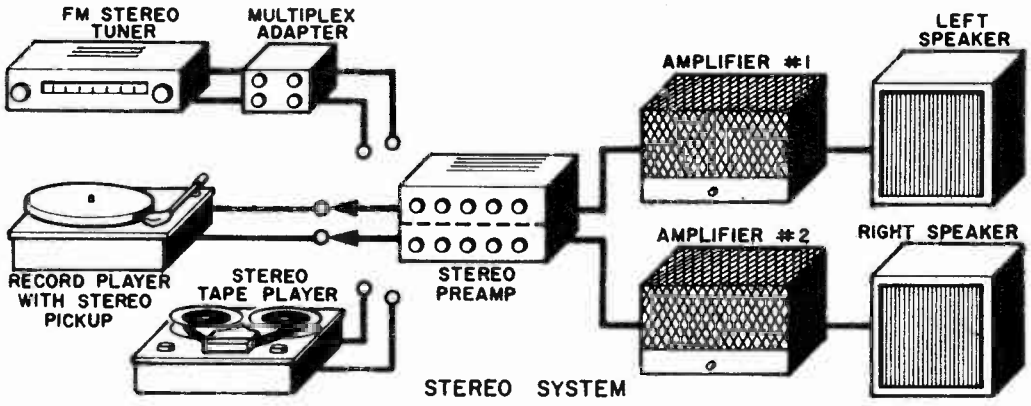
How To Buy High Fidelity

BUYING a high fidelity system can be as simple as buying tooth paste, or as complicated as trying to choose a wife or husband wisely. It is quite possible to pick up the telephone and simply order a hi-fi costing any given amount of money with a high assurance of obtaining good value for your money. On the other hand, some people can make the process of choosing a hi-fi one of the most excruciating experiences of a lifetime. Most people fall in a middle category. They want to be prudent about their purchase, to make sure they get the highest value in satisfaction for the money they spend, but they don't want to make a federal case out of the shopping process. If, as is most likely, you belong to this category, what you want is some uncomplicated guide lines and the fewer the technicalities the better.

First of all, let's be absolutely clear about what you're shopping for. To many peo-

The best way to judge equipment in a dealer's showroom is by listening to and by making rapid comparisons among different speakers, preamps, amplifiers, tuners, and record players. This can be achieved most efficiently with a patch panel that permits instantaneous switching from one hi-fi component to any other.

Block diagram shows what a stereo system consists of. The arrangement can be simplified by combining the power amplifiers or by combining them with preamp. Tape and record players can be added later.



ple—possibly most people—a hi-fi is a piece of more or less handsome furniture which incidentally will play music from records or radio. If this is what you're looking for, my only advice is to spend no more money than the thing is worth to you as a piece of furniture. As far as its ability to play music is concerned, the difference between the $1000 outfit and the $400 outfit, or even a $200 outfit may be extremely small, if, indeed, there is any difference at all.

The kind of high fidelity we're talking about, on the other hand, is a system for reproducing music from records or radio so faithfully and naturally that you have the feeling of being right there in the concert hall where it was played in the first place. If that's the kind of hi-fi you want, forget the furniture-packages completely. It is doubtful that even the most expensive of them will meet even the minimum standards of genuine high fidelity. Secondly, you can get far better sound for the same or less money by buying what is called a "components-type high-fidelity" system. One reason is that in the furniture-type hi-fi, much of your money goes for the cabinet—which adds nothing to the sound, and in fact makes it difficult to get good sound.

Another reason is that the distribution system for components hi-fi eliminates one of the distribution steps common for furniture type hi-fis. In the components hi-fi field, the dealer buys directly from the factory; and the equipment is shipped to the dealer from the factory. In the package field, the factory sells and ships to a distributor, who sells and ships to the dealer, who in turn sells to you. There is thus one less mark-up and profit margin in the components field and a lower delivery cost. In the case of a furniture hi-fi the cost of *shipping* the cabinet from cabinet factory to assembly plant, from assembly plant to distributor, from distributor to dealer, and from dealer to you can amount to as much as the cost of the entire "innards" of the system.

Overhead and advertising and promotion cost is far less in the components than the package field. Those double spread ads in the Saturday Evening Post, and Life, and sponsored shows on TV, also add considerably to the cost.

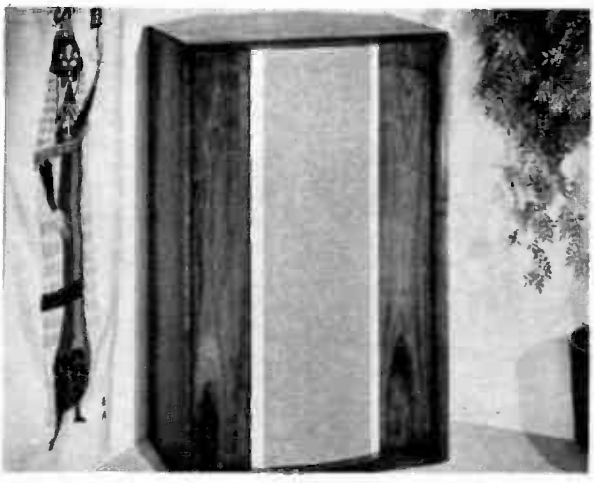
It has been estimated that the cost of parts and labor for the entire working portion of a package system—amplifiers, tuners, changers and speakers—selling for $1000 is less than $100; the rest representing the cost of the cabinet, particularly shipment of it, advertising, promotion and profit margins for three different steps in the distribution system. In a components system the cost of the parts and labor would represent a cost of at least $250 and probably $300.

Finally, the standards of the package industry are very much lower than those of the Institute of High Fidelity. For example, they tolerate 5% distortion, whereas the components industry specifies 2% or less.

What is a component-type hi-fi system? It is an assembly of from three to five or more pieces of precision equipment which, when properly interconnected, make up a complete sound reproducing system. There are dozens of types and brands of components in different price ranges and different quality classifications. You can put them together, like building blocks, in various combinations to suit your needs,

	MINIMUM HI-FI	GOOD HI-FI	SUPERB HI-FI
Loudspeakers	50-15,000 cycles less than $80 each	40 to 17,000 cycles $80 to $150	30 to 20,000 cycles $200 up
Control-Amplifier	20 w Music Power 40-15,000 cycle power bandwidth $50 to $125	20 w sine wave or 25-40 watt music power per channel 30 to 15,000 power bandwidth $100 to $250	Separate preamp $100 to $350 separate amplifier 35 w or more sine wave power per channel 20 to 20,000 full-power bandwidth $100 to $700
Record player	Changer with —40db rumble $50 to $70	Changer with —45db rumble Turntable with —50db rumble $80 to $125	Turntable with —50 to —60db rumble $100 to $150
Tone arm	Integral with changer	Balanced universal $30 to $50	Balanced universal $30 to $50
Pick-up	Low compliance 3×10^{-6}cm/dynes $20 to $30	Medium compliance 6 to 9×10^{-6}cm/dyne $30 to $40	High compliance 9 or more $\times 10^{-6}$ $40 to $50
FM tuner with multiplex	10 microvolts $50 to $100	5 uv or better wide band $100 up	4 uv or better wide band $150 up

The Klipschorn delivers knee-bending bass: naturally and when needed. Its efficiency is high.



Electro-Voice Patrician has 30-inch woofer, two mid-range speakers, tweeter, and super tweeter.

your standards of sound quality, and your budget. The purpose of a components system is to give you the best possible sound for a given amount of money; not the biggest piece of furniture.

This does not mean that a components hi-fi cannot be handsome and decorative. On the contrary, modern components are handsome in themselves just as they come. Arranged on a bookshelf, window ledge, cabinet, room divider, or built into walls, they can make a very decorative addition to a home. They can also be housed in pieces of furniture, and there is a wide variety of styles and qualities of such furniture. But the emphasis is primarily on delivering a natural, faithful and impressive sound.

If it's this kind of hi-fi you want, the first guideline is to avoid the big brand

names, such as G.E., RCA, Magnavox, Zenith, Admiral, etc. They do not make this kind of hi-fi. Secondly, do not go shopping for your hi-fi in furniture, department, appliance, hardware or most music stores. They do not sell this kind of hi-fi.

If you live in a metropolitan area, look in the yellow pages under "High Fidelity" for dealers who handle "high fidelity components" or such brand names as Fisher, Scott, Dynaco, Pilot, Harman-Kardon, Sherwood, McIntosh, Acoustic Research, Marantz, Bogen, Bozak, Bell and Weathers. If your city has no components dealer you can buy by mail from several large mail-order dealers whose ads you will find in this book.

Each of them has a very large catalog, handles most of the genuine high fidelity brands as well as their own house brands, and offers discounts for complete systems, and time-payment plans.

Because there are so many brands and types of components which can be combined into a high fidelity system, your first glance at a catalog or your first visit to a high fidelity store may get you very confused and indeed may scare you out of the idea of buying a components system. Actually, buying a components system can be just as simple as buying a furniture-type hi-fi.

First of all, let's take a look at what a components system is. Figure 1 roughs it out in block form. It can be divided into three sections: 1) the loudspeaker section; 2) the control-amplifier section; and 3) the program sources.

The loudspeaker system in a stereo hi-fi will have two *separate* speaker systems. The reason is that you cannot get good stereo unless the speakers are separated by at least six feet, and preferably 9 to 12 feet.

The speakers are driven by a control-amplifier unit. In most systems this will be a single unit consisting of a control unit or preamplifier combined with two power amplifiers. In de luxe systems, the preamplifier or control unit may be separate; and the amplifier may be one double amplifier or two entirely separate amplifiers.

Program material is available from three sources—radio, phonograph records, and prerecorded or home-recorded tapes. You can use any one or any combination of these program sources. You can start with one—the radio, for instance—and add a record player or tape recorder later.

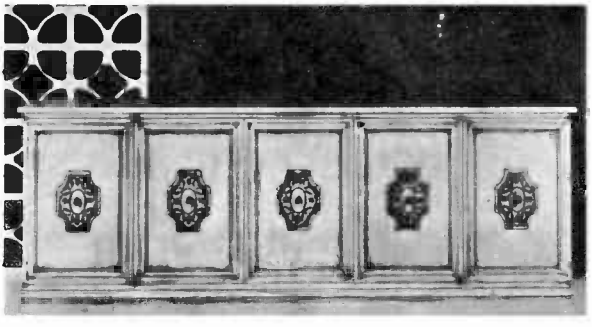
HOW GOOD A HIGH FIDELITY SYSTEM DO YOU NEED?

	GOOD QUALITY SYSTEM	BETTER QUALITY SYSTEM	HIGHEST QUALITY
Do you listen to music	As background?	Attentively?	For greatest realism?
Do you prefer	Popular, mood and dance music?	Dixieland or Modern Jazz?	Classical or Opera?
Your favored source is	Mostly radio	Radio, sometimes records	Mostly records.
Your tonal preference	None	Big bass Bright highs	Facsimile of original
Do you play music	Softly?	Loudly?	Very loudly?
Size of your living room ...	Less than 225 sq. ft.	225 to 400 sq. ft.	More than 400 sq. ft.
Listening periods	Less than 1 hour at a time	1 to 3 hours at a time	Periods of 3 hours or more.

To estimate the quality of a system you need, underline the proposition in each horizontal line that best reflects your taste, or requirements.

Photograph above shows Barzilay Model 900. It's 29 inches high, 78 inches wide, 18 inches deep.

Photograph below shows C-6000 Majorca console called "Sarabande." It's made by Barzilay, too.

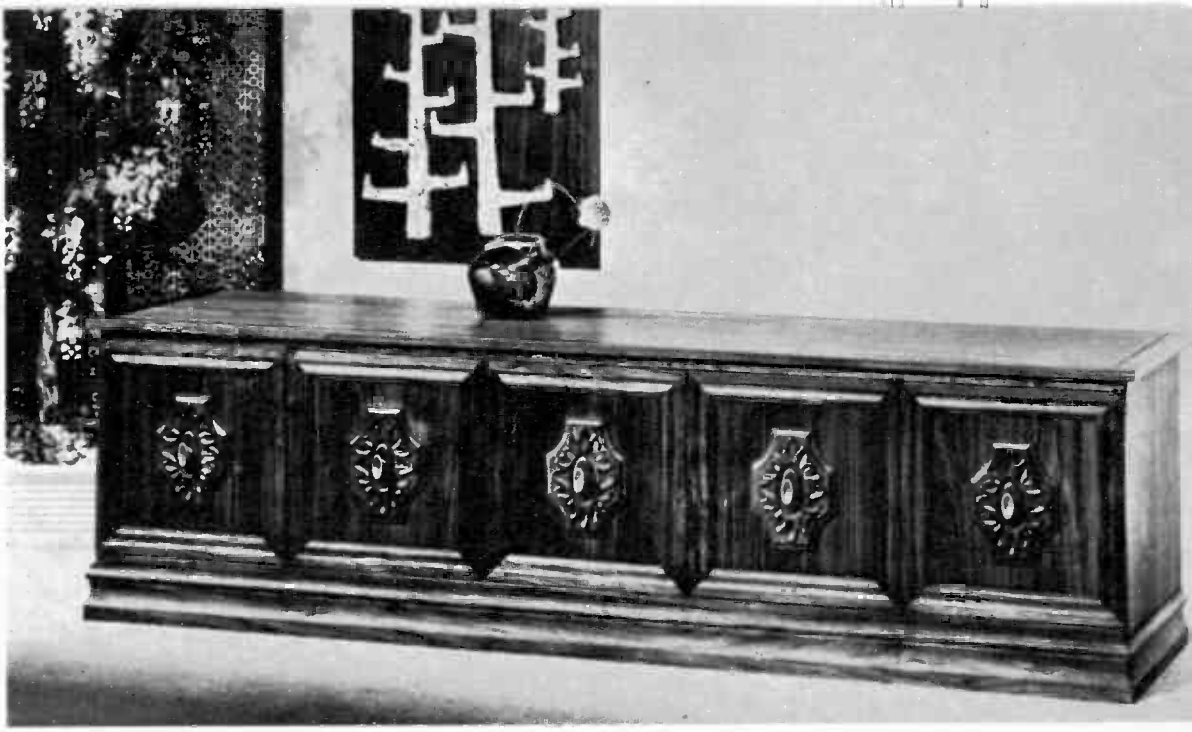


Although there are a great number of combinations that can be put together, your choice is simplified because, in general, components come in three categories which produce three qualities of performance: minimum high fidelity, good high fidelity and superb high fidelity. These come in three price classifications, to meet your budget or your needs, or both. The table shown here will help you determine what quality of system is needed to fit your requirements. Underline the proposition in each horizontal line that best reflects your taste or requirements. If all or most of your underlined propositions fall in one of the three columns, then you are pretty safe in choosing a system of that particular class. If your choices are equally divided between two columns, it is best to choose the higher of the two. Keep in mind that the higher quality system is better even for the less demanding needs—if you can afford it.

As a general rule, the minimum systems will run from $300 downward with a record player but no radio; the good systems from $300 to $750; and the superb from $750 up. A radio, in addition to a record player, will run an additional $75 to $200 more, depending on the quality.

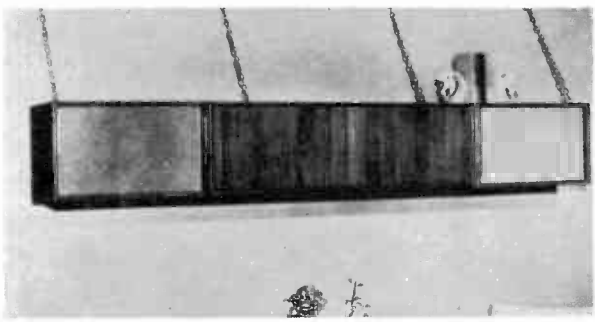
What will this buy you in terms of sound? Almost any components system costing more than $200 will give you a better sound and a better stereo effect than furniture-type hi-fis costing up to $1000. The "medium" category of systems will give you more detail and more impressive quality; the superb systems will bring a symphony orchestra (or a train or a parade or a sports car race) right into your living room.

As we explained in the previous chapter, most of the difference between these three classes falls in the bandwidth of the system and particularly the reproduction they yield of the lowest bass tones below 60 cycles. The minimum systems do not have



This Barzilay 9011 model is set into wall-hanging cabinet which is held by four gold chains.

Barzilay Model 6009 "Turina" has cabinet of walnut, has shelves for components, space for records.



much response below 50 cycles, the medium systems go down to 40 cycles, and the superb systems to 30 cycles or lower. There is no significant loss of *musical* values if the system stops at 50 cycles. You will hear all the music well enough to appreciate it. However, the naturalness and "you-are-there" quality improves very dramatically as the response broadens down to 30 cycles or lower. In other words, the additional money you spend to buy a medium or a superb system, buys you a greater illusion of being right there in the concert hall where the music originates.

There is also a progressive improvement in overall "cleanness" and "definition" and transient response as you move up in these three categories. You can distinguish the individual instruments more distinctly, and they will sound more natural to you as you move from one class upward. Finally, the better the system, the longer you can listen to it without feeling any fatigue. Poor sound reproduction is as hard on the ears as poor light is on the eyes; listening to a poor system with high distortion for long periods will cause irritability and headaches. That's the reason why so many people with furniture-type hi-fis never play them at all, or for short periods only.

If your budget is limited, your choice is limited to the first or second categories. You can make your money stretch in various ways (see next section) to get the best quality for whatever money you can afford to spend. But if you can afford it, it is best, whatever you score on the Test Table, to buy a system of medium or superb quality. The best system will give you best performance with any class of material under any circumstances, to begin with. Also, once you get a taste for high fidelity you will find your preferences get upgraded rapidly. You may not care for opera or symphonic music at all today, but it may well be that once you have heard

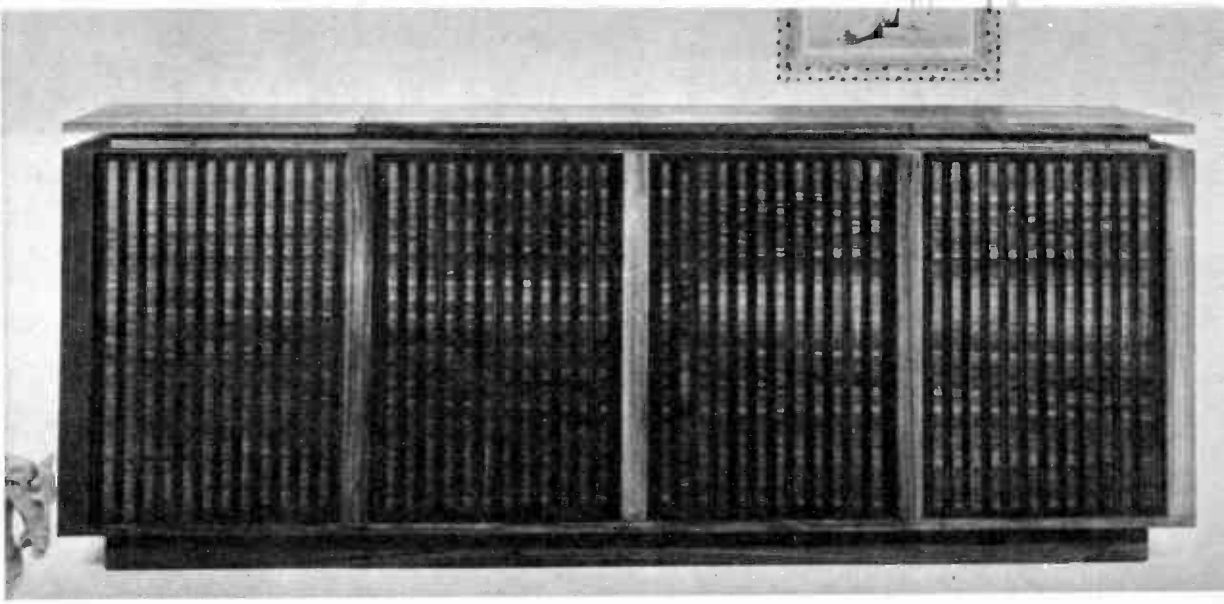
Barzilay Model 9009 with wall-hanging kit is 14½ inches high, 72 inches wide and 18 inches deep.

it on a superb system, you will not be able to get enough of it.

Generally you will get your best buy if you purchase the entire system from one dealer because he will usually give you a discount when you buy a complete system. So the total cost can be from 10 to 15% less than the sum of the cost of the individual components.

Most dealers will be able to sell you a full system in each of these classifications. If you want to make shopping very simple, just tell your dealer the price range you can afford or the quality of performance you want and he will assemble a system for you within that price range or performance class. Most dealers have demonstration rooms in which they can hook up with push buttons various combinations of units so that you can hear how they work together.

In planning your system apportion about 40% for the loudspeakers, about a third for the amplifier-control center and the balance for the record player or radio. Add a minimum of $75 to $100 if you want a



This unit is typical of the great simplicity of line and style now available in all hi-fi equipment.

stereo FM radio in addition to the record player, or vice versa.

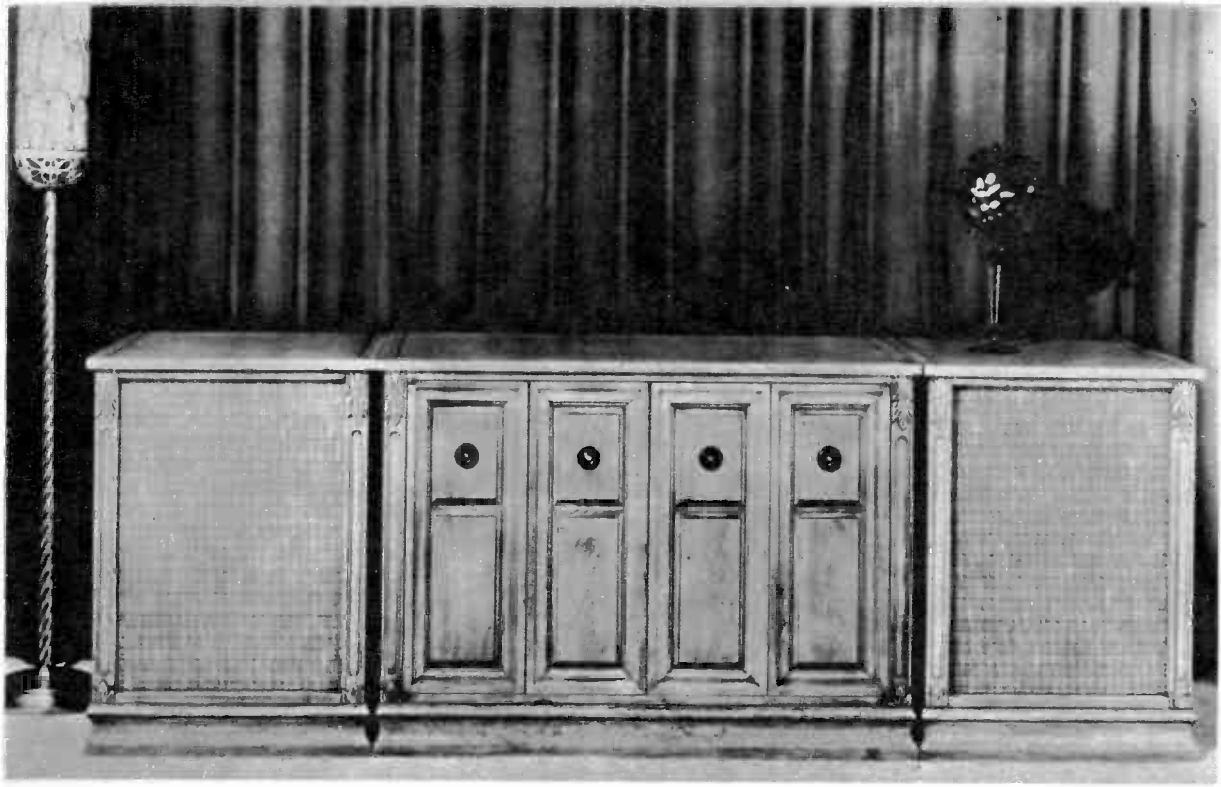
Stay within a given class in choosing your components. You will be wasting your money if you buy superb loudspeakers and a cheap record player, for instance. Whatever the brand, the components in a given quality or price range, will tend to balance each other. Above all, don't try to save money on loudspeakers. It doesn't matter how good the preceding equipment may be; if the loudspeakers are poor, the final sound will be poor. The safest thing to do is to start by choosing the loudspeakers in the particular price range your budget can afford, and then to pick the other items to match them. If you stay within the specifications and relative price ranges given in the table shown here you will be reasonably sure of having a well-matched system.

LOUDSPEAKER SYSTEMS

The loudspeakers are the key elements in a hi-fi system. A loudspeaker system consists of a combination of loudspeakers *and* an enclosure. The performance depends at least as much on the enclosure as on the speaker itself. Although it is possible to buy speakers separately and enclosures separately, we do not advise this unless they are designed to match each other, or come as a kit. The cost of loudspeaker systems varies with quality. They can be divided into three classes: 1) Those which cover the full range down to about 30 cycles or lower; 2) Medium quality speakers which cover the range down to about 40 cycles and good quality systems which go down to 50 cycles with reasonable fidelity. You'll have to pay a minimum of $200 each (or $400 for a pair for stereo) for speakers in the first class; a minimum of $80 for those in the second class and $50 for those in the third class. You'll find a wide choice of styles and types in each of these three classes; big ones, small ones, and thin ones, using different principles, and yielding different qualities of sound. There is no necessary relation between the size of the speaker and its sound quality. Today's small systems using current "high compliance" speakers and either "acoustic suspension" or "ducted port" enclosures can yield as big and clean a bass down to 40 or 35 cycles as some systems using large enclosures. However, to get down into the bottom octave below 35 cycles it does take size and space.

Generally speaking, you will find speakers delivering two types of sound quality: a highly damped, rather dull but extremely faithful sound, like a piano with the soft pedal on; or a bright, somewhat reverberant sound, like that of the piano with the loud pedal on. Most experts and audiophiles prefer the former; many listeners and even musicians prefer the latter. Each make of speaker has a rather individual quality and this is one place where the buyer with a critical ear and definite preferences can express his personal taste.

Aside from the quality of the sound, there are a couple of other practical factors to consider in choosing a loudspeaker. The speaker system should complement



the record playing equipment. If you intend to use an automatic changer—even the finest—it is safest to stick to the medium category of speakers. Changers will have considerable rumble. This occurs at a frequency around 30 cycles. The finest speakers will, in effect, amplify this rumble and hence their ability to cover the lowest frequency may cause more pain than pleasure to the ear. On the other hand, if you intend to use the finest speaker, avoid automatic changers completely: choose a turntable with the lowest possible rumble.

Acoustic suspension speakers, though they provide an extremely high quality, particularly for the money, are less efficient than ducted port or bass reflex systems. They need more powerful amplifiers to deliver their best. Most of them should be driven by amplifiers with a power output rating of at least 15 watts sine wave, or 25 to 35 watts "music power" per channel. If economy dictates the use of lower powered amplifiers, ducted port speakers are a safer bet.

AMPLIFIER CONTROL UNIT

The highest quality is achieved by using separate amplifiers and control units. This, however, runs into money. The trend for the past few years has been to an "integrated" combination of stereo control unit plus two amplifiers in a single package. These range in price from as little as $50 to several hundred dollars, depending largely on the power output of the amplifiers.

The power output of current amplifiers is most commonly rated in terms of "IHFM Music Power Output," although some brands still use the older, and more significant, "sine-wave power output" rating. The power ouput of different amplifiers is not an absolutely accurate measure of performance capabilities. (See Chapter I).

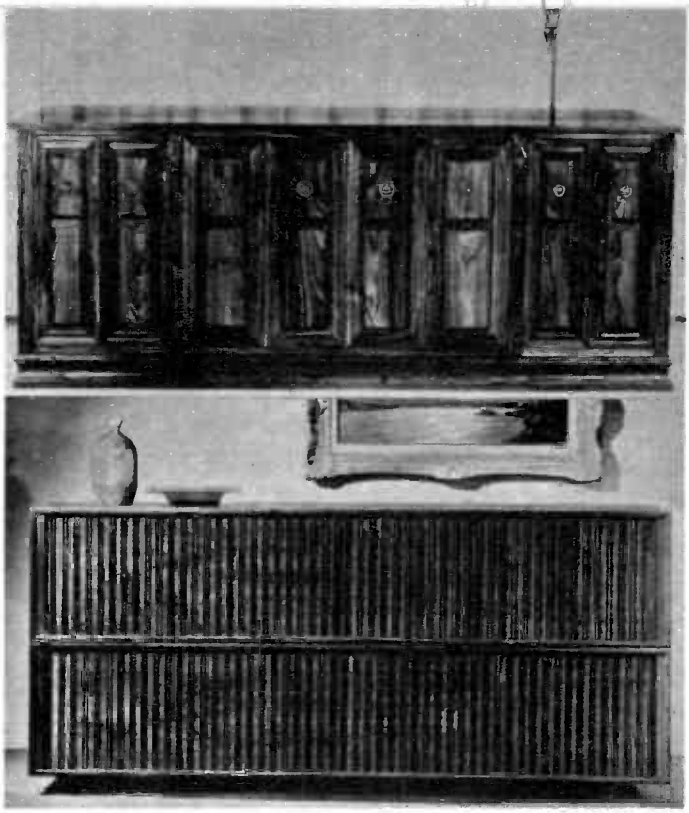
Amplifiers can be classed roughly into three classes in terms of their power output: 1) minimum types from 20 to 24 watts "music power" per channel (which is equivalent to about 10 to 14 watts sine wave per channel); 2) medium types with music power outputs of 30 to 50 watts or 17 to 35 watts sine wave per channel; and 3) top quality amplifiers with *sine wave* outputs between 35 and 70 watts per channel.

The quality of the amplifiers should match the speakers. The finest speakers must have the top quality amplifiers to deliver the performance you pay for; otherwise that low frequency speaker response that you paid $100 premium for

Across page is "Sarabande" by Barzilay, DaVinci ensemble. It has 1061 equipment cabinet and 1062 speaker enclosures. By Chas. Van Sloten.

At top of this page is "Sarabande" by Barzilay, C-1000 DaVinci console, 29 in. high, 77½ in. wide, 20 in. deep.

Other photo is Barzilay 809 equipment cabinet on 809-K-RS record storage cabinet.

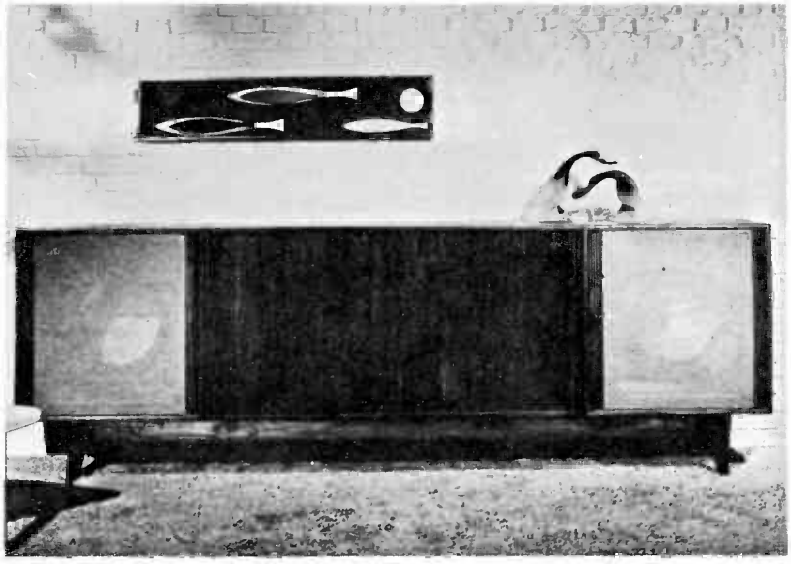


will merely show up the distortion of the amplifiers.

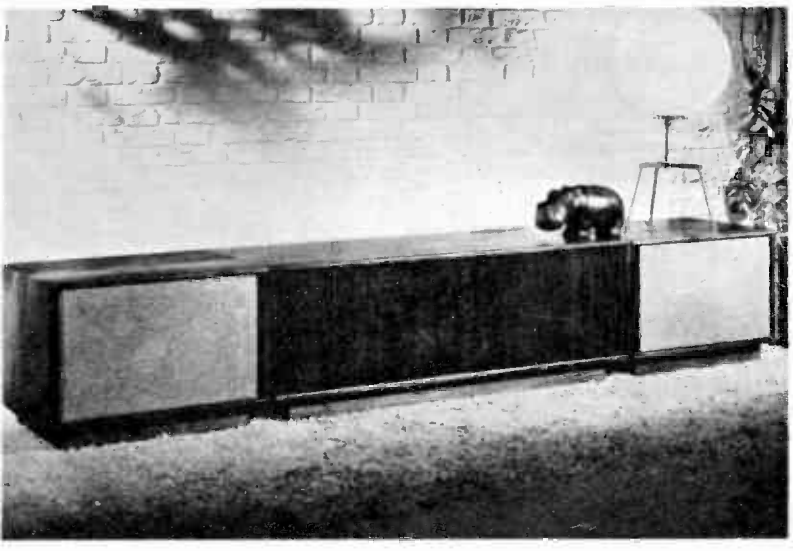
Control units provide switching to choose the program source, controls to choose monophonic or stereo operation, tone controls to shape the tonal response to suit your preference or the acoustics of the room. Some provide additional controls such as treble roll-off or scratch filter, rumble filter, stereo reverse, phase reverse, etc. These additional controls are not essential. There is no excuse for record scratch with modern playback equipment and modern records. If you need the rumble filter, you have wasted your money on an inferior record player and are wasting the money you put into good speakers and amplifiers. Once the system is set up there is no need for reversing stereo channels or phase. It does no particular harm to have these additional controls, but neither is worth paying any premium for an amplifier or control unit to obtain them.

The essential quality in both control units and amplifiers is low distortion, and particularly low distortion at the bottom of the audio range. Any amplifier worthy of being called a hi-fi amplifier will have less than 2% distortion at maximum output at 1000 cycles. The better amplifier will have no more than 2% down to 40 cycles and up to 15,000 cycles, and the superb amplifiers will have less than 1% throughout the entire audio range from 20 to 20,000 cycles at maximum output.

There are now several lines of completely transistorized amplifiers. They can do as good a job, but not necessarily a better job, than vacuum tube types in their class. Only two or three transistorized amplifiers can compete with vacuum tube types in the highest class of performance. Most transistorized units fall in the minimum and medium categories of high-fidelity performance, but cost appreciably more than vacuum tube counterparts in the same class. To balance the higher cost, transistorized amplifiers of the same *music-power* rating, usually do a better job at the low frequency end, *provided the speakers are chosen to match amplifier efficiency.* It is very important to choose speakers with an impedance that corresponds to the output impedance of the transistor amplifier which yields the highest output. Vacuum tube amplifiers will deliver nearly equal performance to 4, 8 or 16 ohm speakers. Transistor amplifiers usually deliver peak performance at one of these impedances, fall off very sharply at any other. Transistor amplifiers should be judged strictly on their merits —the fact that they use transistors rather than tubes gives them no special virtue



Elongated hi-fi stereophonic systems are highly popular these days, and a look at this one explains just exactly why.



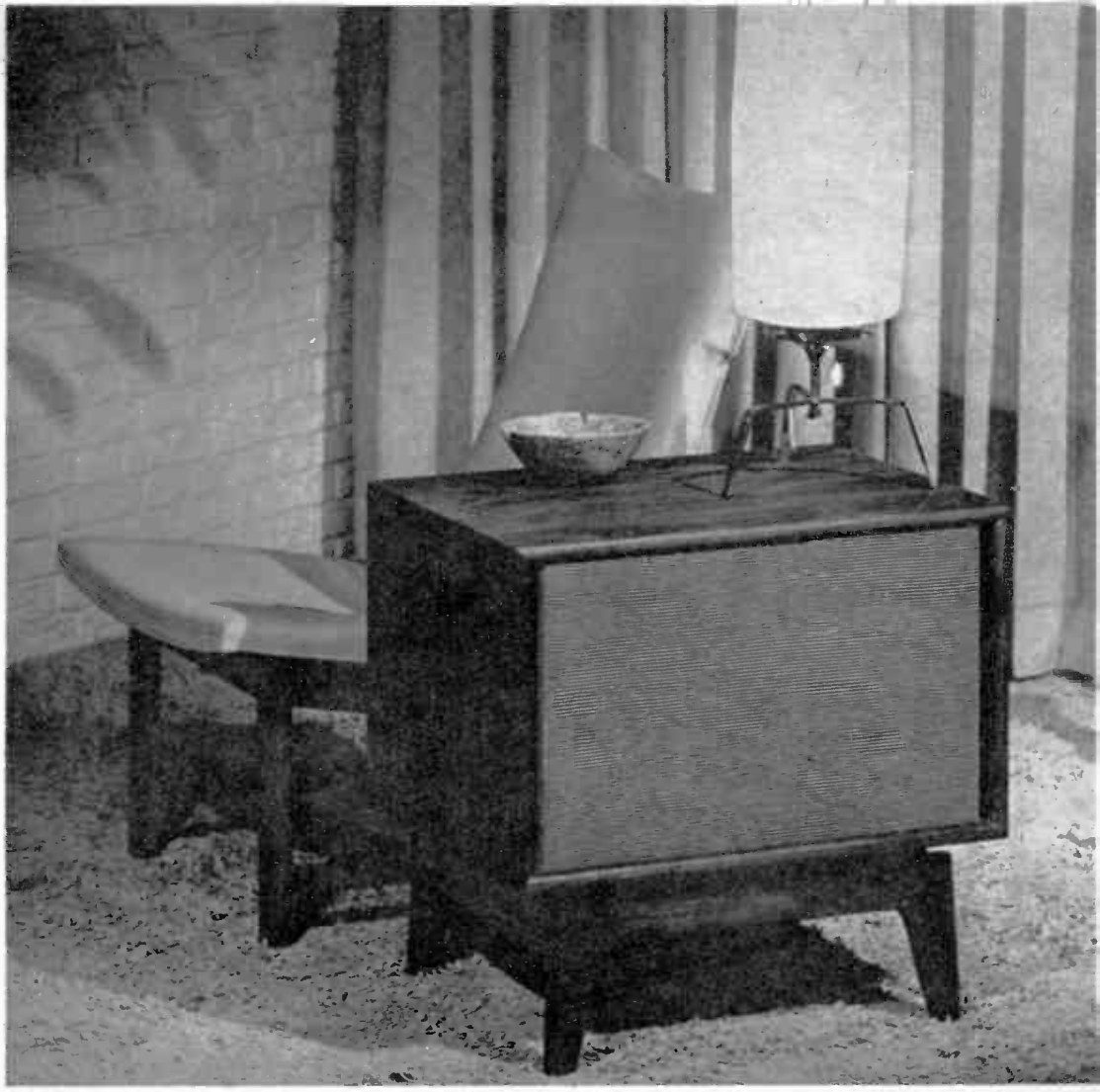
This setup by Barzilay is three separate units (No. 9011K, No. 9067K, and No. 9011K) placed side by side, for a full unit.

that is significant from a high fidelity point of view. The reliability of transistors in high fidelity service is not yet completely demonstrated, and transistor amplifiers will be more difficult and expensive to service when they need servicing. (For more complete discussions of transistor vs. tube types see chapter on this subject.)

RECORD PLAYER

There are more than 26,000 different disc recordings available today, providing every possible variety of entertainment from hillbilly to Bach, and from night club comedians to long-hair poets. To play them, you need to add to your basic system a record player consisting of a turntable or changer, tone arm and pickup. Here, too, there is a wide choice of combinations. Most dealers offer a complete package of changer and pickup, or turntable-arm-and-pickup at a total cost which represents a considerable saving.

The idea of an automatic changer is very attractive. However, even the finest changers are inferior to good turntables and cheap changers will spoil a good hi-fi system completely. This is because all changers have considerably more rumble than turntables. If the rumble is audible, it will be annoying and spoil the music. One way to avoid this trouble is to use speakers which have little or no response below 50 or 60 cycles; and this is what the furniture hi-fis do. However, this takes away most of the "you-are-there-in-person" realism.



Here we see Barzilay speaker enclosure No. 9011B which is 22 inches high, 24 inches wide, 18 inches deep.

To get this kind of realism you must have record playing equipment with very little rumble.

The Garrard Model A, the Miracord Studio models, and the United Dual changers will provide acceptable quality, provided you use speakers in the medium category—whose response stops at about 40 cycles. But if you want the highest realism and speakers of the highest quality, you'd better use a turntable.

Changers are convenient if you listen mostly to music as background, or if you have young ones who want to play current pop tunes on the 7-inch discs. If you listen to music attentively, you'll find it is no trouble to change a record once every 15 to 25 minutes and a turntable will pay off for the extra trouble by giving you much longer record life.

Although the idea of being able to play all four record speeds is attractive, a single speed—33 rpm—will do in 99% of the cases. Practically all stereo records come in this speed. Just about anything recorded at any other speed is available on a 33 rpm recording. Changers play all four speeds, but you pay the price in higher rumble as well as much higher record wear. Turntables are also available in two or more speeds but cost more than the single speed 33 rpm types.

Current turntables come in two types —lightweight models using small synchronous motors; and heavyweight types using larger four-pole or hysteresis synchronous

Modern hi-fi components blend in with modern functional furniture, as our photograph above proves.

motors. The Weathers and AR are examples of the first; most other makes are of the heavyweight type. Either approach can yield very low rumble levels; but the lightweight types do so at a considerably lower cost. The three top changers with good pickups will run from $80 to $125, complete. The AR turntable with one of the top pickups can be had for around $100; and the Weathers with arm and pickup for $100 to $125. The heavier turntables with arms and pickups will run from $100 up to $200.

Today's finest "high compliance" pickups, in current completely balanced tone arms, will play records with stylus pressures well under 2 grams—some with pressures as low as ½ gram. At these pressures record wear is insignificant, and reproduction is as good as that of broadcast quality tape recorders. *These superb pickups must be used with turntables and modern balanced arms only.* For average installations and for use in the three changers mentioned above, choose medium compliance pickups that operate with pres-

sures between 2 and 3 grams. If you must use a cheap changer, use a pickup designed for changer service with pressures between 3 and 5 grams.

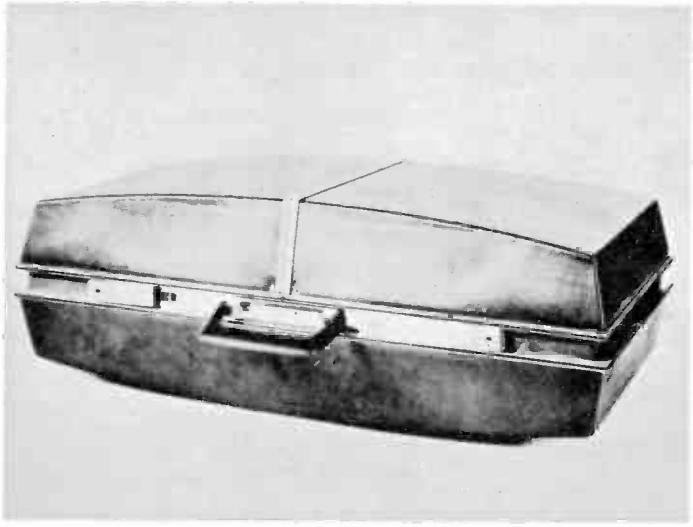
FM TUNER

In most of the metropolitan areas there are from 6 to 20 high-fidelity FM stations broadcasting every type of music, live and recorded, and offering between them a choice to suit any taste. Many of these stations broadcast multiplex stereo programs. A good FM tuner, therefore, provides the least expensive and most convenient source of high fidelity programs. FM tuners connect to the control unit of a hi-fi system and play through it. They provide very much higher quality than any radio.

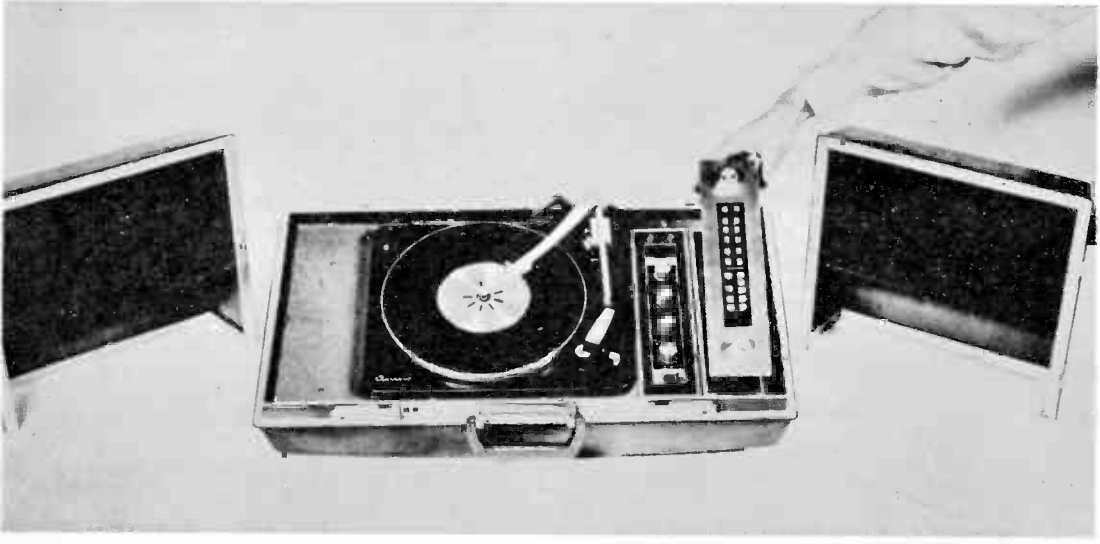
FM tuners are available at prices ranging from $50 to $500. You can also get a one-package unit containing an FM tuner, the control center and the two stereo amplifiers. These run from $150 up and are a good buy for the minimum and medium quality hi-fi systems. With one of these "all-in-one" units you can have a complete stereo system with only three pieces —the tuner-amplifier and two speakers. A

Here we see two Barzilay 8062 enclosures alongside an 8061 equipment cabinet to form entire hi-fi unit.

Here are two more cabinets, typical of the many you will find on the market. Both are by Barzilay.



Pilot's new portable stereophonograph allows for addition of matching AM/FM stereo tuner, making it first portable available for playing both monaural and stereo records and AM and FM stereo broadcasts. Comes in airplane luggage type case, is very strong.



record player and/or a tape player can be added at any time.

By all means, buy an FM tuner capable of receiving *multiplex stereo* programs. Such a tuner will cost you from $30 to $100 more, but it will give you both stereo and monophonic reception.

You can also get tuners that provide reception of the standard broadcast band AM stations, as well as FM. In most cases you will not find the additional investment worth while. The better broadcast stations also have FM stations, and the poorer ones do not yield high fidelity quality.

Almost any FM tuner will do a good job in the primary area of a station—within about 50 miles. If you live farther out you need a tuner with an IHFM sensitivity of at least 4 microvolts. You will also need a good antenna.

TAPE RECORDERS

Prerecorded tapes yield a very high quality of sound but only a very small fraction of the material on discs is also available on tape, and tapes are considerably more expensive. Furthermore, only the very finest tape machines, costing in the region of $400 to $600 will yield as good quality as a $100 to $200 record player.

Actually, unless you are interested in making and playing your own tapes, a tape recorder is a very secondary source of high fidelity program material. Almost any tape recorder can be connected to almost any hi-fi system. If you buy a tape recorder, choose one for its value to you as a recorder, rather than as a source of program material.

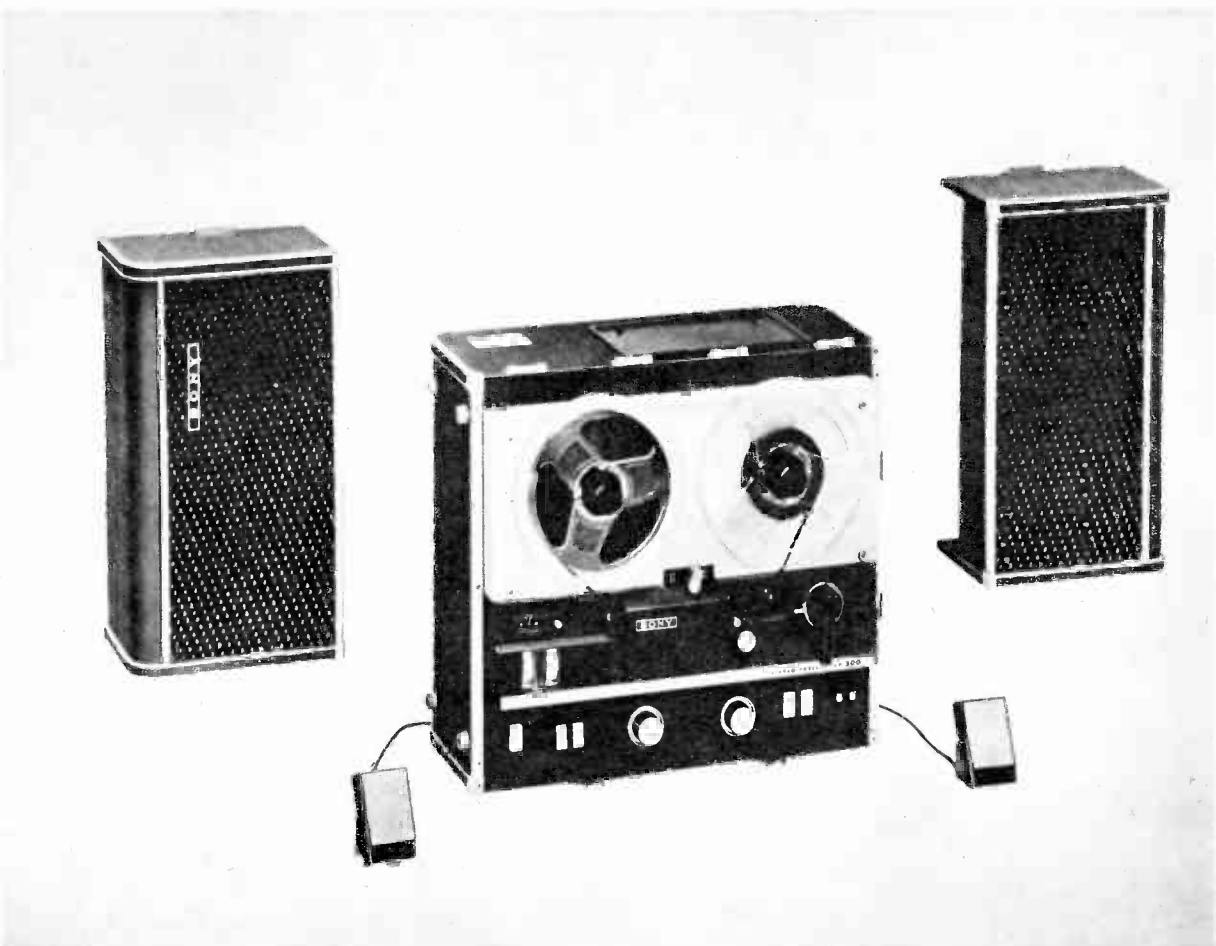
HOUSING THE HI-FI

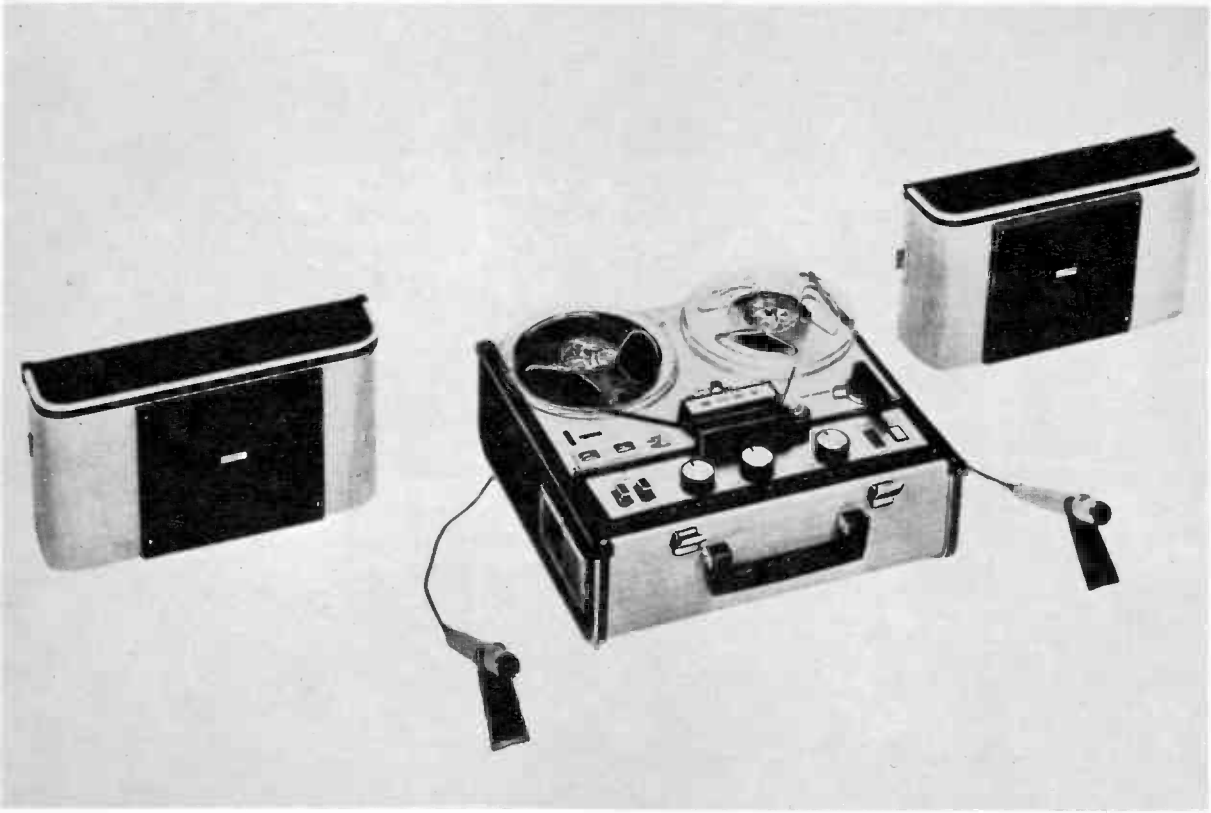
Hi-fi components today are designed for eye-appeal as well as performance. The simplest thing to do with them is to place them on bookshelves, window ledges, etc. You can, however, buy cabinets in which to put the record-player, radio and control center-amplifier components. Practically every dealer offers some type of such cabinets. You can also have them made for you by your local cabinetmaker. In any event, do not be tempted to put the speakers in the same cabinet with the other components. Even with the best technique and the highest skills, the resulting performance will be markedly inferior.

COMPRESSING THE HI-FI

Let's face it: a symphony orchestra, or even a five-piece jazz combo takes up quite a bit of space; and expecting to duplicate the sound they make in a package small enough to carry, is expecting a miracle of a degree that is not realizable even in this day of technological miracles. Therefore, a hi-fi system capable of bringing a symphony orchestra or a jazz combo into your house, is going to occupy some space.

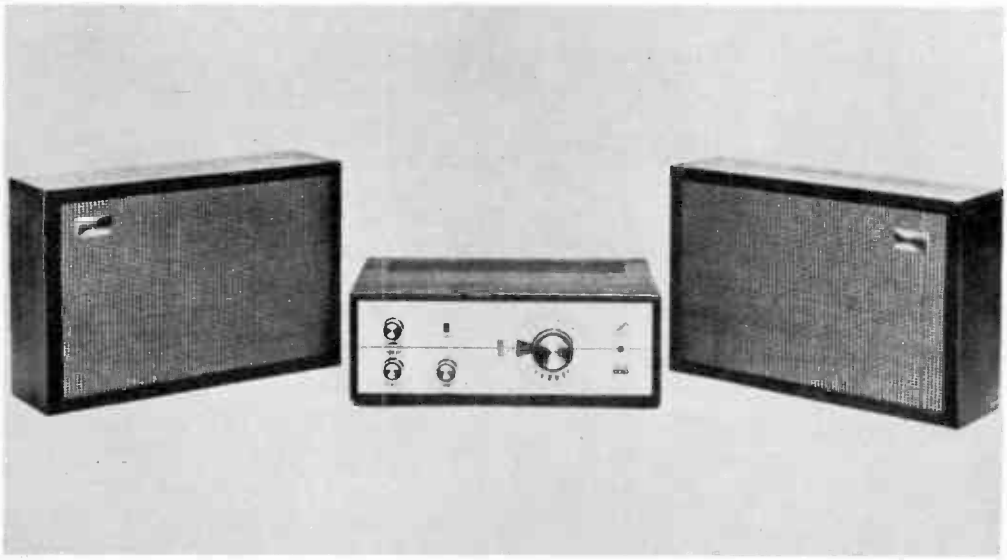
Here is Sony Model 500, a four-track stereophonic and monophonic tape recording system. Price $400.





Photograph above shows Sony Model 200 Sterecorder, a compact lightweight, 4-track recording system.

Here is a complete, compact hi-fi receiver (Eico) for $200, needs only record player to complete setup.



In the past few years designers of amplifiers and particularly of speakers have done a marvelous job of reducing the size of these components. Speakers with two cubic feet of volume or less, produce a sound as good as most very big speakers produced 10 years ago. Integrated combinations of a stereo preamplifier and a pair of stereo amplifiers are available in packages as small as 14x5x8 inches overall, and even smaller. There are hi-fi receivers which combine a tuner, a stereo preamp and two stereo amplifiers in a single package not much larger.

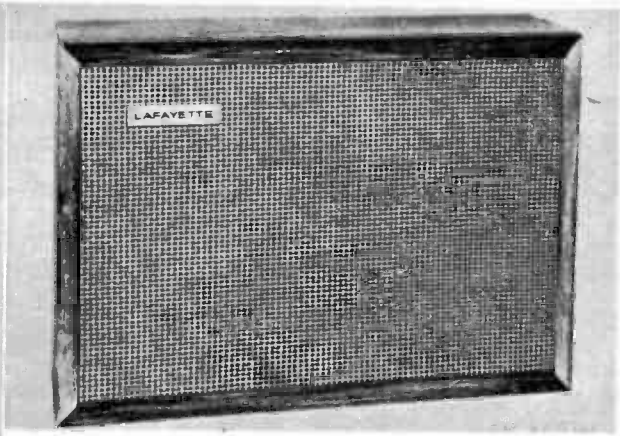
Small as these systems are, they are still too large for practical use by some people under some conditions. There is a limit to what you can put into a college dormitory room, a one-room kitchenette apartment, or a mobile home; and by the time you allow for the essentials there is very little room left for a hi-fi. The simplest solution has been a "portable" package hi-fi which, however, fails miserably to approach the sound quality delivered by a genuine hi-fi system. Is it possible to compress a components hi-fi system into a size that will fit a dormitory room, a one-room kitchenette apartment, or a mobile home?

The answer is yes, though you will have to pay a price in some degradation of the sound delivered. There is no problem in the case of the electronic unit; there is a wide choice of single unit tuner-amplifiers, or amplifiers that will occupy no more space than 3 or 4 books.

The Dynakit SCA35 stereo preamp-amplifier packs performance which falls little short of the superb in a package only 13x8x4 inches. The Heathkit AA 151 is little larger and yields performance in the medium category. There are completely wired combinations by Scott, Bogen, Pilot, etc., of comparable size, capable of delivering all the quality that small speakers are capable of handling.

Speakers are the problem. There is a limit to the compression that can be achieved without sacrifice in range and quality. Lately speaker manufacturers have been applying themselves to this problem and there are a number of very compact speaker systems which yield quite creditable sound. None of these will cover much of the bottom two octaves below 60

Here is a Heathkit four-track portable stereo tape recorder, Kit Model AD-72. The speakers swing out.



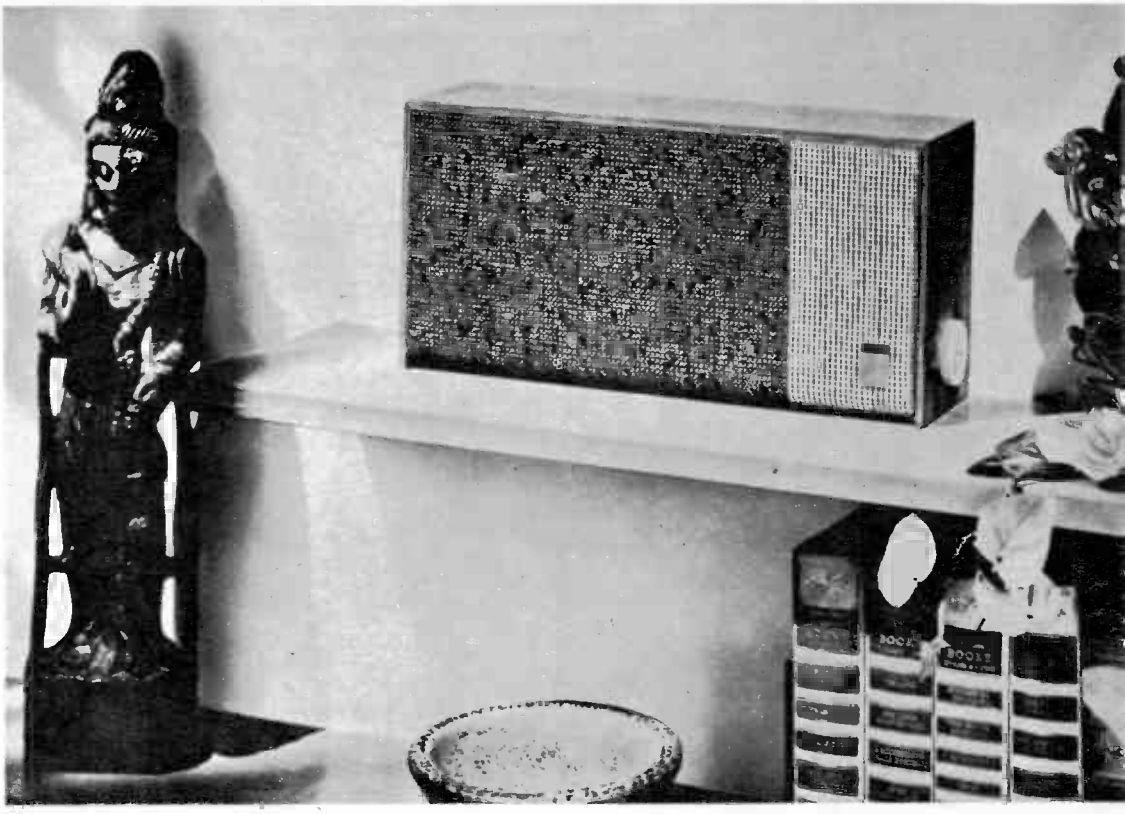
Heathkit miniature hi-fi speaker, kit model AS-81 W, provides surprising bass in small package at low cost ($17.50 each). 6½x11x6½.

The LaFayette SK 265 is 12x18x5¼ inches, is inexpensive (two for $38.50) and valuable for compact systems or for extension speakers.

This Eico HFS 10 (at the left) provides smooth response from 60 to 15,000. It sells for about $30.

cycles; and therefore, they will not give the awesomely impressive and realistic sound available from larger speakers. They will, however, yield excellent musical quality. One of the earliest and an outstanding example is presented by the Jensen X11 and X20. The former is only 13½ inches wide, less than 7 inches high and 4 inches deep. The latter is larger, but thinner: 13x15½x2⅝ inches. They have an excellent high-end response—to 14,000 cycles or above; a smooth middle; and are reasonably flat to about 100 cycles, sloping down to around 60 where they stop dead. The transient response is quite good and one seems to hear a lot more bass than one would expect to issue from such small packages. The Heathkit AS81 in kit form with a mass-loaded high compliance woofer offers comparable performance at an even lower cost. Another miniature system which will give quite gratifying performance is the Realistic Solo 1 (14½x 11x10—$20). Comparable speakers are expected to be presented by other speaker manufacturers. One miniature speaker that does go below 60 cycles is the University Mini-Flex which is only 15x9x5 and is said to have a response down to 40 cycles. It is naturally the most costly—$70 each.

There is a limit to the compression possible in a record player. Since hi-fi records are usually 12 inches in diameter a 14x14-inch space is about the minimum that can be occupied by a record player. The AR turntable, and the Weathers turntable are both very compact and very light, both yield performance in the superb category. Since the response of small speakers to the rumble frequencies is extremely low or completely attenuated, relatively inexpensive and simple changers *could* be used in such systems. The factor here is how much record wear is desired or tolerable. The turntables mentioned with highest quality pickups will operate at pressures of 1 to 2 grams and this means a record life of hundreds of plays. The better changers, such as the Miracord, Garrard Model A, or Dual will operate with 2 to 3 grams. With care in handling, records can sustain a hundred or more plays with these. With the cheaper changers, pressures of 3 to 5 grams will be necessary, and serious degradation in record quality can be ex-



Handsome miniature Jensen X-11 speaker system is book-sized, inexpensive and smooth in response.

pected after about 50 plays. Under 1 gram pressure stylus life is indefinite; under 2 gram pressure, diamond styli will need changing at least once a year; with more than 3 grams, styli should be changed quarterly if the player is used every day. Thus, the better changer or turntable, despite its higher initial cost, may be more economical even in a relatively short run.

THE PORTABLE HI-FI

Strictly speaking, the systems mentioned above are not portable in the sense that you can take them with you anywhere at a moment's notice, though most of them could be packed in a couple of suitcases. Truly portable genuine hi-fi systems are very scarce. One example of a portable phonograph, playing disc recordings, is the KLH Model 11. Weighing only 28 pounds and packaged into one three-section case, this offers a Garrard changer, Pickering pickup, two transistorized amplifiers with output ratings of about 7 watts sine wave and 15 watts peak apiece, and two very small KLH acoustic suspension speaker systems. Somewhat larger but with a better response at the low end is the KLH Model 14 which has larger speakers but is still portable.

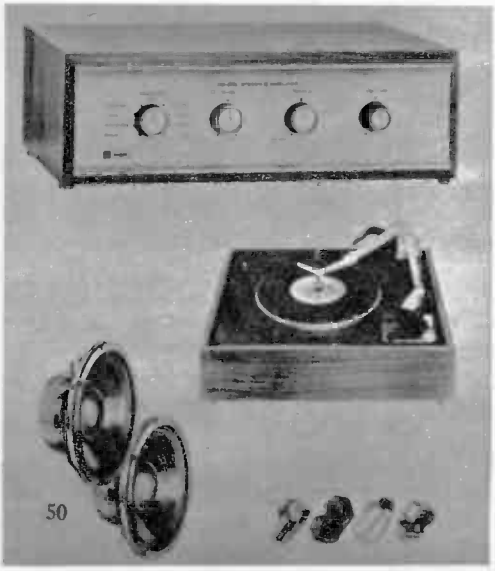
Another transistorized portable is offered by Pilot Radio. This includes a Garrard changer, a transistorized amplifier with 15 watts music power output, two speakers and optionally an FM stereo tuner. The entire assembly fits into one case.

There are several stereo tape recorders available with a pair of compact speakers which are part of the case, or in an accessory case, and which can deliver acceptably good stereo and sound quality with tape sources. The Sony Model 500 and Model 200, at around $300 and $240 respectively, complete with the two speakers, cases and two microphones are outstanding examples, offering good facilities for 4-track stereo or mono tape recording and playback of either commercial tapes or tapes made on the machines themselves.

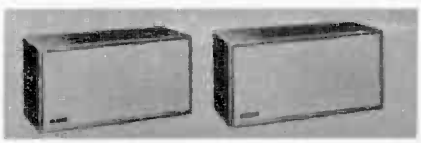
In kit form there is the Heathkit AD 72 which includes amplifiers with about 2 watts output per channel and a pair of speakers on the order of the AS 81s, which can be detached from the case and spaced as much as ten feet apart. •

Stretching the Hi-Fi Dollar

Handsome cabinets also come in kits like this Barclay 100E, which cost $270, and represents a saving of $150 over factory-finished version.

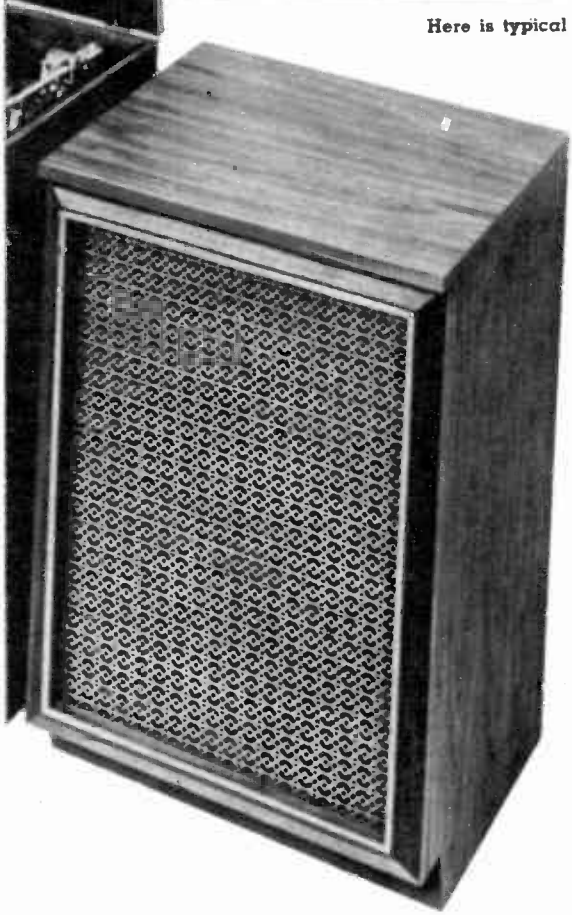


Allied's $122.50 outfit is in kit form, complete with cables. The cabinet is $10 more.



COMPLETE SYSTEM MATCHED COMPONENTS
Lafayette LA-224 24-Watt Stereo Amplifier
Garrard Autoslim 4-Speed Record Changer Base for Changer (Specify finish)
Pickering U38/AT Diamond Needle Cartridge
2-Lafayette SK-124 Ultra-Compliance 2-way Speaker Systems (Specify Walnut or Mahogany)

Here is typical ad you'll see for hi-fi components.



GOLDEN ears do not always come paired with golden purses; all too often those who most appreciate high fidelity sound can least afford it. Fortunately, there are a number of ways of stretching the hi-fi dollar to close the gap between desire and realization.

STEREO HI-FI FOR $125

If you have to get right down to rock bottom in the way of cost, it is quite possible to buy a stereo high fidelity system for between $125 and $150. Such minimum cost systems are offered by the three big mail-order dealers: Allied Radio, Lafayette Radio and Radio Shack of Boston, Mass. Each of these has several stores in its metropolitan area where you can see and hear these combinations.

We show two examples of such systems sold by Allied and Lafayette Radio. Each consists of a stereo amplifier which delivers about 10 watts sine wave power per channel over the range of 40 to 15,000 cycles; an automatic changer with a high quality pickup; and two speaker systems complete with enclosures. They sell for $130, and can be bought on a $10 a month installment plan. They will yield a sound at least as good as that of furniture-type hi-fis costing several times as much, and a far better stereo effect. Radio Shack and other big hi-fi houses have similar systems in this price range.

Knight KN-360 has 20 tubes, 30w per channel, AM-FM reception, versatile controls, is $250 less case.

Handsome new Eico receiver is very easy to assemble, requires no alignment, $155 in kit, $230 wired.

THE ALL-IN-ONE UNIT

A saving in the total cost of the system, as well as in the space required to house it, can be obtained with an "All-in-One" tuner-preamp-amplifier unit or "Stereo Receiver." These are available in several quality and price ranges both in wired and kit form from around $175 to more than $500. They need only a record player and a pair of speakers to complete a full system providing both phono and radio program sources.

Just about the rock bottom in cost is offered by the Knight KU-45 kit stereo receiver, which offers performance well above the minimum quality for $140, has 15 watts sine wave per channel from 30 to 16,000 cycles; a sensitive FM multiplex tuner, plus an AM tuner.

Another kit is offered by Harman-Kardon at $170. This is the FA30XK, identical to the FA3000X wired version, which sells for $220.

Sherwood, Bell, Bogen, Fisher, Scott, Harman-Kardon, Altec Lansing, Grommes, Eric—and indeed, just about every hi-fi manufacturer—offers one or more of these "receivers" in fully wired form. Performance-wise, these fall into the minimum and medium categories, depending on the price. The lower-priced ones will usually have amplifiers in the 10 to 15 watt sine wave, or 20 to 25 watt music power class, with a response at full output down to about 40 cycles. The higher priced ones will offer amplifiers up to 30 watts sine wave per channel with power response down to 30 cycles, or lower.

One of the disadvantages of the all-in-one is that packing as many as 20 or 25 tubes into one package results in a unit which tends to get pretty hot, and in the interest of preserving performance and avoiding parts breakdown it is desirable not to place them inside walls, or enclosed spaces. This is where transistors are beginning to find a useful application. The Altec-Lansing Astro takes a "hybrid" ap-

Heathkit cabinets run from $80 to $100 for equipment cabinets, and $38 to $45 for matching speaker cabinets.

Bogen RP60 AM/FM receiver provides excellent FM receptions, standard AM, $340 with cabinet.

Award FM receiver by Harman-Kardon has tuner, preamplifier, power amp on single chassis, $225.

proach combining tubes and transistors to achieve good performance with low heat dissipation. Either of these can be built into confined places without undue worry about heat dissipation; and the transistorized output stages offer a better transient response than tube amplifiers of the same music power rating.

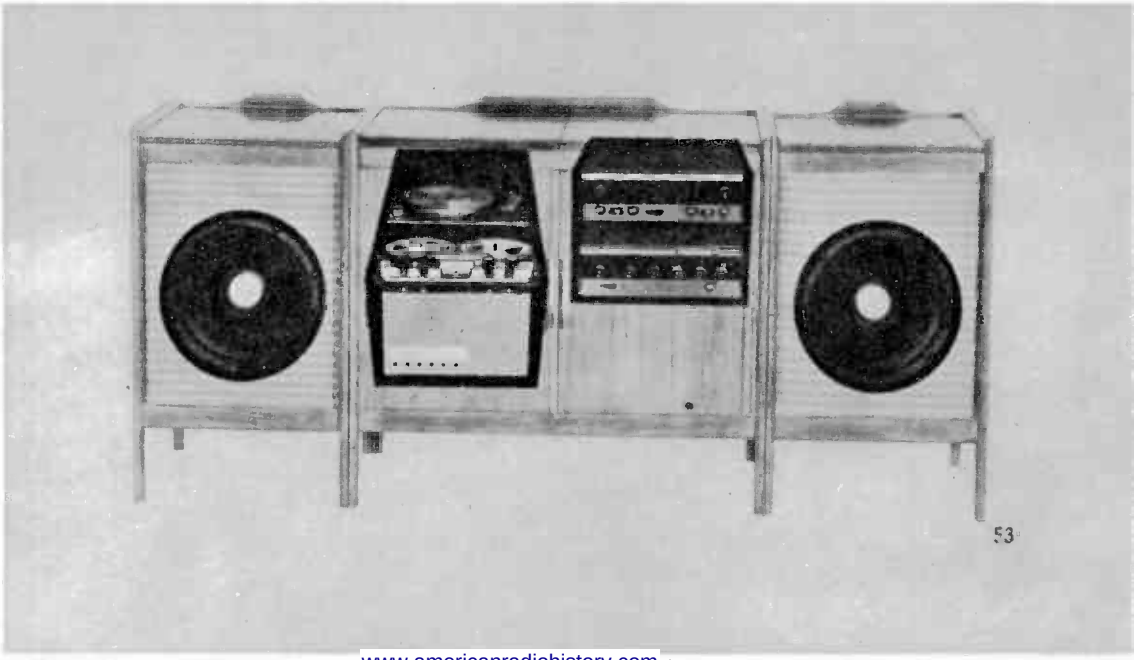
It is not practical to pack the components needed for a *superb* high fidelity system in a single package, and even if it were done, the result would be an unwieldy and extremely heavy package. However, having both the FM tuning controls and the various controls for the stereo phono system on one panel does offer a real convenience, and a combination of a tuner and a stereo preamplifier is thoroughly practical and desirable. One such combination is the McIntosh MX110 which combines one of the finest tuners with an equally fine preamplifier and can be used as part of the finest systems. You might consider this as a possibility.

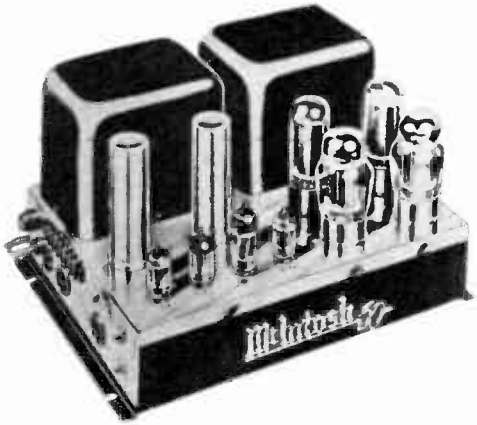
DISCOUNT HOUSES

In the large metropolitan centers, where competition is keen, there are high fidelity "discount" dealers selling the standard hi-fi brands of components at lower than net prices. Particularly when you buy a complete system, you can get a saving of as much as 25% from them.

An even larger saving is possible from these and other dealers on systems using "last year's" or discontinued models of some of the standard hi-fi brands. High fidelity manufacturers do not make annual changes in their equipment, but in any given year several of them will replace one or another unit in their line with a new version and the discontinued units then become available at discounts as high as 50%. The changes in design are no longer as dramatic in terms of sound quality as they once were; and these discontinued models usually deliver performance as good as that of current models in their original price class. Therefore, the pur-

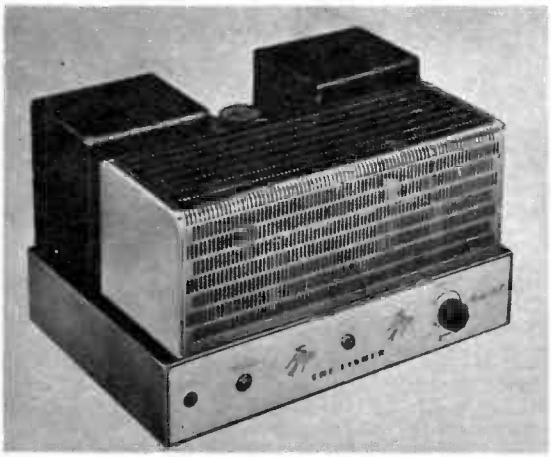
This cutout drawing shows how speakers can be fitted into end cabinets, rest housed in center cabinet.





McIntosh amplifiers use unique circuitry. They are considered to be among the best in the world.

The 30-watt McIntosh amplifier shown above sold for $143.50. The 60-watt, above, sells for $198.50.

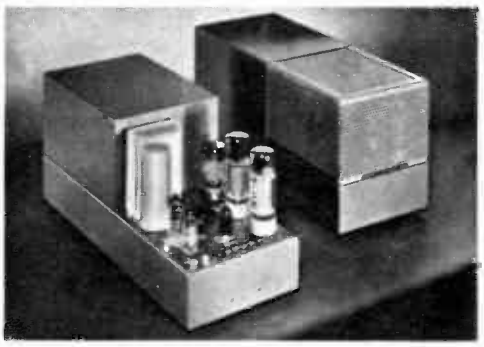


Pictured is Fisher's Model 200 60-watt amplifier.

Fine used monophonic amplifiers (like those pictured on this page) when bought cheap, can be paired for some superb stereo systems.

The Scott 250 Lab Amplifier, at left, gives 40 watts with very low distortion. Priced at $129.

Marantz 40w, below, considered one of the best amplifiers, sold originally for price of $147.



chase of such a unit makes it possible to obtain a higher class of performance at a given cost.

USED HI-FI COMPONENTS

High fidelity components are built much better than the ordinary radio or TV or package-type hi-fi, and use superior parts. They can yield their original quality of performance for a decade or more, and the highest quality lines can serve a generation with a few replacements of such parts as tubes and filter condensers. Thus, used components can provide high quality sound at a fraction of the cost of new equipment. If you do not care for stereo, or can do without it, you can get especially big bargains in monophonic components, particularly large speaker systems, control units and amplifiers. On the other hand, used turntables and pickups and changers are likely to be poor buys even at a very small fraction of their original cost. Current stereo pickups are superior to most of the older monophonic pickups. Furthermore, even if you do not have a stereo system it is well to use a stereo pickup so that you can play stereo records monophonically without damaging them. The turntables and changers of the monophonic era have much higher rumble than current turntables—especially when used with stereo pickups; hence, more recent turntables are safer to use even with a monophonic system. Used FM tuners may not provide a saving either unless you are content to give up the possibility of stereo reception. The cost of adding a stereo adapter may bring the total cost up to a point where the saving is very small; and for that matter the adapter tuner may not work as well as a current tuner designed for multiplex.

Early stereo components, made before 1959, are a good buy only if they are either of the highest quality lines, or obtainable at a small fraction of their original cost. The top quality lines of stereo amplifiers and control units are good buys if the price is low. The "improvements" here have often been in the direction of more compact and more integrated units: and the performance of the older ones may actually be superior. On the other hand, the low and medium priced stereo lines more than four years old may not be as good as current models in the same category which sell for a lower "net" price. Hence, these are a bargain only if they are available at something like 25% of original cost, or less. Stereo units, built since 1959, however, are comparable to current models and will give good performance. Early stereo pickups were highly experimental and much inferior to current models, and should be replaced in the interest of improved record wear, even if not for better performance.

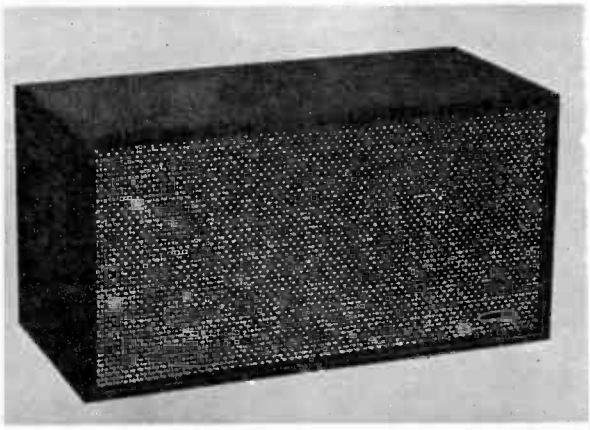
Buying used hi-fi equipment takes judgment and the safest way to do it is with the help of someone who knows a good deal about high fidelity and who is familiar with the older types of equipment and their performance capabilities. But, if prudence is used, it is a way of getting superb performance for the price of medium or minimum quality current systems. Some dealers take older equipment in trade-ins. The Audio Exchange in New York specializes in used equipment. And the classified ads in any metropolitan newspaper have offerings of complete systems or individual components by individuals or dealers.

KITS

The cost of assembling and wiring electronic components is the largest single item in the final cost. A very considerable saving can be achieved by buying hi-fi components in kit form and assembling and wiring them yourself. Just about every type of hi-fi component can be bought today in kit form, and this includes some which yield the very highest obtainable quality. Thus if you can or would like to use your spare time to put together a series of kits you can save anywhere from 25% to 40% in overall cost.

There was a time when some knowledge and skill were required to put electronic kits together. Some knowledge helps, but thousands of people with no previous experience or knowledge have successfully assembled kits without trouble. Manufacturers of kits have gone to great trouble to make the kits themselves simple, and to work out assembly instructions which can be followed by anyone with average intelligence. There are some kits which should be avoided by the novice—the Harman-Kardon Citation line, for example, though it is capable of yielding the highest type of performance, is safest in the hands of those who have had some experience with kits or equipment building. On the other hand, many of the kits are partly assembled, or come with wired sub-assemblies; some kits require only three or four hours and a couple of dozen soldered

Photograph above shows Harman-Kardon Citation A kit, which is solid state stereo control center.



Representing just about rock-bottom in cost at $40 each, is the Heathkit AS50, shown in photo above.

connections. If the instructions are followed rigidly and with care; if each step is checked and double-checked; almost anyone can put together most of the current hi-fi kits.

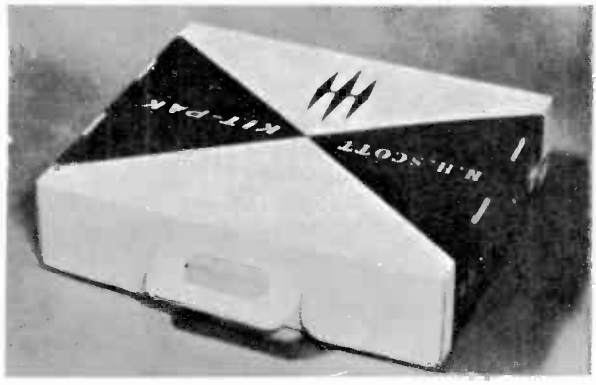
It does help if one has a friend with experience or electronic knowledge to turn to for help and advice in case of trouble, and to assist with the final adjustment. But patience and meticulous attention to the instructions are the primary requirements. The one thing that must be learned is how to solder. Most of the troubles with kits come from poorly soldered joints. Use only rosin-core solder with *60% tin* and 40% lead. This is harder to find than the normal solder which has only 40% tin, but you will save yourself a great deal of possible trouble by insisting on 60% tin solder. It has a lower melting point, flows more easily and does not crystallize into "cold" joints as easily. Before you try to solder any actual joints in the kits, practice with pieces of wire until you get the hang of getting a good, smooth, *shiny* solder joint. The trick is to heat the parts to be soldered with the iron until they are hot enough to melt the solder. Do NOT apply the solder to the iron itself, but rather to the wires or lug to which they are to be connected. Let the solder flow smoothly around the wire and lug: do not use too much solder. A joint with a big blob of solder, with a dull or crystalline appearance, may be a "cold" joint with poor electrical conductivity which will cause trouble in performance.

Kits do not usually come with tools. You will need a soldering iron, a pair of needle nose pliers, a pair of wire-cutting pliers, a wire stripper, one small-tip and one ¼-inch tip screwdriver as a minimum. The best soldering iron for the newcomer is a small 35- to 50-watt pencil type iron. It is also the least expensive. A soldering gun of 100w power is a convenient permanent tool. However, the pencil type will stay hot and thus give greater assurance of good joints. There is a temptation with a soldering gun not to wait until it is thoroughly warmed up.

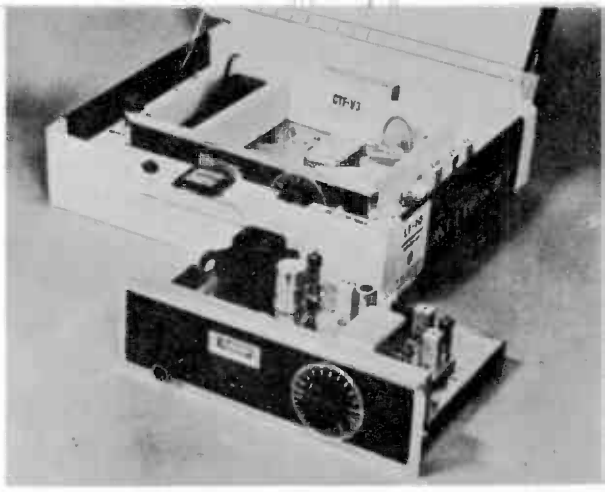
The main thing in putting a kit together is to follow the step-by-step instructions rigidly and carefully. In this the novice actually is safer than the experienced technician since the latter tends to jump to conclusions or to try to "improve" on the kit designer's procedure.

The simplest kits are speaker and turntable kits. These are a matter largely of mechanical assembly with little or no wiring. The next simplest kits are power amplifiers, especially those like the Dynakits using printed circuit boards. Preamplifiers are more complex, although the Dynakit preamps with preassembled circuit boards, are not at all difficult. Tuners are the most critical, particularly the final alignment and adjustment. The Scott and the semi-kit Dynakit tuners are the simplest. If you are building a complete system with kits, it is best to start with the simplest and go on to the more complex as you gather experience.

Kits come in the same quality categories as commercially wired units and it is best to assemble systems using components in the same category. Heathkit, Eico, Knight, Lafayette and Realistic offer units in all three categories—minimum, medium and



Build it yourself to save money. Kit design has been simplified so a novice who has never held a soldering iron or screwdriver can build equipment that is as good as that assembled in factory.



Scott Model LT-10 FM tuner is shown in front of Kit-Pak in which it was shipped. Kit-Pak opens to provide neat work area. All parts are identified and assembly time is six to eight hours.

superb. Dynakit and Citation restrict themselves entirely to units in the highest category of performance.

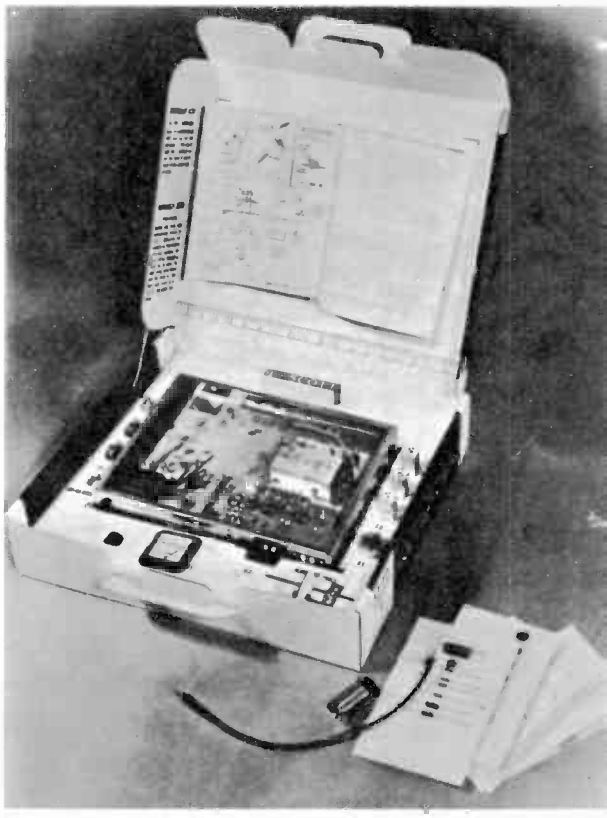
In the past two years several manufacturers of standard hi-fi lines, notably Harman-Kardon, Scott and Fisher, are offering kit versions of their lines. These are not entirely identical with, but do parallel the standard wired lines, and offer closely comparable performance. On the other hand, most kit manufacturers—notably, Heathkit, Dynakit, Eico and Harman-Kardon Citation, also offer their kit units in fully wired form.

The three big mail-order houses mentioned previously also have lines of their own kits (Knight, Lafayette and Realistic), though they also sell most of the other kits. Most hi-fi dealers carry a line of kits in addition to their wired standard lines.

Thus the kit-builder has a choice just about as wide as the purchaser of completely wired units. In fact, the only hi-fi component that does not come in kit form is the phonograph pickup. It is too small and requires far too great precision for home assembly.

BEST BUYS

Finally, in every field it happens that at any given time somebody offers an especially good buy in terms of quality per dollar. This is also true of high fidelity components. In just about every portion of the system, there are one or more units which yield a higher than average yield in performance per dollar spent. Here is a listing of some of these currently available, starting from the speaker end and



Open Kit-Pak shows all parts lined up around chassis. A full-color instruction book is mounted on the back cover. Screwdriver, alignment tool and solder are included. The tuner price is $90.

Among the best buys in tuners are the Dynatuner (above) Scott LT, and Eico Classic (below). They deliver top stereo performance and at low prices.

Photograph at the right shows Eico 2000FM stereo tuner, a good member of the Eico Classic series.

working back to the front end of a hi-fi system.

The Acoustic Research AR2 and AR2A speakers selling at around $100 for the former and $125 for the latter, represent an extremely high value in speaker performance, and have become by far the largest sellers for this reason.

Kit versions of these are available from Heathkit as the AS-2U for $73; and possibly the best of all buys in speakers is Heathkit's own version of acoustic suspension principle called the AS-10 which sells for $60 in unfinished form and $65 in finished form. Another good buy is the Realistic Electrostat sold by Radio Shack for $60 which uses an electrostatic tweeter for a particularly smooth and clean high end response.

Lafayette specializes in low-priced speaker systems and offers several different types in kit and assembled form for less than $50. Especially notable is their Mini-duct enclosure which is available with a variety of speakers at prices ranging from $32 to $52, and will deliver surprisingly good quality for the price.

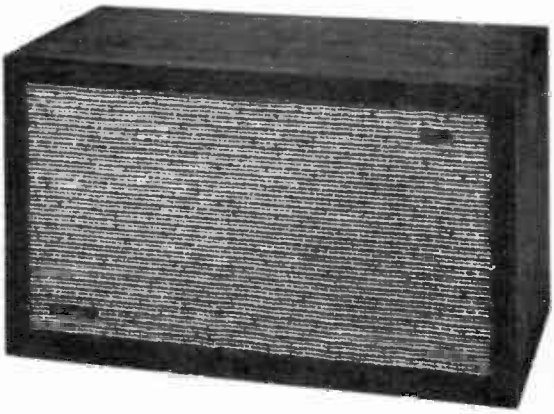
Lafayette KT-550 dual amplifier is rated at 50 watts per channel. Selector switch and meter permit monitoring its operation. The kit is $135.

The Dynakit Mark III rates at 60 watts, uses a prewired circuit board, can be built in four hours, is widely used in pairs in finest systems, $80 for kit.

In amplifiers the Heathkit AA-151 at $60 in kit form or $120 wired, offers performance which is at the top of minimum-quality amplifiers. It is a complete preamplifier combined with two 14-watt stereo amplifiers which deliver the full rated 14 watts throughout the entire audio range from 20 to 20,000 cycles. With the AS10 speakers it will deliver a quality at normal home listening levels which is equal to that of most medium quality systems.

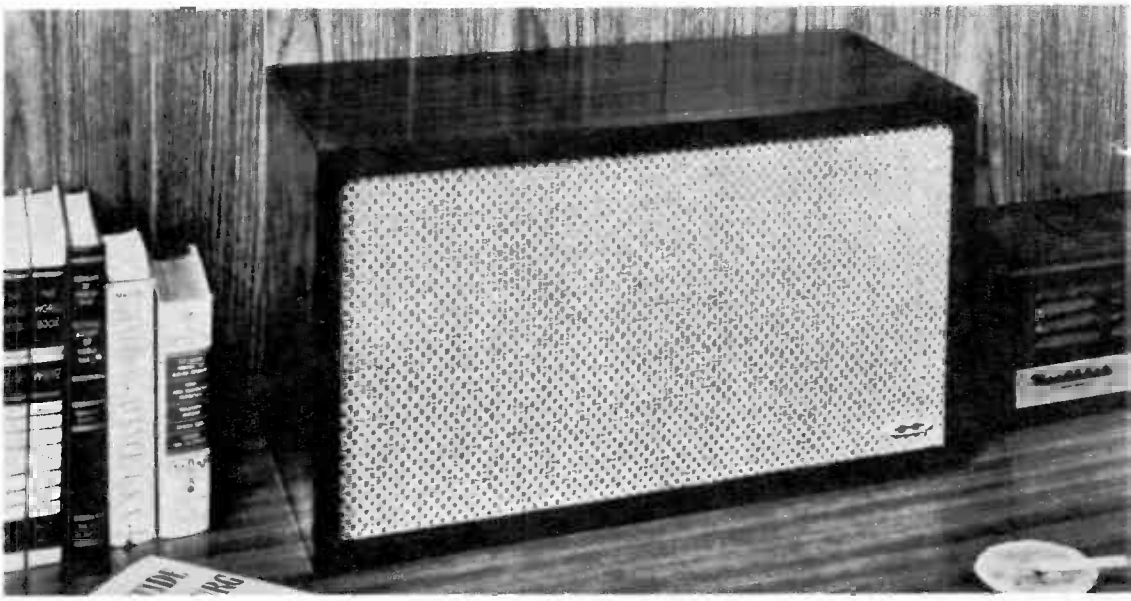
The new Dynakit SCA35 preamp-amplifier at $90 in kit form and $130 wired, delivers 17 watts sine wave per channel with less than 1% distortion over the full audio range and will drive just about any speaker system, including AR3s, to performance which falls short of the superb

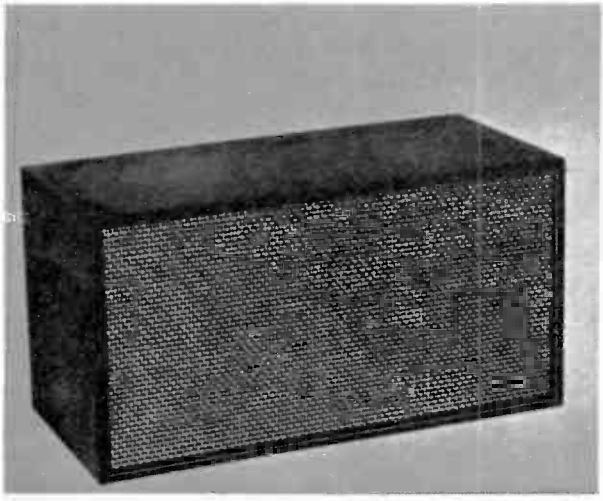
Heathkit AA-121 delivers 40w sine wave per channel over full audio range. Amplifier sells for $80.



Shown in photograph above is Radio Shack's Electrostat-2 speaker, an outstanding speaker for $55.

Heathkit's AS10 uses acoustic suspension, and it represents a very good buy. It sells for about $60 to $65.

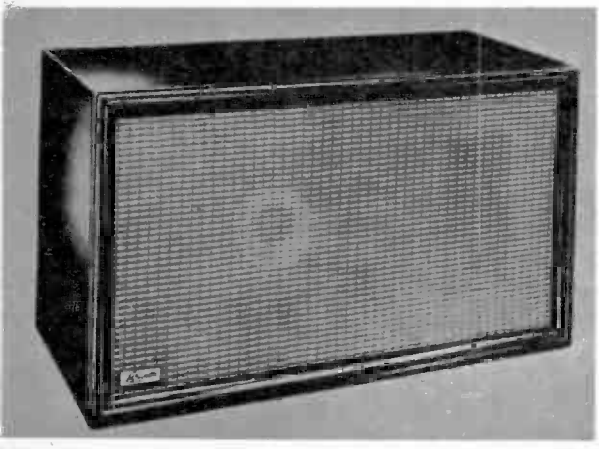




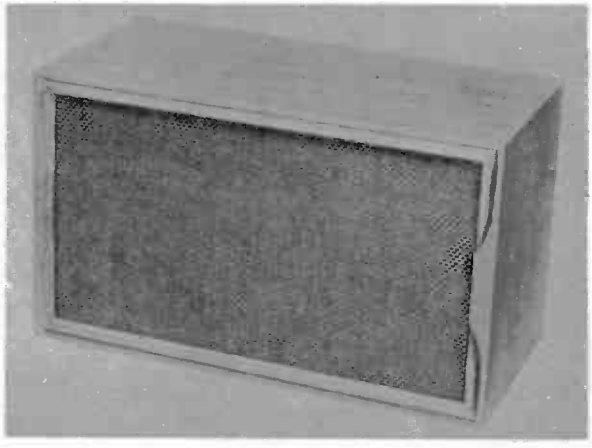
Photograph above shows Heathkit Hi-Fi Speaker System, kit model number AS-51. Easy to assemble.

Garrard type A automatic turntable combines convenience of changer with precision of quality. $80.

With a variety of speakers, Lafayette mini-duct sells for as little as $30 in stores everywhere.



A best buy in speakers, this AS10 by Heathkit gives better than 40-20,000 response for only $60.



only in the lower power output. The combination of the Dynakit PAS3 preamp and the Stereo 70 or Mark III amplifiers has for years offered performance in the very highest category.

The EICO ST70 combined preamp-amplifier at $100 is an extremely fine value, as is the EICO 2336K Classic complete Stereo receiver at $155.

In transistor amplifiers the Knight KN 950 at $120 wired and the Lafayette KT 900 at $135 are outstanding buys.

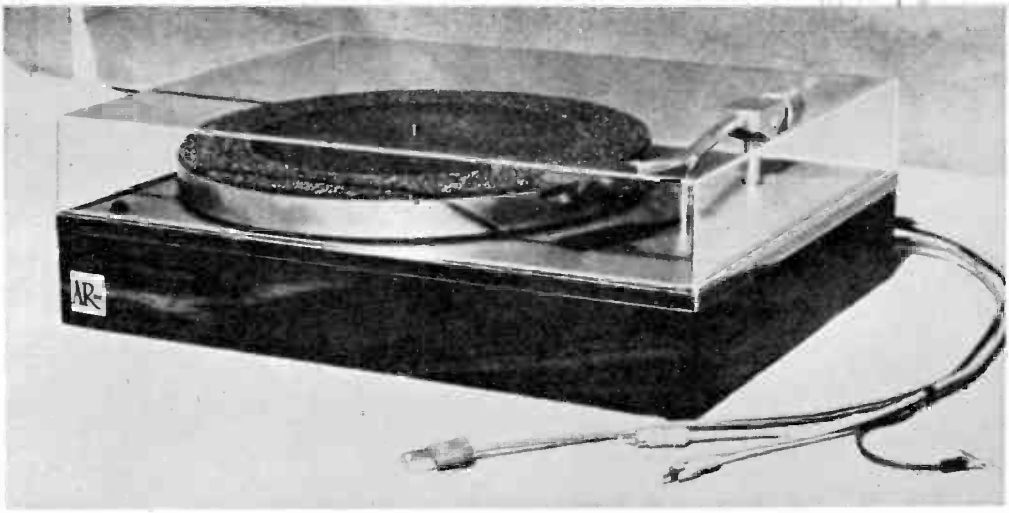
A high value in turntables is offered by the AR turntable which sells for $69 complete with tone arm but less cartridge. Equipped with a top quality cartridge it will deliver highest possible performance.

Lafayette has two high values in turntables. In the medium category they offer the PK-677 outfit which includes a four-speed turntable, tone arm and a choice of Pickering, Shure or Empire pickup for $60. In the minimum quality range they have a 4-speed turntable arm and choice of the same cartridges for $38.

The three Garrard changers are available almost anywhere with a choice of Shure, Pickering or Empire cartridge at around $80 for the Model A, $55 for the AT6, and $40 for the Autoslim.

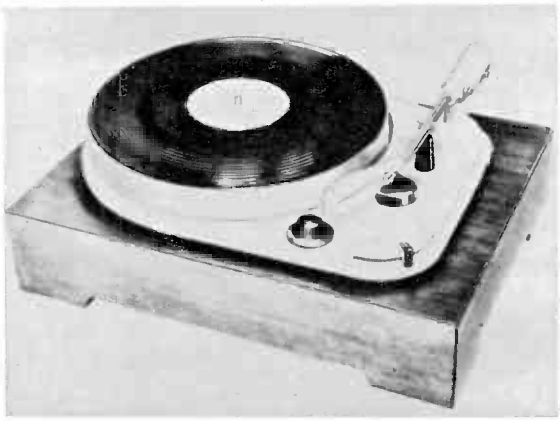
The Knight KN990 4-speed changer of new design is a fine value at $50 with choice of the same cartridges.

The Rek-O-Kut R34 turntable with synchronous motor, belt drive, latest type of tone arm and a choice of cartridges is



Newest contender is Acoustic Research. Single speed job (shown in the photograph above) includes tone arm, the base, dust "cover" for protection, and needle pressure gauge. It sells for $58 less a cartridge.

Lafayette 4-speed turntable is fine value at $50 less base and pickup, $70 with pickups and base.



At $50, Knight 990 changer provides high value, includes adjustable pressure and built-in level gauge.

available at many dealers at around $90 and will provide superb performance.

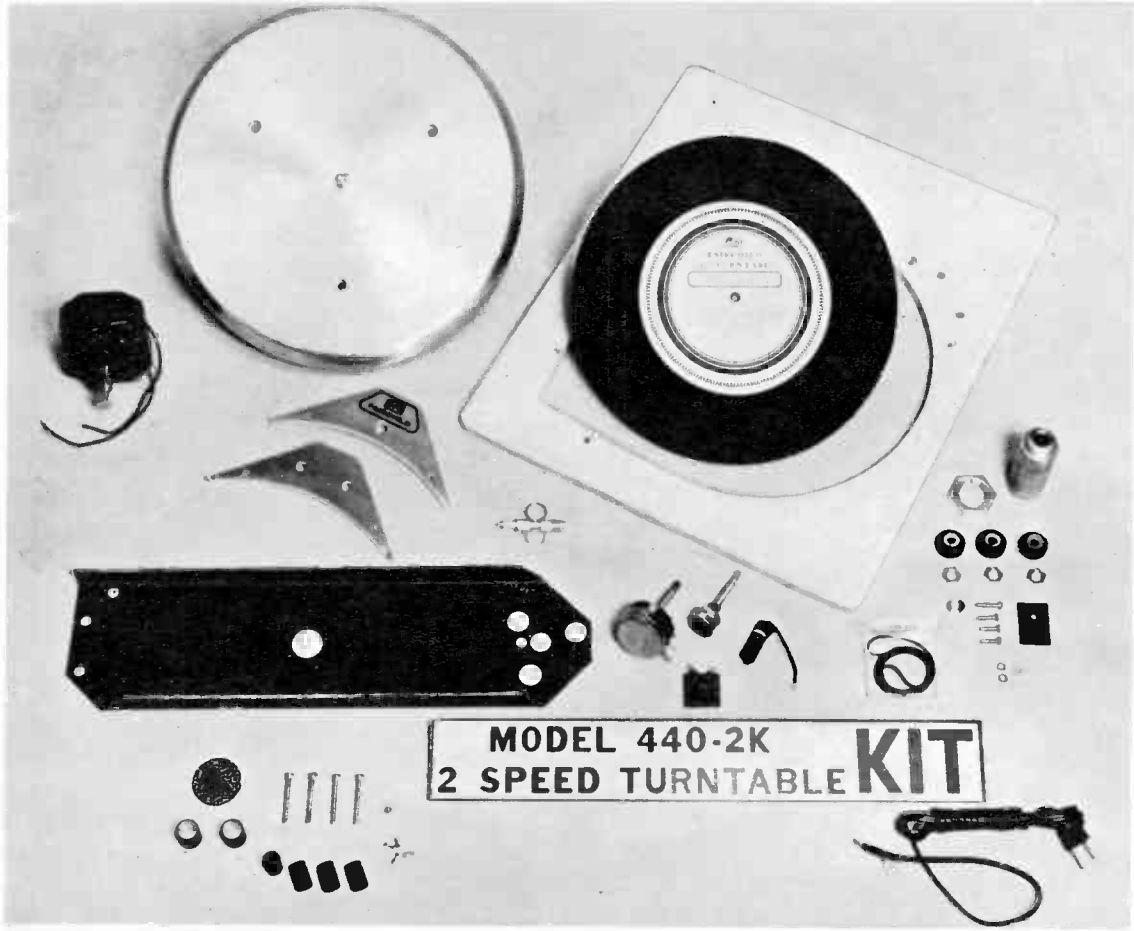
In FM tuners the EICO 2200K kit at $92.50, the Scott LT 111 kit at $120 and the Dynatuner at $99 will give very fine stereo reception in either local or fringe areas. In wired stereo tuners the Scott 370B and the Sherwood S-3000 at $160 and $165 continue a series renowned for high performance at modest prices.

A judicious combination of these best buys can yield a high ratio of performance per dollar. For example $300 invested in the following combination will bring stereo reception of records only one step short of the finest and give an illusion of on-the-spot presence that no furniture type hi-fi at any price can approach.

Dynakit SCA-35 amplifier kit	$ 90
Acoustic Research Turntable with Empire 880 cartridge	90
2 Heathkit AS10 speakers	120
Total	$300

If you need or prefer a changer the following system will give excellent performance at a lower price:

Garrard Type A changer with cartridge and base	$ 85
Heathkit AA-151 amplifier kit	60
2 Lafayette X-347WX speakers	75
	$220



Fine turntables like this Fairchild are also available in simple-to-put-together kits, are fun to assemble.

All About Record Players

IN THE last 15 years, since the Long Playing record was developed, some 100,000 different disc records have been introduced and sold by more than one thousand record companies. At any given time some 25,000 to 30,000 are listed in Schwann's Record Catalog as current and available. Between them they offer the means of bringing into your home just about anything that can be experienced by the ear.

Of course, there is music. Every type of music. The owner of a hi-fi system today, even if he lives in the wilderness, can hear more music in more parts of the world in one week than the richest music lover of any other generation could hear in a lifetime: a large portion of all the serious music written in the past 400 years; every major work and most of the minor works of every important composer; and at least one example of practically every composer, even those whose music no one has heard for generations; the music of contemporary composers in every country. Not only can you hear the music of practically every composer who ever lived, but in the case of the major works of major composers, you can hear it as played by several of the world's greatest conductors. In the instance of Beethoven's Fifth Symphony, you can have your choice of no fewer than 35 conductors and 25 orchestras. More than 200 different operas and 125 ballets,

Rek-O-Kut Model N-34H operates at 33⅓ and 45 rpm. Heavy-duty turntable is belt driven by a hysteresis-synchronous motor. $90 less base.

Garrard Type A Automatic Turntable combines convenience of changer with precision of quality turntable. Plays all four speeds. Price, $80.

and at least that many popular musical shows have been recorded, in whole or in part.

As for popular music, practically every tune written in the past 60 years, every singer and every band, can be found on records—everything from ragtime, Dixieland, Swing to modern jazz and rock and roll, not to forget country music. The folk songs and folk music of virtually every country and, indeed, every tribe of people has been recorded. Every variety of instrument—ancient, modern, primitive or improvised—from the simple shepherd's pipe, and lute, to the modern Trautonium and electronic synthesizers, is available.

But music is only a fraction of the audible world. The world is never silent; everywhere it produces sound, and virtually every sound audible to any ear anywhere is available to you through your hi-fi: bird songs and animal sounds, including the rattles of every variety of rattlesnake, and the "talk" of porpoises; the sound of the wind, of water, thunder earthquakes; the sound of virtually every man-made device from the telephone to racing cars, missiles, ships, tanks and space ships. The sound of just about every trade and profession and of practically every spectacle from auto races to bullfights, the distinctive sounds of the world's big cities.

You can bring into your home the voices of most of the great personalities of the present and past generation—presidents, kings, poets, writers, statesmen, philosophers and scientists.

The theater is as near as your loudspeakers. More than 100 great plays by the great playwrights, living and dead, have been recorded. You can hear the poetry of most of today's great poets read by the poets themselves. Or you can have some of the world's great novels and essays and virtually all of the Bible read to you.

For laughs you can hear just about every current comic or comedian of any consequence and indeed, some from the past, in some 250 records. Or you can improve yourself by learning almost any language, including Arabic and a smattering of Chinese; or how to navigate an airplane, to dance a ballet, to play just about any instrument; or golf or tennis; to do several varieties of exercises, including yogi; to reduce in several ways; and indeed to do just about anything worth doing and a lot that is just for fun.

Whereas, before 1945, there were two dominant record manufacturers in this country; there are almost 500 today all over the world, producing about 500 records a month. Furthermore, because of the remarkable advancement in the techniques of recording and of high-fidelity reproduction, you can experience all this with all the vividness you would if you were there at the original event. Like the time-machine of science fiction, stereo high fidelity can literally take you in time and space to the place where and when an event occurred to enable you to hear it as if you were there in person.

Revolutions are not always announced by fanfares and cannon fire. Some of the most significant ones spring up quietly and their full significance does not dawn on most people until they have almost run their full course. We have experienced

In the Weather's Pro, a transistor preamp insures a good signal to noise ratio, equalization.

Walnut arm of Grado tone arm minimizes arm resonance; every parameter is adjusted to optimum.

in the past 15 years just such a revolution in the field of record reproduction. There have been a few dramatic events, like the introduction of the Long Playing 33 rpm disc, and then the stereo disc; but mostly the advances have been by a gradual evolution. In the past two years, there has been no really dramatic or revolutionary development; and yet, this period has seen one of the most significant jumps in performance in the history of disc recording. Through refinements in all the elements which compose a phono reproducing chain, we have suddenly found ourselves capable of performance so close to the ideal that for most people the difference with a perfect system would be inconsequential.

Current record playing devices are not only capable of reproducing the finest nuances of sound, but deal with the record so gently that it can last indefinitely, if not damaged by handling or improper storage.

The record reproducing system consists of three units: a turntable, a "pickup" and the "tone arm" which supports the pickup. Only the pickup is directly involved in the reproducing process, but both the turntable and tone arm can have a very significant effect on the quality of the sound and all three must complement each other.

The function of the turntable is simple enough: to spin the record. But few jobs are as difficult to do really well. For one thing, the record should revolve at a uniform and constant speed. If the speed is not exactly 33⅓ rpm, the pitch of the sound will not be exactly the same as it was originally; and if there is a variation from moment to moment, the change in pitch produces an effect called "wow" and "flutter", which are both unpleasant and change the entire character of the sound.

Unfortunately, our house current which we use to operate the turntable is not a steady current—it varies in voltage at the rate of 60 cycles a second. Hence electric motors are not energized continuously but in a series of kicks. During the kick they tend to accelerate, and in the interval between kicks they tend to slow down. There are several ways to minimize this variation in speed. Some types of motors are smoother than others. The inexpensive two-pole motor has a large variation in speed. The four-pole motor is better but still leaves a great deal to be desired, and is used only in the minimum quality turntables and changers. Hysteresis synchronous motors are very much smoother and have the additional advantage of locking-in with the frequency of the line current. Since power companies maintain the 60-cycle frequency to very close tolerance, synchronous motors have the most uniform speed and will maintain the same speed with changes in line voltage.

Another way to smooth out the variation in speed is by using a heavy flywheel, as is done in an automobile engine. The weight of the flywheel tends to resist speed up during the kicks, and the momentum it acquires tends to reduce the slowdown in the intervals between kicks. A flywheel is very conveniently provided by the turntable itself and the heavier it is, the greater its smoothing effect. Thus, good turntables, with a few exceptions which we will discuss later, have heavy platters. The combination of synchronous motors with well-balanced heavy turntables can produce a speed constant enough so that "wow," and a more rapid change in speed called "flutter," are both held below the point of perception by the ear.

Rek-O-Kut Model K-34H comes in kit form, features hysteresis-synchronous motor and belt drive, $60.

But there is still another problem. Any irregularity in speed or lack of balance in the moving parts, causes vibration. The phono pickup is a device which translates mechanical motion into an electric current. It is intended to be energized only by the wiggles in the groove of the record; but if the vibration of the motor is communicated to the record, it will translate this vibration into an electric current which in turn will be translated into sound at the output of the hi-fi. The vibration periods of AC motors are low and the sound the vibration produces is therefore low in frequency, and is aptly described by the name "rumble." The amplitude of the rumble depends on many design factors.

Two-pole motors produce very high rumble, partly because they vibrate more, but partly because the frequency of the rumble is 60 cycles. Any loudspeaker worthy of the designation high fidelity will have a good response to 60 cycles; hence, the rumble of the two-pole motors is very audible.

Four-pole motors are smoother, vibrate less, and also their rumble is between 26 and 30 cycles a second. Thus they generate less rumble to begin and this is less obvious to the ear because even good loudspeaker systems are less sensitive at this point in their range.

Multipole synchronous motors are still smoother and with rumble frequencies usually below 20 cycles, to which very few speakers respond efficiently. Thus the better the type of motor the less bothersome the rumble problem.

Rumble is also minimized by measures which prevent the vibrations of the motor from reaching the stylus tip, through the transmission which drives the turntable, or through the mounting board. Motors are usually mounted on some type of vibration absorbing mount—springs or elastomers like rubber or some synthetic—to minimize the transfer of the vibration to the tone arm through the mounting board. In some cases, notably the AR turntable, the entire turntable and tone arm are "floated" for more complete isolation from the motor. This has the additional virtue of isolating them also from outside shocks, such as footsteps or the vibration produced by loudspeakers when they emit very low frequency bass.

The most direct route of communicating motor vibrations to the stylus, however, is the path provided by the drive or transmission from motor to turntable. The simplest transmission is a more or less direct drive to the rim of the turntable, through a rubber-tired wheel on the motor shaft. The rubber not only provides the friction needed to transmit the motion but also absorbs some of the vibration. A very common variation is the "idler" drive. In this, a rubber-tired idler is inserted between the motor shaft and the turntable rim. This is very widely employed in simple record players and most changers because it provides a simple way to change turntable speed. All that is necessary is to use a stepped shaft on the motor with two, three or four diameters. By shifting the idler to these different steps, it is possible to obtain any of the record speeds from 16 to 78 rpm.

Using a belt drive between motor and turntable provides much greater isolation from and absorption of the vibration and therefore much lower rumble. Much of the vibration is dissipated in that portion of the belt which runs in air and does not touch either the motor or the turntable. The finer turntables usually use belt drive, for this reason. Generally the belt runs from the motor to the rim of the turntable. This, however, results in a rather awkward arrangement and also exposes the belt to the room where it can pick up dirt and grime. In some cases, therefore, the belt drives a smaller wheel, to which the turntable itself is attached. To provide even greater resistance to the movement of the vibration from motor to turntable, the turntable is sometimes isolated from this inner wheel by pads of some sort of damping material. The Fairchild uses two belt drives for more complete isolation and vibration damping.

An interesting and very effective arrangement is found in the Thorens turntables. Here there is a belt drive from the motor to a small wheel, which in turn is coupled to the turntable through an idler drive, thus offering the damping provided

both by the belt and by the idler wheel.

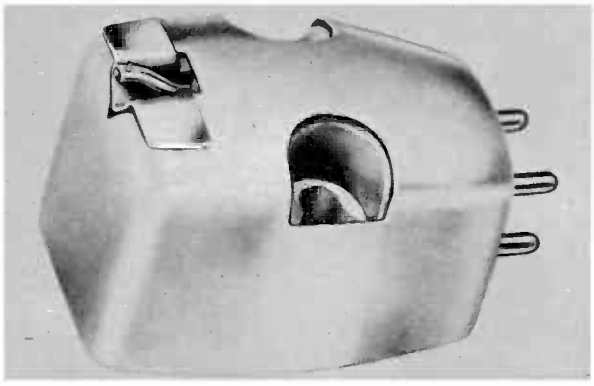
By using various combinations of motor, drive and vibration damping, as well as precision balancing of motor and turntable damping, it is possible to reduce rumble to a level which is quite insignificant and inaudible. The combination of synchronous motors and belt drive produces a particularly satisfactory freedom from audible rumble.

The classic approach to the low rumble turntable has been through the use of a heavy turntable and belt drive. However, the use of a heavy turntable requires a rather powerful motor, and the bigger the motor the greater the vibration problems. Furthermore, hysteresis synchronous motors are very expensive, costing the manufacturer as much as 10 times more than a relatively good four-pole motor. Paul Weathers some years ago came up with a synthesis of ideas which provides very high performance in a relatively light and relatively low-cost turntable. Over the years there had been developed some small synchronous motors for use in electric clocks and other timing devices. They are inexpensive, have extremely uniform speed, and very little vibration. But they are also not very powerful. Weathers reasoned that a small, smooth motor did not require a heavy flywheel, and having less vibration, required less damping to minimize rumble. Furthermore, it revolved at low speeds and the rumble frequency was in the region of 10 cycles which would be inaudible even with the finest of available loudspeakers. He developed the simple, inexpensive Weathers turntable using two of these motors with direct drive to the rim through extremely flexible elastomer wheels, to provide very satisfactory performance at a hitherto unprecedentedly low price.

The AR turntable represents an in-between philosophy. Permanent magnet motors have an even more constant speed and less vibration than synchronous electromagnet motors; and with modern magnets can be built in very small sizes. They have two faults: they do not possess very high starting torque, and they can turn in either direction. To start it in the right direction and to provide more starting torque, the AR turntable uses a small synchronous motor to help the permanent magnet motor get started. Once the turntable is going, the drive to the synchronous motor is released through an automatic clutch. The turntable is much heavier than that of the Weathers, but not quite as heavy as turntables using larger, more powerful motors. A very sophisticated system of floating the turntable and arm is employed to minimize the transfer of the residual vibration to the stylus.

With the exception of the Weathers, the finest turntables use some combination of synchronous motors and belt drive and with rumble levels low enough to be relatively insignificant.

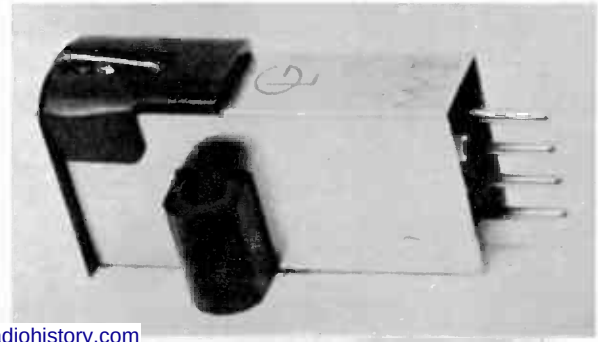
Stereo records have posed an especially severe rumble problem because stereo



ADC pickups has high compliance, low pressure.

The latest design in changers is Dual 1009, which will accept very high compliance pickups and claims rumble level as low as any turntable.

Grado cartridges include XR with the claimed response of from 7 to 50,000 cycles compliance of 25.

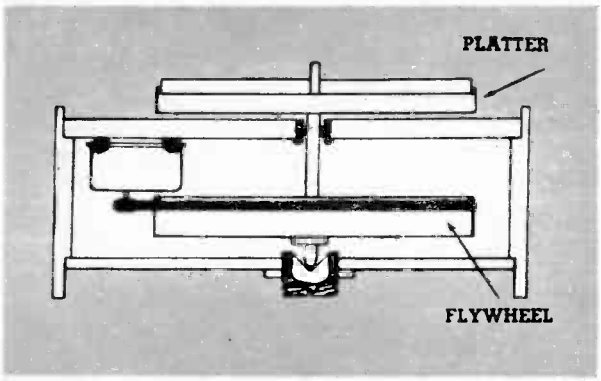


pickups are equally sensitive to both vertical and lateral vibration and vertical vibration is much harder to get rid of. The best of turntables will have an audibly higher rumble on stereo records than on monophonic ones. The difficulty of producing a satisfactory stereo turntable has narrowed down the field of manufacturers to a small handful and hence the prospective purchaser will not be faced with too many alternative choices.

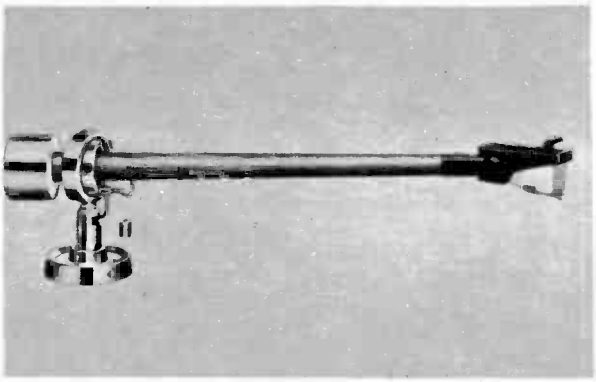
Rek-O-Kut is one of the oldest American manufacturers and offers the widest line in 1, 2 and 3-speed models. Fairchild offers one- and two-speed models. Empire offers three-speed de luxe quality turntables. Weathers offers both one- and two-speed models. The AR comes in single or two-speed models. There are several imported turntables. The most widely distributed are the Swiss Thorens, which come in several combinations of speeds, including four-speed models.

The idea of two or more speeds is superficially attractive, but the single speed 33 rpm turntable will serve practically every high-fidelity purpose. Seventy-eight rpm records are virtually obsolete and in any event would require a change in stylus or pickups as well as a change in speed—there are no "turnover" cartridges in the high-quality field. The 16 rpm speed is for "talking book" type programs and does not provide high-fidelity quality. Forty-five rpm records are almost entirely limited to current pop tunes and much of this is available as well on 33 rpm discs. There is some possibility of utilizing 45 rpm for "super-fi" recordings on 12-inch discs, but so far nothing much has come of this trend. Hence, a 33 rpm turntable and in any event a 33/45 rpm will serve most people and most applications.

The idea of a record changer is also highly attractive superficially. Unfortunately the convenience of being able to play several hours of music without attention is usually paid for by inferior performance. The complication of providing automatic changing makes it virtually impossible to achieve rumble and wow levels as low as those offered by even the less expensive good turntable. Being more complex, the changer is far more subject to failures and needs more frequent adjustment. Except for the Dual 1009, even the finest changers



Grado turntable has two small motors to drive flywheel rather than turntable itself. Has low flutter.



Photograph above shows an ADC arm with its anti-skate correction. It's product you might consider.

require higher stylus pressures than are possible with turntables and independent tone arms. Hence, it is not practical to use the finest pickups with changers and record wear will be greater. Actually, the changer should be considered only by those who are interested in music as background, in which application fidelity is less important than automatic operation.

There are three changers which will provide acceptable performance—the Garrard Model A, the Miracord, and the United Dual, all three of which have been redesigned using some of the design features of good turntables. The Miracord is the most compact, simplest and easiest to operate; can be used as a single play turntable or as a changer. The Studio H model, which employs a synchronous motor, has a particularly low rumble level. The Garrard Model A or Lab model, has been the best selling and most widely available changer for years, offers highly acceptable performance with medium quality systems.

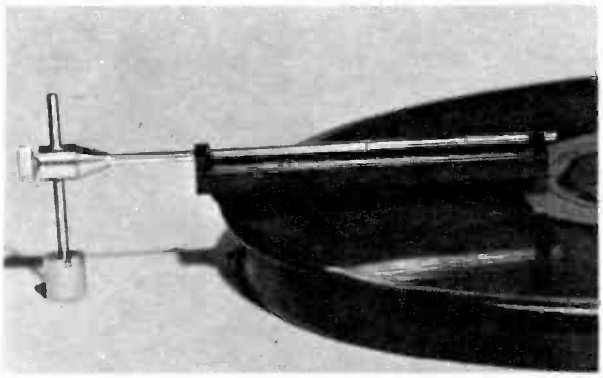
The most recently designed changer, and the one which approaches most closely the performance of high quality turntables, is the Dual Auto Professional. Using a tone arm which embodies most of the features of the highly refined independent tone arms, and a trip mechanism which requires virtually no pressure, this changer will operate satisfactorily with even the highest compliance pickups at pressures less than 1 gram. It also features high isolation for the tone arm and turntable from external vibration, shock and acoustic feedback. It is priced at $95 less pickup and will handle records of any speed or size.

All three of these changers will offer relative freedom from rumble, provided 1) that the system is not operated with loudness compensation or excessive bass boosts; and 2) that speakers with fairly steep attenuation below 40 cycles are used. Most of the medium type speakers, including the AR2s, will be satisfactory.

THE PICKUP

The pickup, of course, is the most important element of a phonograph system and today's pickups are extremely sophisticated, yielding performance which a few years ago was considered quite unlikely of realization. Not only do they provide extremely high fidelity but operate at pressures so low that record and stylus wear are virtually eliminated.

The phono pickup is actually a tiny electric generator, translating minute motion into a small electric current, and most employ one of several adaptations of the same principle used in electric generators. Magnetic pickups are based on three types of movements, depending on which element in the generator is moved. In the moving coil, the magnet is stationary and the coil is moved; in the moving magnet the coil is stationary and the magnet is moved; in the moving-vane or variable reluctance, both the coil and the magnet are stationary and the variation in the magnetic field and hence in the voltage induced in the coils is produced by moving a piece of metal between the poles of the magnet. There is a nonmagnetic pickup —the crystal or piezo-electric. This makes use of the unique property of certain crystalline substances of generating an electric current when they are bent or stressed.



Grado Dustat cleans record continuously with a velvet roller. It is adjustable for any turntable.

Although each of these types of movement has its advantages and disadvantages, it is quite possible to achieve comparable performance with any of them; and among the finest pickups you will find examples of each of these types of movements. Most high-fidelity pickups are magnetic. The crystal pickup offers a simple means of achieving fair performance and is used largely in the low cost or package hi-fi fields. There are crystal pickups, however, which deliver performance fully comparable to that offered by the finest magnetic pickups—notably the Weathers and the top quality Astatic.

The stereo pickup is a marvel of miniaturized precision. Actually in its approximately ½ cubic inch of package, it contains two separate movements, more or less independent of each other. The delicacy and precision required can be gauged from the fact that the mass of the moving tip in the finest pickups is less than one thousandth of a gram, and the radius of the stylus may be as small as 3/10th of one thousandth of an inch, and its flexibility is measured in millionths of a centimeter. The wire of the coils may be as small as the human hair or smaller.

There are many factors involved in the performance of a pickup. As in all other elements of the hi-fi system the desired characteristic is the widest frequency response and the lowest distortion. It is more difficult to obtain response above 10,000 cycles on the 33 rpm record than it was on the 78 rpm, because the lower the speed at which the groove moves past the stylus, the shorter the length of groove into which a given number of wiggles can be cut in a second. It is obviously easier to put 10,000 or 15,000 wiggles in a 2-inch length of groove than in a one-inch. Furthermore, at any speed, the groove velocity—which means the length of groove that passes the pickup in a second—varies with the diameter. In the outermost groove a much longer length of groove passes the tip than on the innermost. Hence, any record has a better high frequency response on the outer than the inner diameters. This is compensated for in the recording process by an automatic equalization which boosts the highs on the innermost diameters.

When more wiggles are cut into a given length, obviously each individual one will be smaller. To reproduce the highest audible frequencies, the stylus must be extremely small. The standard LP stylus was 1 mil in radius. This was reduced in the stereo cartridge to .7 mil. To obtain a better response above 10,000 and particularly above 15,000 cycles the stylus has to be made smaller and hence in the widest range pickups the stylus diameter will be .5 or even .3 mil.

The smaller stylus is advantageous for other reasons as well. It weighs less and hence the mass of the moving system can be made smaller. The lower mass makes possible a higher flexibility or compliance and this means a greater linearity in the response to wiggles of high amplitude. Any moving system is resonant, and the phono pickup is no exception. All other things being equal, the smaller the mass the higher the resonant frequency. It is important in a pickup to keep the resonance above the audible range, and the smaller stylus and lower tip mass help to achieve this.

Today's high-fidelity pickups are practically all flat within 2db or so to 15,000 cycles. There are several pickups whose response is flat to 20,000 and even extends to 30,000 cycles. There is a limitation which the pickup designer is rather helpless to deal with. The stylus *and the walls of the groove* in the record together form a resonant system, which is a factor partly of the pickup characteristics and partly of the record characteristics. In the case of the record, the material of which it is made, and the thickness of the walls between grooves are factors. Materials vary with manufacturers and wall thickness varies on each individual record with the depth of modulation. In any event, any pickup will have a resonant peak at some frequency on almost any record. Again it is important to keep this resonant peak above the audible range, and since the pickup designer cannot control the parameters of the record, he is not in complete control of this

You buy a record because you like it. Each time you add a record to your collection, you're building up your personal library of musical favorites. Here's how to make sure each record you own gives you maximum pleasure each time you play it.

1 Avoid getting fingerprints or smudges on the playing surface. Handle the record by its edges, or by one edge and the center label.

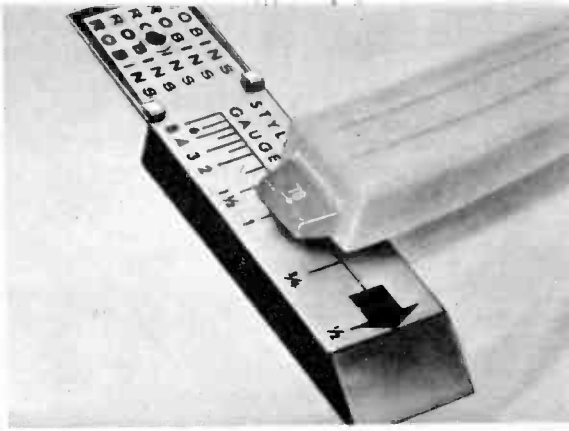
2 Hold the record jacket against you and buckle it when removing or replacing records.

3 Remove surface dust before playing a record. Do this by gently wiping the record with a slightly damp soft cloth, chamois or brush or a specially treated record cloth available at your record dealer.

4 Store record albums upright as you would books. Single records should be kept in a rack but may be stacked or stored vertically with your albums.

Courtesy Mercury Records

Swiss-made, this Bogen turntable plays all four speeds at pressures as low as 1.5 gr. Price is $65.



A gauge like this Robins should be used to adjust pressure for the best performance from the records.

resonance. Nevertheless, in good pickups whose own resonant frequency is at the top or above the audible range, the incidence of this groove-to-stylus resonance will be small and limited to the very top of the range. Because of this some pickups give better performance with records of one manufacturer than other pickups; and conversely, the performance of any pickup will tend to be better with some makes of records and poorer with others.

Although there have been no significant new developments in pickup design in the past two or three years, there has been a tremendous leap in their performance capabilities, largely through refinement of the moving elements.

In view of the many factors that enter into the performance of a pickup it is difficult to evaluate a pickup accurately from the specifications. The most significant single specification, however, and the simplest rough and ready guide to performance capabilities is the compliance. This is a measure of flexibility and therefore of linearity. The higher the compliance, in general, the better the performance of the pickup—not simply because of the higher flexibility but also because to obtain high compliances the other significant factors have to be controlled in the optimum direction. Thus high compliance pickups will invariably have lower tip mass, a smoother and wider frequency response and lower distortion—assuming that they are properly adjusted.

Compliance is measured in terms of the distance in centimeters that the stylus will be displaced by a force of one dyne. It is expressed, for example, thusly: 6×10^{-6} cm. dyne, which means that this particular pickup would be displaced 6 millionths of a centimeter by a force of one dyne. The significant number is the first number, and the higher this first number the higher the compliance. Two or three years ago a compliance of $6\text{-}10^{-6}$ was notable; today practically every pickup manufacturer offers at least one model with compliance in the region of 20, and ranging all the way to 30 or even higher.

Generally speaking, pickups can be divided into three classes by their compliance: superb pickups with compliance above 9 or 10; medium pickups with compliance from 5 to 10; and pickups with compliance of less than 5.

It is not possible to interchange these types in just any system. As a matter of fact, the superb pickups can be used only with tone arms specifically designed for use with high compliance pickups. They must be free of the influence of the arm to yield their performance. In unsuitable arms they may well give performance inferior to that with medium compliance pickups.

The medium compliance pickup is most suited for average applications. The lower compliance pickups, below 5, are used principally with record changers.

The very high compliance pickups operate usually with pressures of 2 grams or less—indeed, as little as ½ gram. At these low pressures, record wear and stylus wear are practically eliminated. On the other hand, the high compliance pickup is quite easily damaged. In the past year, for example, we have had to replace stylus assemblies in two of our very high compliance pickups because they were damaged by accidental mishandling.

By all means choose the highest compliance cartridge—with a suitable arm—for highest fidelity; occasional replacement of the stylus will be no more frequent or costly than that needed to make up for wear on lower compliance pickup styli; and the saving in record wear will be a very significant economy, not to mention the higher quality or performance.

On the other hand, do not attempt to use one of these with older arms or in changers

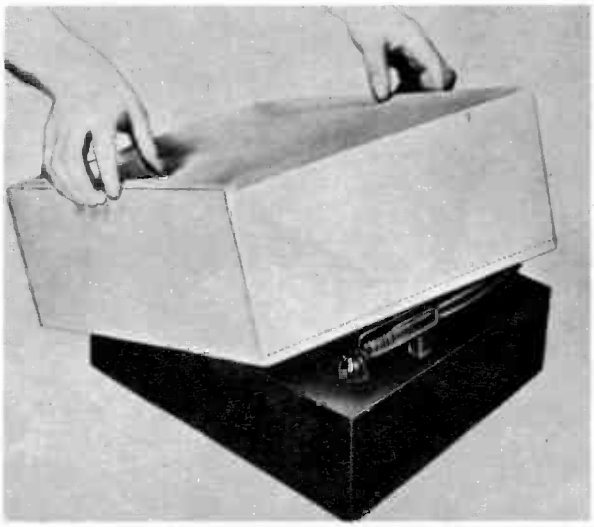
(with one exception noted below). The three good changers will give good results with the medium compliance cartridges. Other changers will need low compliance pickups.

Pickups of equivalent compliance are likely to differ most in the separation they provide between the two channels of a stereo recording. In the ideal cartridge there would be no sound issuing from the left speaker when the cartridge is energized solely with a right channel; and vice versa. No cartridge made will be this good; but a number will come so close to it that you will have to put your ear to the "dead" channel to hear the crosstalk. The simplest way to test separation is to use one of the "gimmicked" stereo spectacular records, like some Command records, in which the sound is shifted from left to right with no common component. Variable reluctance movements like the Pickering and B & O tend to have the best separation, and moving coil types the lowest, with moving magnets in the middle. On the other hand, variable reluctance types must be properly loaded and used with the shortest possible cables, to minimize the possibility of a peak at the high end; while moving coil types are very tolerant of loading and cable length.

All pickups involve compromises of vices and adaptations of virtues, and hence generalization like the above should not be applied categorically. Actually, competition in this field has not only driven the designers into movements of higher performance but performance which is quite comparable from make to make.

One of the newest trends in pickups is the use of transistorized pre-preamplifiers. The very high compliance pickup tends to have very low output. Most stereo amplifiers are designed to handle a pickup input in the region of 5 millivolts or more. The very high compliance pickup may have outputs well below this, as little as 1 millivolt or even less. Used with the normal amplifier this would result in a relatively high noise and hum level. Therefore, Weathers in their top-quality Professional pickup, and Fairchild, in their top-quality F-7 pickup supply a transistorized battery operated pre-preamplifier which boosts the cartridge output to levels well above those of the average pickup.

We noted that it is not advisable to use high compliance pickups in even the best changers (with the exception of the Dual Auto/Pro). This is partly because the tone arms are not quite good enough to make use of the high compliance; partly because the stylus pressure must be high enough to operate the change mechanism and this usually means more than 2 grams, which is too high for these cartridges; and finally, because the fine pickups may be damaged during the change cycle. Shure and Astatic, however, offer new high-compliance cartridges in special mounts which make it possible to use them in the Garrard Model A and Miracord changers, In both of these the stylus is protected from excessive pressure, such as would occur in a rough drop, by a mounting which permits the entire cartridge to retract within the shell when the pressure exceeds 3 grams. The Shure uses a mechanical spring, the Astatic what could be called a magnetic spring. At pressures around 2 grams the pickup stylus is easily bounced out of the groove by footsteps and vibration of all types. In the Astatic, the repulsion between the two magnets is used to keep the stylus in contact with the groove without subjecting it or the record to excessive pressures.



Covering record player is best insurance against record wear. Robins cover shown is collapsible.

It will be noted that practically all of the high compliance pickups must be used with pressures of 2 grams or less; and those using .5 or .3 mil stylus need to be operated with pressures of 1 gram or less to prevent record deformation and wear. This requires tone arms of unprecedented refinement.

TONE ARMS

All the tone arm has to do is to support the pickup so that the stylus can follow the groove as it revolves. This was a simple task to fulfill in the days of stylus pressures

Rek-O-Kut Model N-34H runs at 33⅓ and 45 rpm. Belt-driven by hysteresis-synchronous motor. $90.

of as high as one-half ounce, or even more. It is a difficult job when the stylus pressure gets down in the region below 2 grams.

Consider that the arm may weigh a pound or more; obviously we cannot let this weight rest on the stylus, or provide a load that the stylus must drag behind it as it moves from outside to inside of the record.

The modern tone arm is completely weightless so far as its effect on the stylus is concerned. It is made weightless by balancing the weight that would be applied on the stylus with an equal weight provided by a counterweight. To eliminate its mass in the lateral plane, another counterweight is provided either on a separate outrigger or by making the main counterweight eccentric. In either event the tone arm can be adjusted so that it is perfectly balanced, and therefore, weightless at the stylus tip, no matter how the turntable is setting. With one of these arms a record can be played with the turntable upside down, or turned on its side. Not that anyone would want to in ordinary use, but simply to demonstrate its balance.

To deliver optimum performance the tip of the stylus needs to be in exactly the right position in every plane. It should be precisely vertical to the grooves in the vertical plane, at right angle to the tangent of the circle in the horizontal plane, and at a proper tilt to the groove in the plane parallel to the groove. Most modern tone arms permit adjustments for practically all of the angles important to proper tracking.

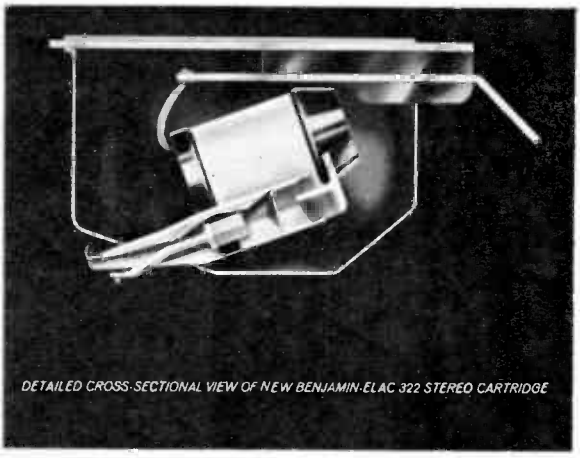
Once the weight of the tone arm has been eliminated, and assuming there is no friction in the bearings, there is only one external force working on the stylus—the spiral in the grooves tends to pull the stylus toward the center of the record and this tends to put higher pressure on the outer wall of the groove than the inner wall. When stylus pressure is reduced to less than 2 grams this "skating thrust" may be the only remaining "drag" on the compliance of the movement. In some arms, therefore, there is a compensation for this "skating thrust" either in the form of a spring or a small weight on a string, which apply a backward drag exactly the same as the forward drag of the spiral and thus neutralizes it.

With all of these adjustments, the modern tone arm is a rather bizarre device, with all sorts of protruding arms, knobs, counterweights, levers, etc. But it does make it possible for the finest pickups to make the most of their capabilities.

RECORD WEAR AND CARE

The modern disc record, although it is far more delicate in its materials and contents, has a far longer life expectancy than the old shellac or earlier plastic records. The life of records is affected by a number of factors, including the conditions under which they are played, and equally important, the conditions under which they are stored.

The pickup wears records in two ways. First the sheer force of the stylus deforms the groove. This deformation occurs the first time the record is played, and assuming proper tracking with an optimum pickup, this deformation is not aggravated by further playing. The deformation force of a stylus depends partly on the diameter of the stylus, its tip mass, and partly on the pressure applied on the record. The smaller the stylus and the higher the pressure, the greater the deformation; on the other hand, the lower the tip-mass, the lower the deformation for a given stylus size and pressure. The trend to lower tip mass and lower pressures has been a step toward minimizing record deformation; on the other hand, the accompanying trend to smaller styli which make lower tip mass and high compliance possible, works in the direction of increased deformation. It was once thought that the deformation force increased as the square of the decrease in stylus size; more recent evidence seems to indicate that the deformation is arithmeti-



This shows only one coil. Another coil is on this side of stylus. A tiny magnet at the end of the stylus lever is the only moving part in the element.

cally proportional to size. In any case, reducing the stylus radius from .7 to .5 mils increases deformation by some 65% and going to .3 mils doubles the deformation force. To make up for this, stylus pressure needs to be reduced correspondingly.

The evidence appears to be that with a .7 mil stylus and a stylus mass in the region between 1 and 3 milligrams, the deformation is not significant with pressures in the region of 2 grams. A reduction of stylus tip mass to the region of ½ milligram, seems to insure relative freedom from deformation with pressures in the 1 to 2 gram region. Any of the first quality pickups today will operate with pressures in this region and hence deformation damage can be expected to be minimized.

The rubbing of stylus with groove is obviously a cause of wear. This is aggravated by the fact that the wear works both ways, wearing down the stylus as well as the groove. As the stylus is worn, it acquires sharp, chisel-like sides which compound the damage to the record tremendously; and indeed, most of the damage to records is caused by these "flats" on the stylus.

However, it has been verified that with stylus pressures of less than 2 grams and particularly around 1 gram, the rubbing wear on stylus and groove is virtually nil. Hence, if the stylus is not damaged some other way, both stylus and groove could last indefinitely. We have records in our collection more than 10 years old, which have been played hundreds of times, but never with pressure greater than 1½ grams; and which appear to sound as brilliant as they did virgin, and show no visible signs of wear.

It is important to emphasize, however, that low pressure will minimize record wear only if it is sufficient to keep the stylus in firm contact with the groove. A stylus which "rattles" in the groove will wear the groove far more rapidly than a tight cartridge at higher pressures. The permissible pressure depends very much on the pickup and the optimum adjustment is that in any case which presents undistorted sound, since minimum distortion evidences proper coupling.

Records may wear, despite low stylus pressures, if dust and dirt are permitted to accumulate on them. Dragged by the stylus through the grooves, the grit in dirt may more than make up for the lack of erosion by the stylus itself. Furthermore, the small stylus operating at light pressure is highly sensitive to dirt. Specks of dirt may cause pops and crackles. They will accumulate on the stylus and lift it right out of the groove at pressures of 1 gram or thereabout. Therefore, records should be kept scrupulously clean and free of dust. Never leave a record on the turntable for more than a few minutes after playing it. Records acquire a static charge and will attract dust from a considerable distance. One of the best ways to protect records from dust and grime is by using one of several brushes which attach to the turntable base and brushes the record continuously as it plays. The Dust Bug performs a similar function though with a velvet pad which is treated with an antistatic and cleaning compound in liquid form.

The records can be brushed before and after playing. The ADC Hush brush uses special bristled brush with tapered ends to penetrate the grooves, and also has an applicator for applying an antistatic cleaning fluid. Brushing with this before playing a record will insure both cleanliness and relative freedom from static pops.

There are "jockey cloths" of chamois-like cloth permeated with a silicone with which records can be rubbed before each playing. The Robbins record care kit has a mitten with a foam rubber side for applying a cleaning and antistatic liquid, and a velvet side for cleaning and drying. There are several other preparations and devices for cleaning and destaticizing records.

Any of these may be used with most pickups—provided care is taken to see that the applicators do not themselves become gritty with accumulated dust, and provided that the rubbing or brushing is done along the grooves. However, the very small styli operating at very low pressures present a special problem requiring special precautions. Any visible scratch will produce a very loud noise with these deli-

cate styli; hence extreme care is necessary to eliminate the possibility. The very soft brush running continuously appears to be the safest device with these pickups. Some of the antistatic and cleaning preparations contain silicones, or other "greases" or leave a film of residue. The larger stylus at higher pressures is not bothered by this. But the very small stylus tends to "plow" this residue and to lift itself out of firm contact with the groove. Also this matter tends to be pushed into the very high frequency wiggles, closing them off so the stylus cannot get into them and thus there is a tendency to wipe out the very high frequencies. This does not matter so much with the larger stylus because it is too big to get into these small wiggles anyhow; but with the small stylus designed specifically for tracking these fine indentations, the accumulation of lubricants or residue has the effect of defeating their virtue. Rubbing alcohol is a pretty safe liquid to use with applicators. It cleans, without leaving a residue except water, which also will evaporate.

Probably the safest cleaning agent for use on records to be played with these very small styli is plain water. If the record is brushed before or during playing, it is only necessary once or twice a year to place the record under the faucet of the kitchen sink and to permit water between 65 and 90 degrees to flow over them with as little pressure as possible. Dry with a very clean very soft old piece of moist chamois, being sure to wipe lightly in a circular motion along the grooves. After drying, touch the record to the faucet itself to discharge the electrostatic charge.

If the record shows fingerprints and other signs of greasy soiling or is heavily charged with static electricity, put a small amount of detergent into a pan of body-warm water, immerse the record and rub lightly with a piece of velvet along the grooves. Dry with chamois as above.

With modern low pressure pickups most of the damage to records occurs in the process of taking them out of, or placing them in, their sleeves. One careless or casual extraction or insertion may put more scratches on the record than a lifetime of careless handling of the pickup. Indeed, many supposedly mint records fresh from the factory and in sealed packages, have been so scratched by careless insertion in the sleeve at the factory that they are intolerable when played with small styli. The .7 mil or 1 mil stylus at 2 to 6 grams of pressure smooths out the rough spot in the groove left by the scratch and is too large to be deflected by the damage to the side. The .3 and .5 mil stylus at pressures of 1 gram or so does not have enough force to wipe away the damage, and is small enough to go in and out of the nick and thus to produce a nice big pop.

Dirt and dust and careless handling are not the only enemies of records. A change of dimension due to shrinkage or expansion resulting in a warp, can produce even more disastrous results. Records should be stored vertically, standing straight up, and packed tightly enough together so that they don't "lean" on each other or the partitions of the shelf. The shelves should be in a spot in which the temperature remains reasonably uniform—and in any event in which there is no exposure to high heat—such as the direct rays of the sun or the heat from a radiator or heating duct. The environment should be neither too dry nor too moist. As it happens the air and temperature conditions most comfortable for humans are also quite comfortable to records.

Do not leave the turntable exposed when it is not being used. Dust will accumulate on the platter and when a record is placed on it will transfer to the record by electrostatic attraction. Robbins has a handy foldable cloth cover that fits practically any turntable or changer. The AR comes with a transparent plastic cover which covers the entire turntable, arm and all. Similar ones are available to cover just about any changer or turntable made.

One precaution—there are on the market little brushes which clip to a tone arm and brush the record groove ahead of the pickup. DO NOT ATTACH THESE TO ANY PICKUP ARM OPERATING AT LESS THAN 3 GRAMS OF PRESSURE. They will reduce the effective pressure and in the case of pickups operating at pressures with less than 2 grams may lift the stylus right out of the groove so no sound whatever issues. Attach nothing whatever to the tone arm or pickup itself unless it is a cheap type operating at pressures of around 5 grams, in which case the harm done by the attachments is insignificant in relation to the harm done to the record by the stylus itself.

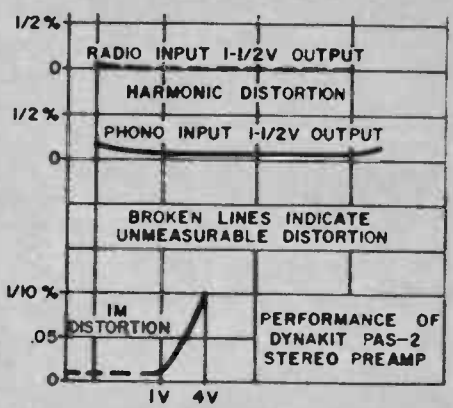
And one for the service technician—never bring a soldering gun in close proximity to a magnetic pickup; you are quite likely to demagnetize the magnet and thus ruin the pickup.

The modern disc recording brings you the world literally on a platter. Played back with fine stereo equipment, you can enjoy most of the audible experiences of our universe (and some outside it) with a vividness that duplicates the sensation of being right there. With care it will provide you with enjoyment, enlightenment or entertainment hundreds of times. •

Tubes or Transistors?

Photographs below show Citation A transistor preamplifier with modular subassembly units.

Top tube type preamps like Dyna Pas-2 come close to ideal of performance. Frequency response is flat to 100,000 cycles and distortion at any usable level is virtually unmeasurable. Transistor preamps are superior only in having somewhat shorter rise times and more complex and sophisticated control circuits. Diagram here shows performance.



THE transistor has been around now for half a generation. Practically everybody now owns a transistor portable radio. Transistors have made tubes virtually obsolete in missile and computer electronics. Only recently, however, have they begun to appear in high fidelity systems. True, there have been transistorized high fidelity amplifiers for some five years now, but no real momentum in the direction of transistorization was developed until two years ago when Allied Radio, one of the largest distributors of hi-fi, introduced a couple of transistorized units in its Knight line. It was followed closely by its two biggest retail rivals, Lafayette and

Boston Radio Shack. Since then Harman-Kardon has introduced a couple of transistorized units in its factory-wired line and the Citation transistorized preamp in its kit line; Bogen is introducing one for its top item. Heathkit took the lead among kit manufacturers offering several units; and Acoustech (formed by engineers and administrative personnel formerly associated with H. H. Scott) has introduced an amplifier and preamp in the highest priced maximum performance class. Thus this year for the first time the purchaser of a hi-fi is likely to run into the problem of deciding between a tube or transistor type hi-fi.

Naturally, those manufacturers who offer transistorized units tout the virtues, while those who use vacuum tubes depreciate them.

To understand the operation of a transistor one needs an understanding and appreciation of molecular physics, and even then the concepts are so unconventional that most people have to accept the principle on faith, rather than true comprehension.

The principal difference between transistors and tubes, and it is a very significant one in considering hi-fi applications, is this: a tube is basically a voltage amplifier. That is, a low voltage at the input produces a high voltage at the output. By the fundamental laws of electricity, high voltages require high resistances or impedances. The same current flowing through a circuit will produce a much higher voltage difference across a high impedance or resistance than it will across a low impedance or resistance. Hence, vacuum tube circuits are generally high-impedance or high-resistance circuits.

The transistor is a *current* amplifier, that is, a small current applied to the input produces a large charge in the current at the output. By the same laws of electricity high currents require low resistance or impedance. Hence, transistor circuits are low resistance or low impedance circuits, and this is where from a hi-fi point of view both their virtues and their vices come from.

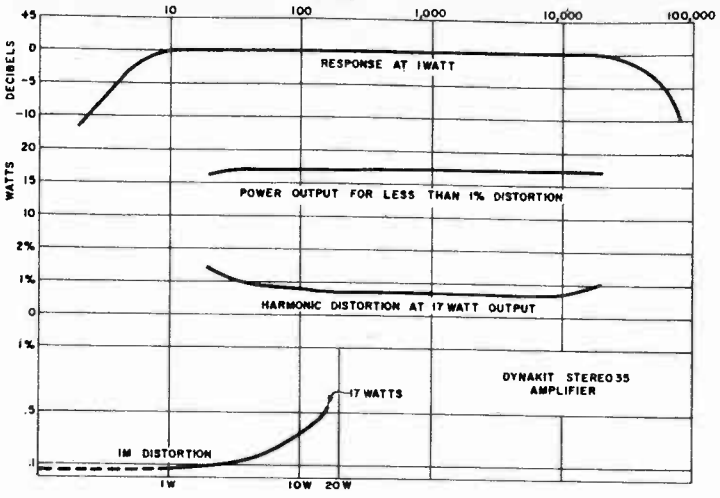
The most advertised advantages of transistors are two: first, the fact that they require no heating of a cathode. Secondly, they are extremely small. These advantages had obvious application in the field of missile control and computers where hundreds or even thousands of electron switches or valves were required. Far more complex control devices could be crowded into the small space available in a missile. Also, most tube failures involve a failure of the filament. Since transistors have no filaments this source of failure could be minimized. For these reasons the transistor was avidly seized by missile and computer engineers and in these applications replaced the vacuum tube almost entirely.

The application to a miniature portable radio was also a natural and the production of the first "pocket" transistor radios by American firms was followed by the present avalanche of Japanese radios.

These obvious virtues of transistors have little point for high fidelity. In most installations and within limits size is not an important consideration. The limit of size is established by the loudspeakers. Although manufacturers have done virtual miracles in producing very high performance from relatively compact speakers; no one has come remotely close to producing a really miniature speaker capable of reproducing the whole audio range, and no one is likely to until some entirely new principles of sound generation are developed. In view of the fact that the speakers could be expected to occupy a couple of cubic feet apiece, the saving in the space of an amplifier through the use of transistors is relatively unimportant.

As a matter of fact, the saving in space in the case of a high fidelity amplifier is by no means of the degree possible in a computer or radio. Actually, to obtain the quality of performance needed for high fidelity, it is necessary to use three or four or more transistors to replace a single tube. Though the transistors are smaller, the associated resistors, capacitors, etc., take considerable space and the result is that there is relatively little economy in space occupied.

Since transistors have no filaments they do not generate heat, and this would seem to be a consideration in their favor, especially in the case of integrated units which combine tuner, preamps and amplifiers in one package. Unfortunately, this characteristic of transistors does not entirely apply in their use for high fidelity. It is true that the transistors in low level amplifying stages do not generate any significant heat. However, in a stereo hi-fi system we must have two amplifiers capable of power outputs of 10 watts or more. No power amplifier is 100% efficient. Part of the power put into it—something on the order of 25 to 50%—is dissipated in the amplifier in the form of heat. Transistors are no exception. On the other hand, transistors are highly sensitive to heat. Changes in temperature seriously change their characteristics. Not only that, after a point a rise in temperature will destroy them. Therefore, power transistors must be used with some form of "heat sink" to absorb, carry away and



Though low in price and modest in power output, the Dynakit Stereo 35 amplifier delivers full power over full audio range at low distortion levels.

dissipate the heat generated in the transistor by its own inefficiency. In the case of high-powered amplifiers these heat sinks may be as large as the tubes and transformers they replace. Even then, care must be taken to see that the heat radiated by these heat sinks does not affect the transistors in low level stages. So that this advantage over tubes is by no means as large as it might seem at first thought.

Another advantage of transistors for many uses is that, being current devices, they operate at low voltages but high currents. This is a distinct advantage in the case of a portable radio since ordinary flashlight type dry cells can be used instead of the large, high voltage batteries needed by tube portables. But this is no factor for high fidelity equipment which operates most conveniently from the power line. Indeed, it is rather harder and more expensive to convert the high voltage of the power line into the low voltage at high currents needed by transistors, than to the high voltage at low currents needed by tubes.

Finally, the low impedances needed by transistors makes it difficult to use them with the circuits developed for tubes. Entirely new designs have had to be worked out and, as is always the case when a new field is opened, these designs by no means approach the refinements of the circuits which have evolved over several decades for vacuum tubes. Not only that, there are certain very intrinsic disadvantages to low impedance devices for hi-fi, especially in receivers, particularly FM tuners operating in the VHF range.

There is one point in a hi-fi system where the low impedance is an advantage—and it is from this almost alone that the transistor derives a really significant value in high fidelity applications. Loudspeakers are also high-current low-voltage devices. To use them with vacuum tubes it is necessary to have an output transformer between the tube and the loudspeaker to transform the high impedance of the amplifier tubes to the low impedance of the speakers. It is this transformer that poses the biggest problem in a high fidelity amplifier and which spells the difference between good, better and superb amplifiers.

To reproduce all the waveforms perfectly, the output transformer has to be big, heavy, specially designed and expensive. The compromises in amplifiers occur right here. The minimum quality amplifier whose response is flat only to 40 cycles, has a poorer, smaller, and cheaper transformer than the good amplifier; and the superb amplifier with response to 20 cycles or lower, has a very large, very heavy and very costly transformer. The transformers for a superb grade 50-watt amplifier may weigh 15 or 20 pounds apiece and cost the manufacturer more than that many dollars.

The output transformer poses another limitation. To reduce distortion to the low levels desirable for high fidelity, negative feedback loops are employed. Without going into a description of how they work, it is only necessary to state that the more feedback the less distortion. But the amount of feedback that can be obtained is limited by the transformer. All transformers have resonances. In the very fine ones these resonant peaks are above 100,000 or 200,000 cycles. Nevertheless, if the feedback is pushed too far, these resonances will result in oscillation and instability. High fidelity engineers really earn their pay by figuring out circuits and means of running a high amount of feedback

Shown in round-the-clock order are two amplifiers by Heathkit and the Knight KN999, which delivers 50-watt music power per channel; this is the top unit in the Knight transistor lineup of equipment.

around the output transformer without producing instability and they can accomplish this only with superb transformers. Many efforts have been made to eliminate the transformer in tube amplifiers, but such amplifiers turned out to be either too complex or too inefficient.

The transistor, with its low output impedance, opens the possibility of getting rid of the output transformer and thus of its bulk, weight, cost and its limitation on feedback. Very closely related to this is the possibility of widening the bandwidth which, as we saw in a previous chapter, leads to an improved transient response. It is this which gives transistors special virtue in high fidelity applications, or any real possibility of approaching ideal reproduction more closely than tubes permit.

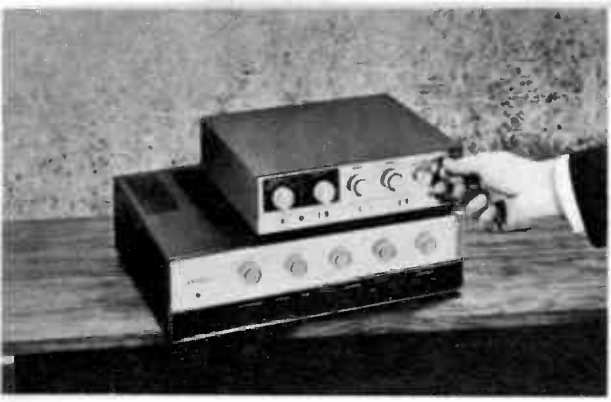
This is especially attractive in the case of stereo systems since two output transformers can be replaced.

Vacuum tube amplifiers have two initial and important advantages over transistor amplifiers at this time. First, they use tubes which have evolved from the special requirements of high fidelity and have been developed specifically for these requirements. The requirements of high fidelity are very much different and more critical than those for other electronic circuits. For example, power amplifier tubes for service in radios, public address systems, etc., are still rated in the tube manufacturers' manuals as delivering "undistorted" output when their harmonic distortion is 5%. This is about 50 times more distortion than can be tolerated in a superb hi-fi amplifier, and clearly a tube designed for such a tolerant concept of "undistortion" is not likely to be completely satisfactory for high fidelity use.

In the early days of high fidelity, the absence of tubes designed to high standards was a tremendous handicap. In the search for tubes capable of approaching such performance, designers were driven to using transmitting tubes at a small fraction of their capabilities, and complex circuits to make up for tube deficiencies. Tube manufacturers had no interest at that time in high fidelity tubes because the market was too small. Eventually, mostly through European tube manufacturers, there was produced a whole family of tubes specifically designed for high fidelity use. And much of the high quality provided by today's tube amplifiers is due to the availability of these special high fidelity tubes.

The process of developing and evolving transistors specifically designed for high fidelity service is only beginning. Most of the transistors available for use in hi-fis were designed for applications with entirely different standards. As was the case in early hi-fi days, it is necessary to use complex circuitry and a multiplicity of transistors, to obtain performance that approaches that possible with a few tubes and relatively simple circuits.

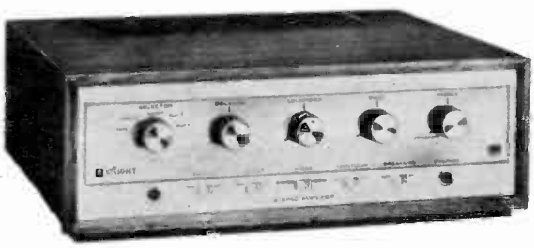
Secondly, tube type high fidelity is now 15 years old and its present state reflects that many years of development of circuits and components. Indeed, the evolution has been so complete that there has been no significant new development in either circuits or components in the past two or three years. Transistor circuits and components, on the other hand, are still at the beginning of their evolution as far as high fidelity is concerned. True, a great deal of the circuitry and components developed for missile and computer service, as well as those developed for high fidelity tubes, is applicable with modifications; but by and large, this whole process of applying the



A Knight transistorized hi-fi amplifier is shown here with its vacuum tube design counterpart.

Knight kit KG320, least expensive transistor ampl.

Knight KN950 lowest price wired transistor ampl.



Knight now offers tube type only in lower price ranges. Its top two amplifiers are transistor types.

Here is another Knight amplifier, the KN924.

transistor to the specialized and highly critical demands of high fidelity is just at its beginning.

Having made these generalizations, let's see how current transistor amplifiers compare with their vacuum tube counterparts. There are presently two amplifiers and two preamplifiers competing with Marantz, McIntosh, Dyna or Citation amplifiers in the highest quality category. These are the Acoustech II and the Lafayette LA-280 power amplifiers; and the Acoustech and Citation transistor preamplifiers. The curves on page 84 compare the Marantz Model 9 amplifier with the Acoustech II in measured characteristics in the author's laboratory.

It will be noted that the differences are not very big. The tube types have one clear superiority. Their distortion is lower at all levels and significantly lower at low levels. The distortion in the Acoustech is just under 1% at maximum output and does not fall much below ¼% at any level. The Marantz, Citation (and the Dyna and Fisher equivalents) have lower distortion at maximum rated output and virtually no distortion at lower levels.

This reflects the fact that at present transistor power amplifiers have to be operated in a mode called Class B, whereas tube types are operated in Class A or AB. The reason is that in Class A operation the average input power, and therefore, the average amount of heat dissipated within the tubes, is very high. Operated Class A transistors would require tremendous heat sinks and even then would be subject to the constant danger of destruction through heat runaway. In Class B operation, tubes or transistors draw very little static current, and therefore dissipate very little power. They draw heavy currents and dissipate heavy power only during peaks.

Class B operation is extremely efficient. Among other things the demand on the power supply is smaller. Power transistors operate at low voltages but very high currents. A power supply capable of supplying the high currents continuously would be quite a problem not only in size and cost but also in stability. The short duty cycle of Class B operation eases this problem greatly.

In Class B operation, output transistors conduct only a small portion of the time. There is a sort of switching action between periods of conduction and nonconduction, which results in nonlinearity which in turn generates high levels of distortion. While very large amounts of feedback can be used, because of the absence of the out-

put transformer, there is after all a limit to what feedback can do to reduce high levels of distortion generated within the loop. Only one tube type high fidelity amplifier using Class B operation has ever won acceptance from critical audiophiles—the McIntosh—and there have always been people who didn't like its sound. It may well be that designers of transistor amplifiers will have to find an economical way to operate Class A or AB before they can achieve distortion levels as low as those possible with tubes.

On the other hand, the Acoustech has a clear and sharp superiority in square wave and transient response. I do not have traces or photos of the Citation and Marantz square wave responses, having tested them some time ago; however, they do not approach those of the Acoustech given on page 85. The extremely wide band pass and the very high stability required to produce these curves result in a transient response which has not hitherto been obtained in any amplifier. As I pointed out in Chapter I, transient response is at least as important as low distortion, and possibly more important in creating the illusion of hearing the sound as if one were there when it was produced. The Acoustech amplifier appears to confirm this because, despite its higher distortion, most of the highly critical listeners who have compared it with others, agree that it produces a more "transparent" or more "real" sound.

Transistors can be operated Class A in preamplifiers and hence the handicap of higher distortion is not present here. However, to achieve high stability and wide bandwidths three or even four transistors are needed to do the job of one tube. Vacuum tubes in low level preamplifier service can achieve very wide bandwidths, and since no transformers are involved, can be highly stable even with large feedback levels. Thus the transistor preamps do not show a very clear superiority over, for example, the Dynakit PAS2, which despite its simplicity and low cost, comes remarkably close to the limits of performance as the chart on page 76 indicates. Their principal superiority is in the refinement of the control elements. The compactness of transistors does help here, since complex control circuits are more easily crowded into the same space. Both the Citation and Acoustech use step type controls, and the Acoustech uses cascaded volume controls, one in 10db steps and the other in 2db steps, so that tracking between the two channels can be maintained to within less than 1db at all levels. In terms of sound, there is a difference, but whether it is significant seems to depend on the acuity of the listener's ears and personal opinion.

Most transistor amplifiers fall in the higher or medium price range. The least expensive factory-wired transistor stereo amplifiers currently available are the Knight KN950 and the Lafayette LA440 selling at between $100 and $120. These are fairly similar in characteristics. They are rated at 20 to 25 watts *IHFM music power* per channel, which is 12 to 15 watts sine wave. This seems to put them in the minimum category. However, they are flat at rated output over the full audio range from 20 to 20,000 cycles and you have to go way up into the medium category to find factory-wired amplifiers capable of delivering 12 or 15 watts sine wave at 20 and 20,000 cycles. They will drive a pair of AR2 speakers quite impressively. Like the more expensive transistor amplifiers they are notable for their transient response. Distortionwise they are not inferior to tube types in the same price class.

The least expensive stereo amplifier is the Knight KG-320 kit at $60. I have not tested this, but it is rated to deliver 16 watts music power per channel (which I presume is somewhere in the region of 10 watts sine wave) from 25 to 18,000 cycles. The top performer in this class for some years now has been the Heathkit AA-141 at the same price. It's a very fine little amplifier. Apparently, the measured performance is quite comparable.

In the medium category, the Knight KN 999 wired unit at $190 and the Heathkit AA-21 in kit form at $140 are representative. These deliver 50 watts music power, or around 35 watts sine wave, per channel, with power response curves which are wider than the audible range on both ends. The Heathkit model AA-21 borrows from missile and computer service not only transistors but also the idea of encapsulated modules for individual stages. The Lafayette Kt-900 and Allied Knight KN450 offer comparable performance. It is notable that measured by the common standards of frequency response and power response, these yield performance which is available in tube types only in the superb category. Again, as in the top level class, the distortion at low levels is higher; but again, the transient response is better.

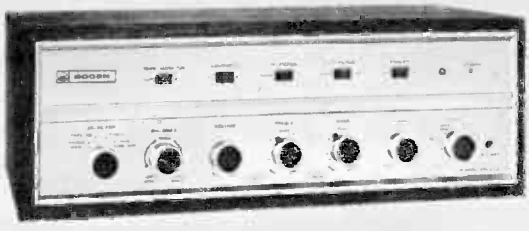
From these comparisons and reviews, it appears that transistor units offer a higher value of performance per dollar than tube types and up to a point this is true. It should be noted here that the lower and the medium priced units are either in kit form, or offered by Allied and Lafayette, whose products generally are

lower priced than equivalent units made by Scott, Fisher, etc. It is notable that the only transistor amplifier in this latter class, the Harman-Kardon is the top of the line in price as well as performance. However, there are also disadvantages involved in all transistor amplifiers. The elimination of the output transformer is not a 100% profit; on the contrary it is accompanied by a significant debit. Transistor amplifiers will deliver their rated power and performance only into a speaker system whose impedance matches the output impedance of the amplifier—they fall down markedly with a mismatch. For example, the Heathkit AA-21 will deliver the rated 35 watts sine wave into an 8-ohm speaker, but only 26 watts into a 16-ohm and only 18 watts into a 4-ohm load. Furthermore, the manufacturers differ in the load they design the amplifier for. Whereas the Heathkit and Lafayette amplifiers are designed for an 8-ohm load, Knight transistor amplifiers are designed for a 4-ohm load. Actually no speaker has a constant impedance throughout its range. The rated impedance is usually at some midrange point; it will be higher at the low end and the high end. The output transformer used with tubes, permits the matching of the amplifier to speakers with 4, 8 or 16 ohm impedances. Furthermore, although a change in load does affect the performance of tubes, the effect is by no means as great as with transistors. To obtain the most from a transistor amplifier it is important, therefore, to choose speakers whose impedance matches the most favorable impedance of the amplifier; or, if you want a specific speaker, to choose an amplifier that will deliver its maximum output into the impedance of the speaker. The Acoustech is the least sensitive in this respect and the penalty of mismatch is little greater than with tube type amplifiers.

There are other disadvantages. Transistors do not burn out like tubes, but they can literally burn themselves up, in a moment under certain circumstances, as for example, if the load is opened or shorted. This can easily happen when installing a system, or by accident after it is installed. The load can be opened, for example, if one of the leads to the speakers is pulled out during sweeping, cleaning up or trouble shooting. Transistors do not have the tolerance to overload that tubes have. A tube will squawk with distortion when overloaded, but it can suffer no real physical damage. A transistor can run away and destroy itself under an overload. Some attempt is made, fortunately, in the Acoustech and Knight units, to protect against

Top of Harman-Kardon line A1000 is all-transistor, 35w per channel, has 28 transistors, sells for $370.

Heathkit 50-watt amplifier ($85) is kit model No. AAW-100; response is 30 to 15,000 at full output.



This year Bogen will offer a transistor amplifier delivering 40w per channel. Model here is $180.

Bogen AP30 is good budget amplifier, offers 10w sine wave per channel. Sells for $130 with the case.

this, either by special circuitry or fuses. Nevertheless, the incidence of destroyed transistors will be considerably greater than the claims of long life you read about would lead you to suppose. We mentioned that transistors are very heat-sensitive. It is very important when installing a transistor amplifier to install it in such a way that 1) it can dissipate the heat it generates, and 2) will not be subject to heating by other objects. Placing over a radiator or where the full summer sun can hit the power transistors or heat sinks, can result in the destruction of all the transistors.

Another disadvantage is that replacements and repairs will be more difficult, more critical and more delayed. There is no standardization of transistors in high fidelity; each manufacturer uses different types and some of these are unique and available only from the manufacturer. The durability of transistors is highly exaggerated as most owners of transistor radios have discovered. The military types used in missiles and computer types used in computers do have long lives—though judging by the repeated failures in our launching programs, even they are not immune to over use. This long life, however, is paid for with very high prices, which even the manufacturers of the top grade of amplifiers cannot afford. Power transistors as we have pointed out, are particularly likely to go out. When they go out they have to be replaced with identical replacements and in most cases this will mean waiting a week or two until the manufacturer sends a replacement. It may be necessary to replace several transistors when one goes out. Transistors are not as uniform as tubes and in critical circuits where two or more must be balanced it may be necessary to replace both or all.

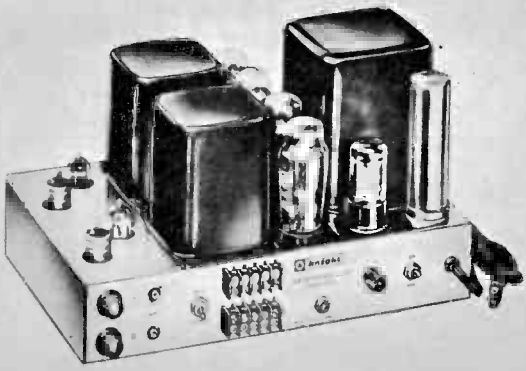
Transistor amplifiers will be more difficult and more expensive to service. This is due partly to the fact that they will use less familiar and more specialized circuitry, partly to the fact that the circuits are always more complicated, more crowded and harder to get into, partly because components values are more critical; and partly because, in the very servicing, transistors may be damaged or ruined by unskilled or careless servicemen.

Because of the many disadvantages and the lack of transistors specifically designed for high fidelity service, most manufacturers are in no rush to jump on the transistor bandwagon, despite the fact that current units do offer performance superior in some respects and despite the evidence that transistors provide a more likely road toward the approach of the ideal of com-

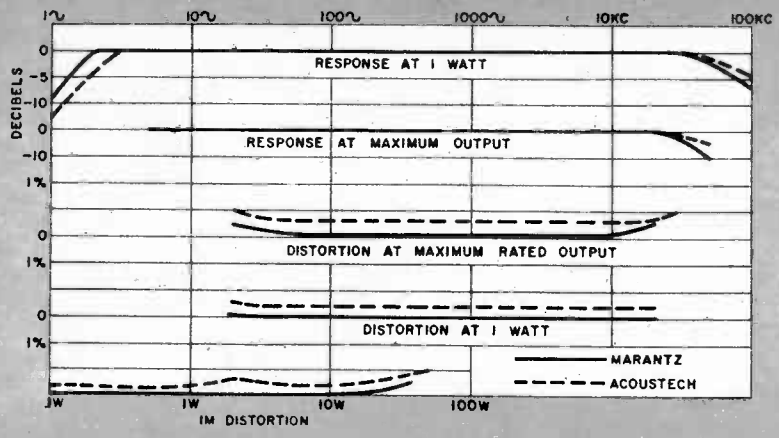
New classic series of Eico amplifiers is available everywhere and features unusual simplicity.

Heathkit stereo amplifier, kit model AA-141, is low in cost ($35) but outstanding in performance.

Heathkit stereo preamplifier, kit AA-11, features push-button program selector and low distortion.



Knight Kit EB-85 offers extremely high performance at the low price of $70 and gives 35w per channel.



Generally speaking, transistor amplifiers have wider band width, better transient response, but higher distortion at all levels than do equivalent tube types. Drawing at the

pletely faithful reproduction in the future. The first effect of serious competition from transistors may well be to push the development of better tube amplifiers, and particularly to upgrade the performance of the minimum and medium category of amplifiers.

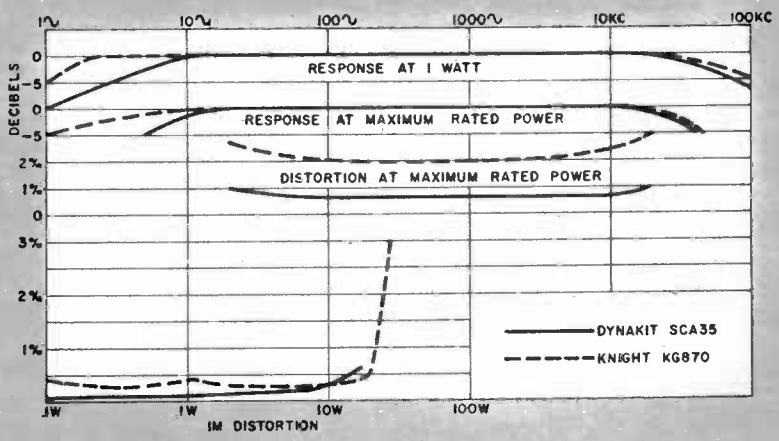
One example is offered by the latest Dynakit units, the SCA35 stereo preamp-amplifier $90 kit, $130 wired, and the stereo 35 stereo power amplifier $60 kit, $80 wired. Dynakit has previously been identified with high-powered amplifiers and, indeed, was probably largely responsible for the trend to high-powered amplifiers which occurred in the past five or six years. As I noted in Chapter I, high-powered amplifiers do provide the easiest road to superior performance even at low power levels, because at average levels the distortion is insignificant and the bandwidth is wide. It has always been perfectly possible to achieve closely comparable performance with lower powered amplifiers, but there was little advantage from a marketing point of view. It is much easier and just about as cheap to obtain an output of 10 watts from 20 to 20,000 cycles with a medium quality amplifier delivering 20 watts at 400 or 1000 cycles, as it is to achieve the same result with a fine amplifier perfectly flat at 10 watts over the full range. Obviously, the "20 watt" amplifier, although it is actually no better in effective bandwidth, sounds better in advertising and promotion and seems to be a better value. Offered a choice between a 10-watt amplifier flat at full rated output from 20 to 20,000 cycles at, let us say, $75, and a 20-watt amplifier, which is flat over the same range at half power, for $80 or $85, most people would choose the 20-watt amplifier.

Nevertheless, there has been a need for really good low-powered amplifiers and a great scarcity of them. The only thing available in this class has been the Heathkit AA-151 and this has been just a little short of power for driving fine speaker systems. The new Dynakits fill this void nicely and provide performance which approaches the superb at a very modest cost.

The stereo 35 is a pair of 17-watt stereo amplifiers; the SCA 35 adds a stereo preamplifier to the amplifiers and thus comprises the entire electronic portion of a high fidelity system. They are very compact—the Stereo 35 is 13 x 5¼ x 4 inches; and the SCA35 is some 3 inches deeper. Page 78 gives the measured performance. Note that the amplifiers deliver the rated power over the full audio range of 20 to 20,000 cycles with 1% distortion or less. They will drive even such relatively inefficient speakers as the AR3 to just about all the loudness most people would tolerate in a home and they have the typical Dyna "solidity" at the low end and excellent transient response due to high stability. The Stereo 35 is very likely the simplest kit to assemble on the market. An expert could probably put one together in little over an hour; and even the veriest novice can do the job in one evening or afternoon. The SCA 35 is a little more complicated but also just about the simplest kit in its class.

Another example, but in the direction of providing the highest possible quality,

left compares top quality tube and transistor amplifiers. Drawing at the right compares lower-priced transistor amplifier and high-quality, low-powered tube amplifier. Study carefully.

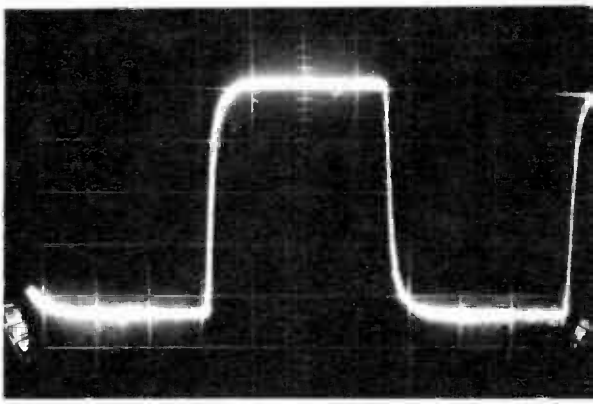


is offered by the new Fisher SA-1000 amplifier, offered in competition to the Marantz, McIntosh and big Dynas. This is a pair of power amplifiers rated at 75-watt music power per channel, but capable of delivering 80 watts sine wave per channel at ½% distortion. Using some new tubes, this amplifier offers performance which any transistor amplifier is going to have real trouble surpassing.

It isn't the ingredients but the way they are handled which makes a stew, a cake or a high fidelity system good, better or superb—or indifferent or bad. Transistors and tubes each have their advantages and disadvantages and both are capable of arriving at similar performance. Tube amplifiers at this moment have the advantage of simplicity, and designs proven by years of development and use. It appears that until special high fidelity type transistors are developed at moderate and low prices, tubes will be the preferred component of the low and medium-priced systems.

The trend at this moment appears to be to use transistors in top-of-the-line components. This is the path being taken by Scott, Grommes and Harman-Kardon and sure to be followed by others. Transistorized amplifiers will be the highest priced items in a manufacturer's line, and in most cases there will be a tube equivalent in the line at the same or lower price. With the exception of the units offered by Knight, Lafayette and Boston Radio Shack, transistorized amplifiers will sell for $200 or more.

As far as the listening quality is concerned it appears that for the moment the tube type amplifier will have lower distortion and a slightly more natural rendition of musical instruments. The transistor will have a better transient response partly because of the wider bandwidth and partly because it can deliver higher peak powers. This may produce a slightly higher illusion of presence by more faithfully reproducing the transient sounds which though not part of the written music and without real musical value in themselves, contribute the you-are-there quality. Some people will prefer one quality and others the other. But in any event high fidelity amplifiers should not be judged alone by what's in them but rather by what comes out of them and whether what comes out of them suits one's needs, tastes and ears. •



20,000 cycle square wave response of Acoutech transistor amplifier (above) is equalled only by the Futterman tube type, shown in other diagram.

All About FM Tuners

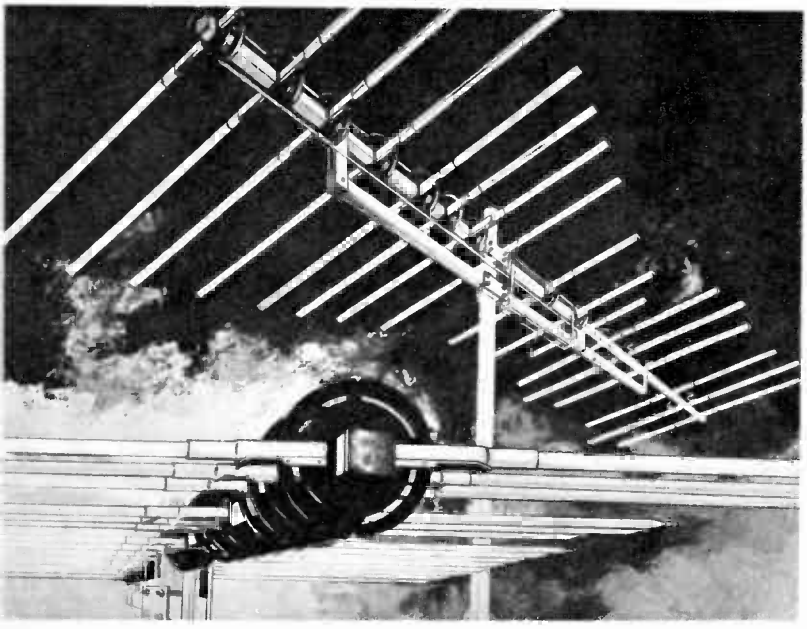


Illustration at left shows Taco "Paralog" antenna which delivers high gain and a very sharp directivity to hi-fi sets.

THE easiest way to fill the home with music all day long is with a good FM tuner. FM broadcasting has had a tremendous growth in the past few years. Hundreds of additional stations have gone on the air, and there are very few places in the country where with a good tuner one cannot receive at least a half dozen stations offering a wide choice of program material.

As a source of background music and for casual listening the FM tuner is a better investment in most areas of the country than a record player. However, the quality of reproduction, even with the best tuners tuned to the best stations will usually not be as good as with a record player playing records directly. This is particularly true of stereophonic broadcasting. Hence, if one's interest is in fine music reproduced with the highest fidelity, the record player is the better choice. The ideal arrangement, of course, is to have both a record player for serious listening to music and an FM tuner for casual listening and to keep up with what is going on.

Stereophonic reception especially requires a sensitive tuner even in the great metropolitan centers. The signal strength of a station is considerably lower when it is broadcasting a stereophonic program than when it is broadcasting a monophonic program. The increase in noise and distortion when a signal fades below a certain threshold is also higher for stereo than for monophonic reception. Finally, the sensitive tuner may make it unnecessary to have a complicated antenna system which can be an important consideration in apartment buildings.

There are several ways to measure and rate the sensitivity of tuners, but the only one that has any real significance for high fidelity purposes is the IHFM (Institute of High Fidelity) rating. For high fidelity listening it is not enough to be able to bring a station in, or even to bring it in with a satisfying degree of noise suppression; if it is going to provide real enjoyment it must also be low in distortion. In FM the distortion depends largely on the bandwidth or bandpass of the tuner. The wider the bandwidth the lower the distortion. It is easy to obtain high sensitivity with a narrow bandwidth, but if the distortion is high the station is not worth listening to.

The sensitivity of FM tuners is always rated in terms of the weakest signal in microvolts (millionths of a volt) that will produce a given degree of noise suppression. The IHFM rating of tuner sensitivity takes both noise and distortion into ac-

count. The IHFM sensitivity is the weakest signal into a 300-ohm antenna that will produce a ratio of 30db between the signal and the noise *plus* distortion. It will range from about 1.5 microvolts upward.

This rating, however, is not an absolutely accurate measure of performance capabilities. Noise and distortion 30db down (3%) is very audible indeed and would provide highly marginal performance on a hi-fi system. From a high fidelity point of view, the only signal worth listening to is a signal with virtually complete suppression of noise—somewhere in the region of 50 to 60db. Almost any FM tuner will provide this degree of noise suppression if it is fed a fat enough signal, but this signal will have to be many times stronger than that required for the IHFM rating. The most significant rating from a high fidelity point of view would be the signal required for complete quieting—or at least the maximum quieting the tuner is capable of. This will depend not only on the absolute sensitivity of the tuner but also on the steepness of its noise suppression curve. Two receivers with the very same IHF rating may differ very greatly in the signal required for complete quieting. The most sensitive tuners with IHF ratings between 1.5 and 2.5 will provide "complete quieting" with a signal somewhere in the region of 10-25 microvolts. On the other hand some tuners like the Dynatuner, with IHF sensitivity of 4 microvolts will also provide complete quieting with a signal in this range. Obviously, from a high fidelity point of view they have equal sensitivity. Sherwood tuners have been renowned for years for their high actual sensitivity.

There is a very definite limit to the usable sensitivity from a high fidelity point of view. All weak signals "fade" or vary in signal strength; they are not very enjoyable when they fade so low that the noise is highly audible. To provide high fidelity enjoyment the signal strength in the deepest fade must be high enough to keep the receiver noise down to a satisfactory level. For example, if we accept 30db as the minimum, the signal would have to be no less than 2 microvolts in the deepest fade, with the most sensitive tuners. The variation in signal strength due to fading can be expected to be at least 10db or three times on each side of the average field strength; hence it is fair to say that to provide even marginal hi-fi quality with the most sensitive tuners a station would have to have an average field strength of not less than 6 microvolts; and in actual practice, it will be found that an average level of 10 microvolts will be needed to provide high fidelity quality at least 90% of the time.

The type of noise that comes up when the signal fades below the threshold of complete quieting is very important. Tuners with narrow bandwidths will keep the random noise "or static type" noise down, but after a point the distortion becomes so high that the signal is completely unintelligible or, in the case of music, intolerable. In wide band tuners the noise may come up, but the distortion remains low and voices are still intelligible and music is tolerable, if not exactly enjoyable.

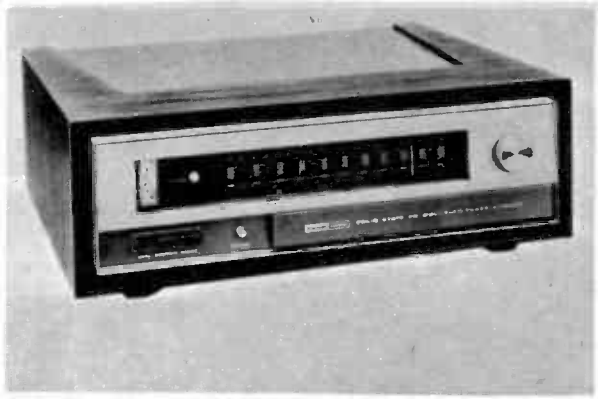
CAPTURE RATIO

One of the big virtues of FM is its freedom not only from noise but also from interference. On the broadcast band when there are two or more stations on the same channel you hear a mixture of the sound of all stations as well as distortion produced by the sums and products of the sound. As we well know, in the evening especially, in most places only a handful of stations can be received with enjoyable quality.

In FM if there are two stations on the same frequency, the stronger of the two "captures" the channel, suppressing the sound of the weaker station completely. The capture ability of tuners is rated in terms of the "capture ratio." This is the ratio of the stronger signal to the weaker signal that is required for the stronger signal to capture the tuner. It is stated in terms of decibels, as for example "capture ratio of 6db." A ratio of 6db is a ratio of 2; so a 6db capture ratio means that one station has to be twice as strong as another to capture the channel. This may seem like a good deal, but in the ordinary type of AM radio a station has to be 100 or more times stronger to be relatively free of interference.

Capture ratio is not too important for listening to local stations. FM stations are carefully allocated by the FCC so that stations on the same channel are spaced far enough apart not to interfere with each other. In any event a local station will have sufficient superiority in field strength to capture the channel from a distant one.

Capture ratio can, however, be an important consideration in the fringe areas where it is possible to receive stations from several cities 100 or more miles away. In some cases there will be two stations on the same channel with nearly the same field strength. A good capture ratio will not only minimize the possibility of interference, but with a directional an-



Harman-Kardon's top of the line tuner is this fully-transistorized model, F-1000T, which sells for $300.

Shown above is Deluxe Citation Tuner which has every feature for flexible multiplex stereo reception.

tenna may well make it possible to receive one station or the other with equal quality, and thus multiply the number of programs available. Fisher and Scott tuners have always been notable for their high sensitivity and high capture ratio; the top Fishers have capture ratios as low as 2db—which means that a station only 25% stronger will capture the channel. In most locations, however, a capture ratio of 6 to 10db will be quite good enough.

SELECTIVITY

As a further protection against interference the FCC maintains a separation of at least one channel between stations in the same primary area. Since the channels are 200kc wide, this means that in any given primary area stations will be at least 400kc removed from each other. This separation as well as the captureability of FM minimizes the need for high selectivity in FM tuners in most locations. There are exceptions, however. For example, in locations between the New York and Philadelphia areas it is quite possible to find stations on almost all the channels, and the ability to separate stations on adjacent channels, only 200kc away, may be very important. The same situation may apply in many other locations where stations from two or more large metropolitan centers, as well as smaller cities, are receivable. The problem is especially severe where the more desirable station is weaker than a station on the adjacent channel and hence would be suppressed by the capture of the stronger.

Selectivity of tuners is pretty much proportional to their cost. This is true because selectivity is obtained by using additional tuned stages with additional tubes (or transistors) and transformers. The typical good, low or medium priced tuner will have adjacent channel selectivity between 40 and 50db, which is good enough for all local and many fringe area locations. The highest priced Fishers, Scotts and the McIntosh and Marantz de luxe tuners, using four or five IF stages plus limiters, have selectivity in the 60db region and with the help of a directional antenna and their high capture ratios, will provide good reception on practically every channel.

EASE OF TUNING

To provide high fidelity quality with minimum distortion, FM tuners need to be tuned carefully and remain in tune. Practically all component tuners have some kind of indicator to guide the tuning. In most instances this is a cathode ray or magic eye tube; in higher priced tuners it is a meter.

It is difficult to keep a tuner stable at the very high frequencies of the FM band. It is quite common, therefore, to use Automatic Frequency Control, a circuit which, in effect, automatically tunes and retunes the tuner to keep the station in the center of the passband. With AFC tuning is simplified since the stations more or less "snap" or lock-in. On the other hand, AFC is guilty of another kind of "capture" and will suppress weaker signals on adjacent channels in spite of the capture ratio of the tuner. Hence, it is a good thing to have a switch or control to disable the AFC so weak stations adjacent to strong ones may be received. In some tuners, the AFC is adjustable.

Some of the finest tuners dispense with AFC entirely. They are very stable to begin with, and use wide band detectors and IF amplifiers so that what little drift there may be makes no significant difference in quality. Whether a tuner with AFC or without AFC is preferable depends to some degree on personal preference. The inclusion of AFC or the absence of it is

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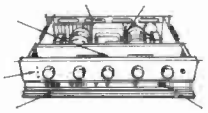
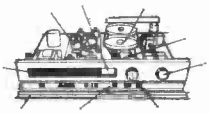
AA-22 40-watt Transistor Stereo Amplifier, 14 lbs. $10 mo. $99.95



• 40 watts of power (20 per channel) • 5 stereo inputs • Speaker phase switch • Miniature indicator light for each position on mode switch • Transformerless output circuits • Brushed gold-anodized aluminum front panel conceals secondary controls • Walnut cabinetry

AJ-33 Transistor AM-FM-FM Stereo Tuner, 14 lbs. $10 mo. $99.95



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not necessarily a measure of overall performance or quality.

CROSS MODULATION

There is another type of interference which may be very serious in primary areas where there are many stations and signal strengths are very high—this is the type where a strong station appears at two or more places on the dial, or even all over the dial, causing interference to other stations. Such interference from television stations on channels 5 or 6 can be a severe problem because of the very high power employed by TV stations. Very sensitive tuners are especially prone to this type of "cross-modulation" or "overload" interference. Transistorized tuners, even insensitive ones, particularly of the big brand package hi-fis, can be very bad offenders in this respect. If you live in a large city and particularly if the antenna of any FM or TV station is within a mile or two from your location, it is well to insist on a trial at home before committing oneself to a tuner. The Dynatuner is notably free of this type of interference despite its excellent sensitivity.

MULTIPLEX STEREO

There is very little point in buying a tuner that does not have built-in provision for receiving multiplex stereo, even if you now have a strictly monophonic high fidelity system. The cost is very little higher than for tuners without MX. Furthermore, the tuner with MX is very likely to give superior performance on the monophonic signals. This is true because it is very likely to have a wider bandwidth, higher sensitivity, lower noise and a wider frequency response. Stereo programs are receivable on a monophonic tuner and playable through a monophonic system without, of course, the stereo effect.

The biggest difference between current tuners is the handling of the multiplex stereo programs. For example, how do you know whether a station is broadcasting stereo or mono? Most tuners have some kind of indicator to tell you. This is usually a small pilot light which will light when the station is broadcasting stereo. In the Dynatuner a double-beam magic eye tube is used, and when a station goes to stereo the words "stereo" are brightly illuminated by one of the beams.

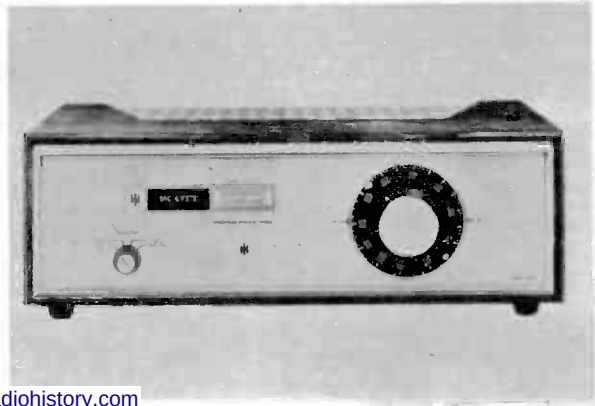
There is a definite trend to automatic switching from stereo to mono or vice versa; so that the listener does not have to do anything at all. A stereo program is automatically heard in stereo and a monophonic program in mono. Dynatuner was the first to do this and now most of the others are following with some type of automatic switching circuit.

This works nicely in local areas but has disadvantages in remote and fringe areas. We noted that stereo signals are weaker than mono signals from the same station. There is a point where stereo reception becomes marginal or even intolerable because the noise is too high. The program may, however, be completely satisfactory if the tuner is switched to monophonic. Many tuners provide automatic switching, but add a manual switch also, so that when stereo reception is poor, the tuner can be switched to mono. (Though the Dynatuner does not have such a switch, the same effect is possible by switching the preamplifier to which it is attached from stereo to mono.)

The most elaborate arrangement is provided in the top Scott tuners. First there is a switch which offers a choice of mono, stereo or automatic stereo. But there is also a stereo threshold control and adjustment. This can be adjusted so that if the stereo signal falls below a certain level that would provide unsatisfactory reception, the tuner switches to mono; but back to stereo if the signal level rises again. In this way the annoyance of noise and high distortion which comes when a signal fades to a level too low for satisfactory stereo reception, is avoided or minimized.

Distortion as well as noise is likely to

Long famous for superb performance, Scott tuners come in several price ranges. They differ mostly in the complexity of multiplex controls. Price range is from $150 to $475. Shown below, tuner in case, uncovered.



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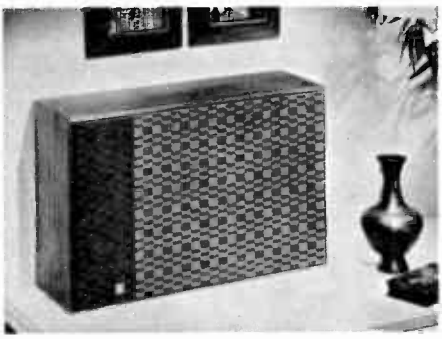

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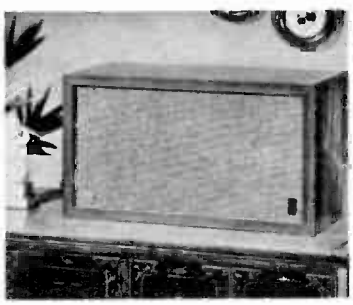

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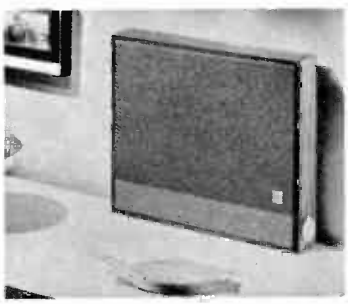

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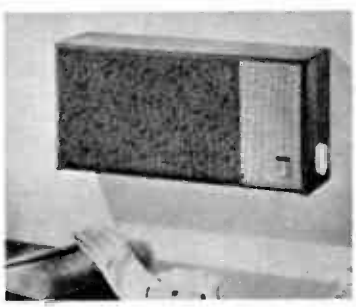

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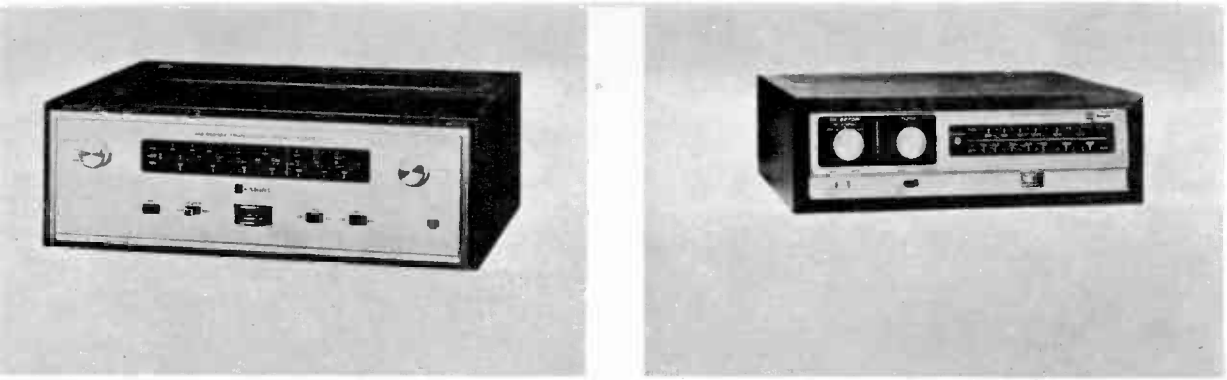

Knight offers the fullest line of transistor tuners. First photo is wired type (KN265); other is kit type (KG-70).

be higher with stereo programs than with monophonic ones. Reflections of the signal from buildings, mountains, water tanks, etc., sometimes combine with the direct signal to produce an odd sort of "whispering" distortion. Some types of distortion as well as some of the noise can be minimized by rolling off the high frequency response of the stereo subchannel or both channels. The Scott tuners have a switch to insert such a filter in either the subchannel or in both the main channel and a subchannel. Similar filters are offered in other tuners. The same effect can be achieved, however, with tuners which do not have filters by the use of the "Scratch filter" on the preamplifier.

SEPARATION

A very important factor in stereo tuners is the separation provided for the two channels. The greater the separation the higher the stereo effect, of course. Achieving a high degree of separation is no problem in the case of preamplifiers and amplifiers; but because of the principle employed for multiplexing stereo programs, it can be a problem in the case of tuners. To insure adequate separation it is necessary to have a wide bandpass both in the tuning section and in the multiplexing and audio sections. Narrow bandpass produces phase shifts, and since the process of combining the two channels for broadcasting and of separating them at the receiving end is based on phase addition and subtraction, a change in phase will degrade the separation.

Unfortunately, it is not easy to judge the separation of two or more tuners by comparison listening. Separation may vary from record to record. Some records which provide a high degree of separation when played directly, have poor separation when broadcast by multiplex. Separation with the same record may differ from station to station. The best way to judge separation is by switching tuners rapidly to provide an AB comparison on the same program material from the same station. This can be done in the demonstration rooms of most dealers. When this is not possible, judgment should be made by listening to a variety of programs and stations so that the variation for which the broadcast station is responsible can be averaged out. This is one place where snap judgments can lead you astray.

TUBES OR TRANSISTORS

Transistors have even more disadvantages for use in high fidelity tuners than in amplifiers. Despite the advertisements they tend to be noisier, and hence it is much more difficult to get high sensitivity with transistors than with tubes. The fact that they are low-impedance devices makes it more difficult also to obtain high gain and selectivity. Transistor tuners, particularly those used in big brand name packages, are, therefore, particularly liable to cross modulation and overload interference. Because transistors are highly heat sensitive it is a problem to keep a transistor tuner stable even with AFC, and important to keep a transistor tuner isolated from any heat-producing source, such as a powerful vacuum tube amplifier. These disadvantages can all be compensated for, but only at the cost of complication. Good transistor tuners will use many transistors in elaborate circuits. Therefore, good transistor tuners, like good transistor amplifiers, are much more expensive than their tube counterparts; and unlike transistor amplifiers, do not yield any significant superiority in performance. Cheap transistor tuners, like those used in big brand name package hi-fis, are usually inferior to even cheaper tube types.

The least expensive factory-wired transistor tuner is the Knight KN255 at $150 and the cheapest kit is the Heathkit AJ33 at $100. The Harman-Kardon F-1000 tuner is $300; while Scott offers the 4312 at $365 and the 4310 at $475. All of these yield good

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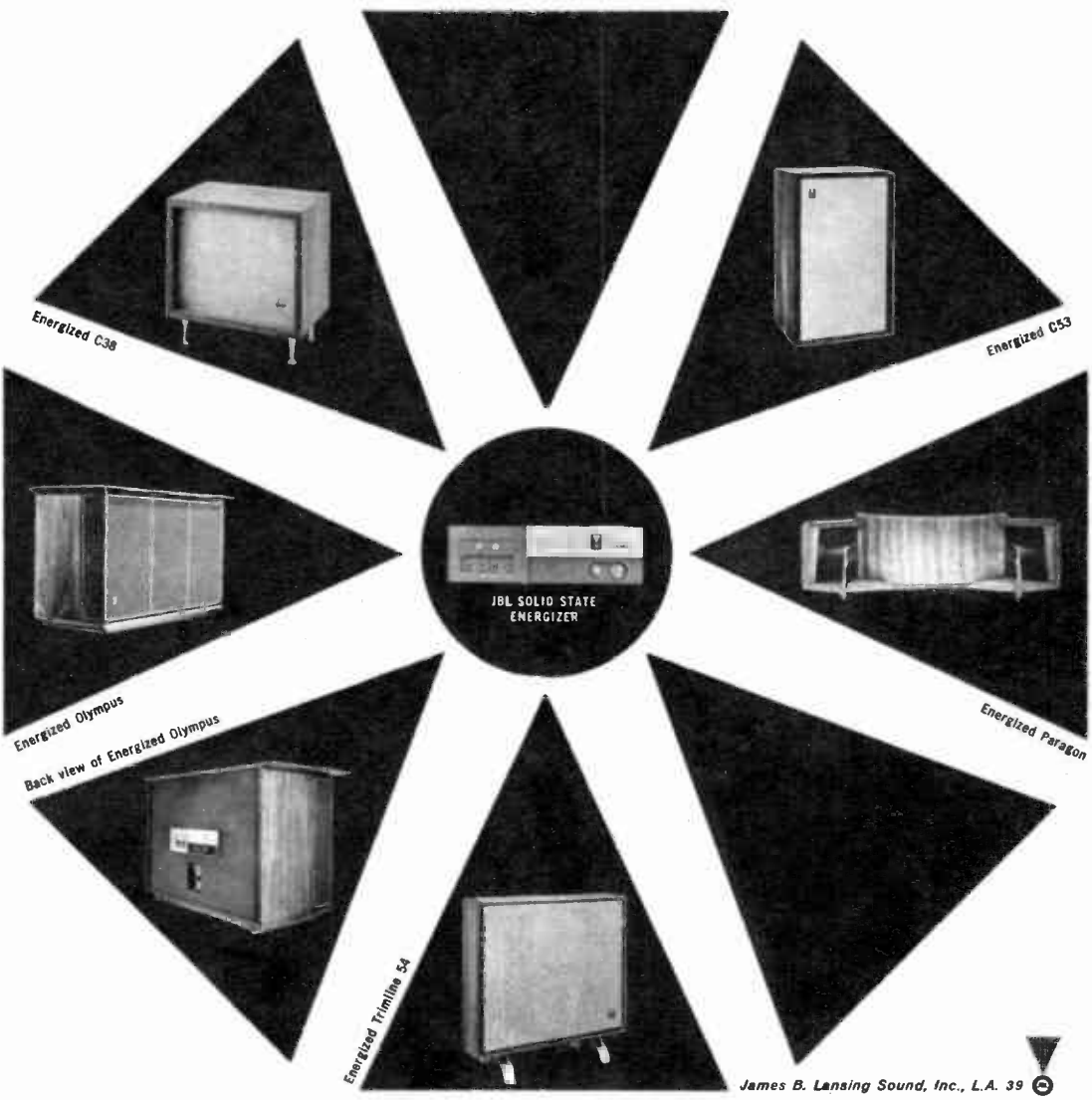
An Energizer/Transducer has its own source of power: the Energizer. The Energizer is exactly matched to the specific loudspeaker-and-enclosure system in which it is used. Energizer and transducer are engineered as a unit. Given a flat, pure signal from a preamplifier, the Energizer/Transducer delivers sound that is perfectly flat and pure — an exact replica — with exactly the right amount of damping at all frequencies. No other home high fidelity equipment can give you these results.

The JBL Energizer is a stereophonic all-solid-state device of scientific-instrument quality. Devoid of microphonics, generating negligible heat, it can be mounted within an acoustical enclosure. All JBL loudspeaker systems are available as Energizer/Transducers. The JBL loudspeaker system you now own can be made into an Energizer/Transducer. When ordering your matched Energizer, you need only provide your Audio Specialist with the complete model number of your system. Write for your free copy of the new Energizer/Transducer six-page brochure.



performance, though no better than the tube types in the same lines.

Most of the problems with transistors are in the front end of the tuner—the RF amplifiers, converter and local oscillator. This is where the problems of sensitivity, noise and cross modulation interference arise. The use of a vacuum tube front-end with transistors in the rest of the tuner, can produce very fine performance. Altec-Lansing uses frame-grid tubes in their hybrid receiver. Nuvistors, which are very miniature tubes about the size of transistors, provide a nearly ideal combination with transistors. Knight used them first in their now obsolete KN310 hybrid tuner and this is the path also taken by Scott in their hybrid transistor tuners. Nevertheless, even in these hybrid types, it is difficult to find any improvement in performance to justify the higher cost.

DISTORTION

As in every other hi-fi component, low distortion is the most important single quality of a tuner. All other things being equal, distortion is largely proportional to tuner bandpass. This is especially true in the case of stereo broadcasts and for weak signal reception. For lowest distortion multiplex tuners should have bandpasses of 300kc or more. Very few tuners actually do have this wide a bandpass because it is difficult to achieve high sensitivity and selectivity with a wide bandpass. Something on the order of 200 to 225kc is more common, and will provide acceptably low distortion on all but the weakest signals.

Strangely enough, wide bandwidth is more important for listening to stations broadcasting popular music than for high fidelity and good music stations. This is true because these stations tend to overmodulate severely in an attempt to make their signals audible on cheap FM radios. On these cheap radios much of the distortion is minimized by the very limited response of amplifiers and speakers. But on a high fidelity system the distortion can be highly annoying and even intolerable. The Dynatuner has an especially low distortion to over-modulated signals.

SQUELCH

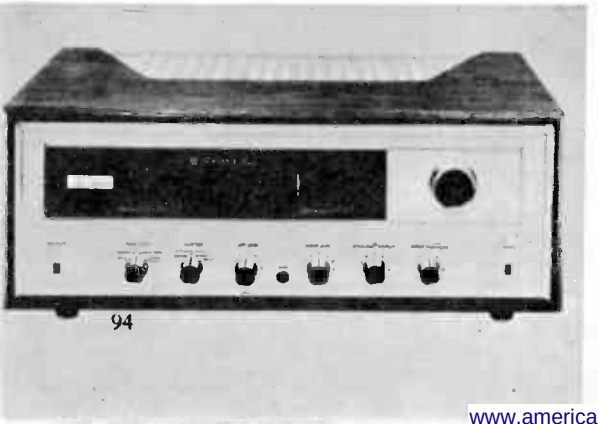
In very sensitive tuners, especially when the system is being operated at a high volume level, the noise between stations can be extremely annoying. A squelch to mute the receiver between stations can be a comfort. Several tuners have a squelch or "interchannel noise suppressor" or "interchannel muting"—different names for the same thing. Some use mechanical relays and some electronic muting. In areas where weak stations are listened to, it is best to be able to disable the squelch; otherwise, the weak station may not be receivable at all. Some tuners have an adjustable squelch, which can be set to operate at various levels to suit the need, or disabled entirely.

The benefits of squelching are not without a price—aside from the higher cost of tuners equipped with it. While a squelch eliminates the white noise between stations, the switching action produces transients as the squelch goes in and out which are even more annoying to some people than the interchannel noise. So there is a Hobson's choice here and the decision rests with the preference of the buyer.

AM TUNERS

Most standard broadcast stations have rather poor fidelity and very few broadcast programs suitable for high fidelity listening. Hence there is little justification for spending money for an AM tuner, particularly since network programs are usually available on one or more FM stations. However, in the past two years or so some stations on the standard broadcast band have greatly upgraded both the fidelity of their transmissions and the quality of their programming; and in some areas some of the best listening is offered by

Combination of Nuvistor and transistors is feature of this, the highest priced Scott tuner. Price is $475.



With 4 IF stages and 2 limiters, McIntosh tuners provide exceptional adjacent channel selectivity.

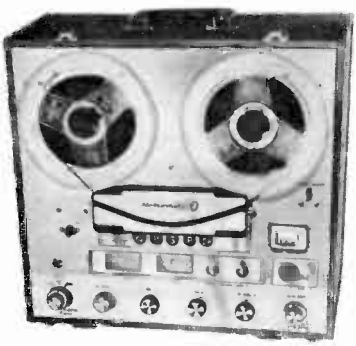
Command Performance

at your fingertips . . .

. . . every time you capture the magnificent world of full fidelity sound on tape.

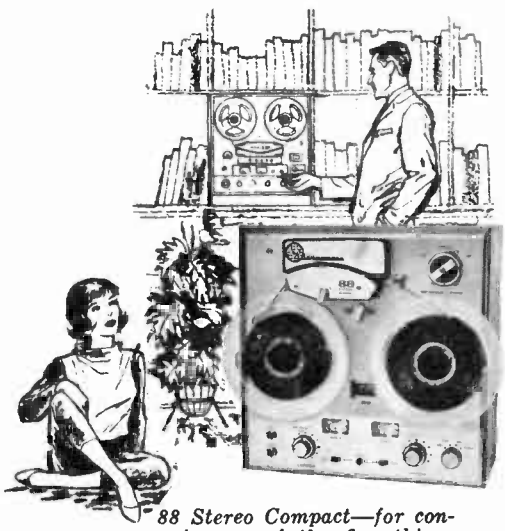
Taped sound retains full fidelity even after hundreds of playbacks . . . yours to enjoy always . . . on VIKING tape components, naturally.

A VIKING invests you with unlimited versatility to record live programs or off the air including F M multiplex, duplicate, put sound on sound and edit with perfect ease.



Retro-matic 220 — ultimate performance with tomorrow's features for discriminating audiophiles and professionals only.

This exquisitely styled quarter track stereo tape recorder plays in TWO DIRECTIONS —reacts silently to every "feather-touch" pushbutton command—even when remote controlled and the 12 watt amplifier for simultaneous record/playback with 20-25,-000 cps frequency response brings out the very best in stereo sound.



88 Stereo Compact—for connoisseurs of the fine things in high fidelity stereo sound.

Of elegant design, this stereo tape recorder lets you monitor off the tape as you record from any source; play back with excellent full stereo fidelity from 30 to 18,000 cps frequency response.

Put Command Performance at your finger tips with VIKING tape components — made by skilled American craftsmen.

Tape recorders, transports, cartridge players—even for your car or boat—at reputable high fidelity dealers most everywhere.

Viking OF MINNEAPOLIS, INC.

Your assurance of Quality in Tape Components

9600 Aldrich Avenue South, Minneapolis, Minnesota, 55420

such stations. Also some people will want to be able to listen to local AM stations whose programs are not duplicated on FM.

The cheapest way to provide for reception of standard broadcast stations is with an inexpensive table model radio. However, there are also FM/AM tuners which cover both the FM and the standard broadcast band. In most cases the AM portion will have much poorer fidelity than the FM because it is necessary to have a narrow bandpass to minimize interference from stations on adjacent channels. More expensive AM/FM tuners will provide a switched choice of wide bandwidth for local stations free of interference, and narrow bandwidth for more remote stations or when adjacent channel interference becomes a problem.

FM RECEIVERS

It is possible to combine all the electronic elements of a hi-fi system—tuner, preamp and amplifiers—in a single unit, and such combinations are designated as "receivers" rather than "tuners." Such "receivers" offer a saving in total cost and space and have become extremely popular. Practically every manufacturer offers one or more "receivers" at prices starting at around $150 for kits and running up to $400 for the most elaborate factory-wired combinations. Transistorization of some portion of the receiver, as in the Altec-Lansing Astro, is something that we can expect to see in future receivers.

These receivers offer performance which is quite comparable to that provided by the same manufacturers stereo amplifiers of the same power rating. In fact, in most instances the receivers will use identical components and circuits in the amplifier section. The performance is generally in the minimum and medium category.

ANTENNAS

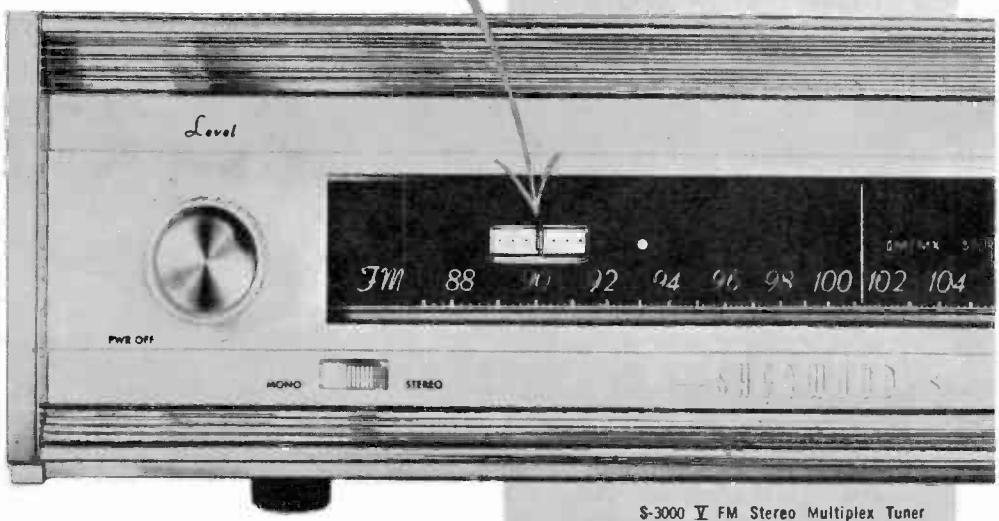
Although most current FM tuners are so sensitive that the most nominal of antennas will do for local reception, a good antenna may nevertheless produce a great improvement, particularly in stereo reception. All tuners come with a folded dipole antenna made of twin-lead transmission line. This antenna can be tacked to the wall behind a davenport, or along the baseboard or, in the upper stories of apartment buildings, placed under a rug or carpet. It will usually suffice. A "rabbit-ear" TV antenna is often convenient and works very well in most city locations. But if reception is noisy and distorted, an outside antenna should be added. The "community" type antenna system offered in some modern apartment buildings usually provides excellent reception of FM as well as TV. Many but not all TV antennas are also good FM antennas. Some TV antennas, however, have a deliberate null through the FM band to minimize interference on TV from FM stations. In some instances it may be advisable to install a separate FM antenna on the roof and run a lead-in down to the FM tuner. For local reception the antenna need not be elaborate. However, a beam antenna, such as a two-element beam, may be desirable to minimize distortion due to multipath reception by reflection from buildings.

A good antenna is essential outside the 25-mile radius of the primary area of a station, and a really good beam antenna should be used in the fringe areas. Again here the TV antenna can be tried before putting up a separate one. The Log Periodic, and the "traveling wave" types of TV antennas provide good gain and directional discrimination throughout the FM band. In the marginal reception areas 100 or more miles distant, a five to 10 element beam should be used. Such beams are available from Finco, Taco and other antenna manufacturers. The Apparaturs Development Co. of Weathersfield, Conn., specializes in high gain FM antennas. The Hy-Gain Company has a very fine Log-Periodic beam with a very uniform gain throughout the FM band. If cost is immaterial the FM version of the Spiralray by Telrex, of Asbury Park, New Jersey, may make the entire difference between unsatisfactory and high fidelity reception.

Outside the metropolitan centers where stations are receivable from several directions a rotator is highly desirable and may multiply by two or more the number of stations that can be received satisfactorily. A TV and an FM antenna can be stacked on the same tower and rotator. The separation should preferably be of the order of 10 feet.

Boosters are not likely to make much difference even in extreme fringe areas. Because they are untuned, wideband devices they will almost certainly not have as good a noise figure as a good FM tuner; hence they are not likely to improve the actual sensitivity. However, it is possible that they may in some places improve reception nevertheless by improving the saturation of the limiters. To do any good the booster should be designed specifically for use on the FM band and have the best possible noise figure—preferably using a nuvistor or a frame grid tube. A transistor booster is not likely to improve matters at all because the noise figure will almost certainly be inferior to that of the tuner alone and there will be a degradation of the signal to noise ratio on weak signals rather than an improvement. •

Why did Sherwood zero-in on the problem of tuning accuracy?



S-3000 V FM Stereo Multiplex Tuner with professional zero-centered tuning meter and Stereo Indicator Light.

It takes wider bands to broadcast the multiple information for stereo FM multiplex, and the most precise "dead-on-center" tuning to receive it . . . with maximum stereo separation and minimum distortion.

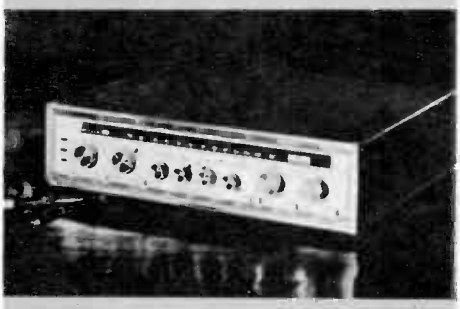
This is why in the new S-3000 V Tuner, Sherwood engineers incorporated a professional zero-centered tuning meter. Superior to tuning eyes, better than peak meters, it uses the same D'Arsonval meter needed to design, align and test FM tuner circuits. When the meter reads "zero". . . you're right on. No guesswork. No maybe's.

Gain three tuning advantages

- Tune accurately, the first time.
- Tune low-power Class "A" stations interspaced between more powerful broadcasts.
- Tune with professional surety.

Added value features of the S-3000 V

- Stereo Indicator Light: identifies stereo broadcasts.
- Superb sensitivity: 1.8μv (IHF) for —30db. noise and distortion.
- No background noise: pace-setting 2.4db. capture effect.
- FM Interchannel Hush: suppresses between-station noises.
- Flywheel tuning: smooth as silk.
- 20% longer dial scales: professional accuracy.
- Price: $165.00. (Leatherette case optional at $7.50.)



New S-8000 III FM Stereo MX Receiver. Combines above tuner features with an 80-watt stereo amplifier. Price: $319.50. (Leatherette case optional at $9.50.)

Prices slightly higher in the Far West.

Sherwood
HIGH FIDELITY
Stereo Receivers • Tuners
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Speaker Systems • Contemporary Cabinetry

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All About Loudspeakers

IN MANY respects loudspeakers are like women. They come in various shapes and sizes—including the very fashionable slim and slender—each with a different character and personality, very difficult to measure accurately and with appeals which depend pretty largely on the personal taste and preference of the customer. The most attractive do the most damage to the budget.

With a few exceptions the current loudspeaker is based on the dynamic movement that is now almost 40 years old. Basically it is an electric motor which produces a push-pull motion rather than a circular motion. The motor is driven by the varying electric current which is a replica in its waveform of the waveform of the original sound. A piston driven by the push-pull motion vibrates the air and produces sound waves which, if the entire process is accurate, are identical to the original sound waves of which the electric current is a replica.

This holds for the higher frequencies; but at low frequencies a loudspeaker alone in free space may vibrate like mad and produce no audible sound at all. The reason is that as the piston pushes the air in front of it forward, it also pulls the air behind it, and vice versa. It thus produces two sets of sound waves—one in front and one in back; but while the front wave is arriving at a "positive" peak, the back wave arrives at a corresponding "negative" peak. When these two sets of sound waves meet, they cancel each other. In the case of the high frequencies the length of one wave is shorter than the distance from the front to the back of the cone. By the time the back wave has traveled the distance from the back to the front of the cone, the front wave has moved forward and is no longer in opposite phase; therefore, cancellation does not occur. But the few inches between front and back of the cone constitute so small a fraction of the wavelength of the very low frequencies that an out-of-phase condition exists and a large part of air motion cancels out.

To reproduce low frequencies it is necessary to delay the back wave or better yet to prevent it entirely from meeting the front wave. This can be done by mounting the speaker on a large "baffle." Cancellation will not occur as long as the distance from front to back of the cone is at least one half the length of a wave at a given frequency. A half wave at 50 cycles is 11 feet, and at 20 cycles more than 25 feet. Thus, to reproduce the full range down to 20 cycles, the baffle would have to be at least 12 feet in diameter.

These three Jensen systems all use much the same components. The biggest one yields the best sound.

Such a baffle is completely out of the question in most homes, even if it were "folded" into a box.

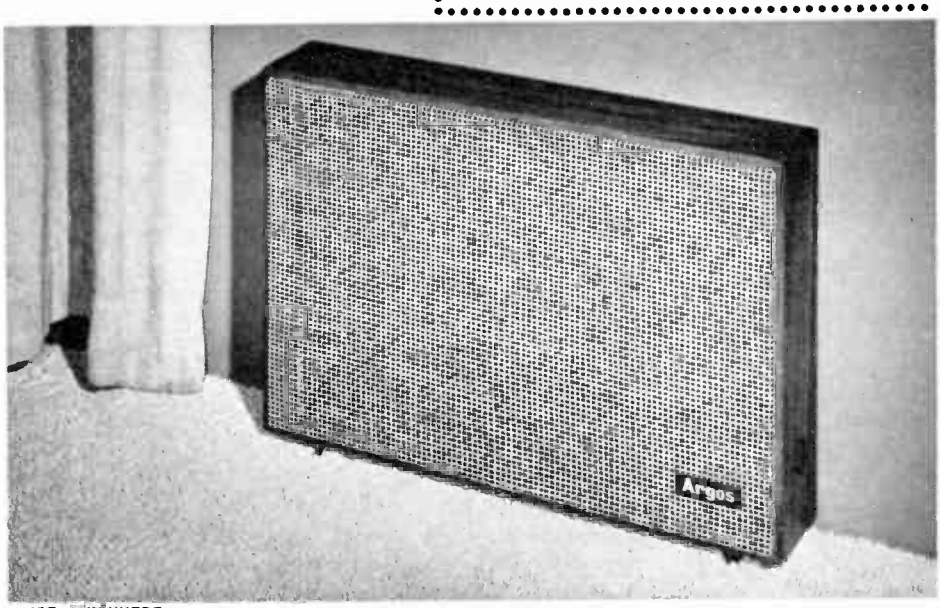
It is simpler to prevent the back wave from getting around to the front at all. The simplest way to do this is to mount the speaker in the wall between two rooms which have no common doors or windows, so that the distance between front and back is infinite. And, as a matter of fact, this is still one of the best ways of obtaining a fine speaker system, where it can be done.

Unfortunately, this, too, is impractical for most homes and some more practical way of preventing cancellation, preferably in a more compact and portable form, is needed.

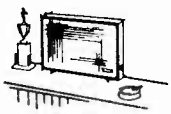
reproduction so good
. . . from an enclosure so small
. . . it's almost unbelievable

Petite

HIGH FIDELITY SPEAKER SYSTEM

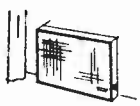


USE ANYWHERE



SHELF

WALL



FLOOR

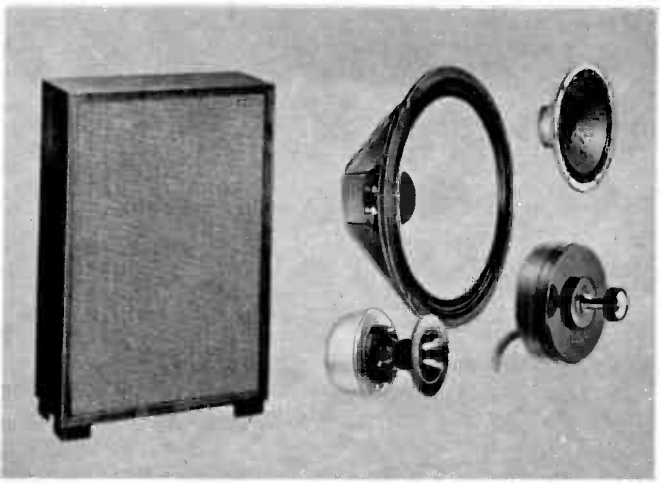
Performance of the Petite is unmatched by any enclosure close to its 18″ x 12″ x 3¾″ size. Bass notes come through rich and resonant . . . highs clean and brilliant. The secret? Argos system-engineered techniques . . . techniques which precisely coordinate the enclosure with the moving system of two Jensen speakers custom-made to Argos specifications. Trim design and beautiful hand-rubbed ¾″ oiled American walnut veneer cabinetry make the Petite a distinctive addition to any room setting. Graceful solid brass legs, plus wall hangers, make your Petite useable anywhere . . . shelf, table, wall or floor. **See it at your hi-fi store, or write direct for descriptive catalog.**

Price $24.95

ADDITIONAL FEATURES

• Speakers include: custom-designed Jensen high-compliance woofer with 200% more cone travel, and Jensen tweeter with matching network • Frequency range, 50 to 17,000 cps. • 8-ohm input • Screw terminals polarized for stereo • Volume control recessed into side of cabinet.

Argos
PRODUCTS COMPANY
Dept. E, Genoa, Illinois



Most loudspeaker systems, like this one by Knight, use three speakers, have a balancing control to regulate the highs.

The most obvious solution is to put the speaker in a totally enclosed box so that the back wave cannot get out of the box. Like most simple solutions this runs head-on into some very serious problems. When you enclose air in an airtight container it is not very compressible. All you have to do to verify this is to take an old-fashioned tire pump and try to push the piston down while closing off the hose opening with your thumb. With the hose open, the piston moves up and down easily. With your thumb over the hose opening, it is very difficult to push the piston down or to pull it up.

In a small box, the piston of a speaker is similarly loaded by the very high resistance of the air in the box. It may move a half inch in free space, but in the box it can move only a fraction of the distance, and its motion for a given driving power is very much reduced.

The loading has another effect. Loudspeakers are resonant devices. They are efficient radiators at frequencies higher than their resonant frequencies, but inefficient or ineffective at frequencies lower than their resonant frequencies. To reproduce the full audio range down to 20 cycles, the loudspeaker resonance should be below 20 cycles. However, when a speaker is put in a totally enclosed box, the stiffness of the air inside it raises the resonant frequency. The smaller the enclosed box, the higher the resonant frequency is raised. The 20-cycle speaker in a box 10 cubic feet in volume might have its resonant frequency raised to 40 cycles, thus limiting its ability to reproduce frequencies below 40 cycles.

Hence the totally enclosed type of infinite baffle has to be fairly large to cover the lower two octaves. Even with very low resonance speakers the box should have a volume of 20 cu. ft. or more to provide an appreciable output at 40 or 30 cycles.

Some highly ingenious ways have been devised to get around this difficulty and to obtain a resonant down to the last octave in an enclosure of reasonable size. These are summarized on page 102.

The coming of stereo, and its requirements for two entirely independent speaker systems, provided a tremendous impetus toward reducing the size of speaker systems. Hence, horns once very popular and available in a wide variety, and to a lesser extent, bass reflex and big infinite baffles have become less popular. Most of the "book shelf" sized and smaller speaker systems today use either the "acoustic suspension" or the "ducted port" type of enclosures or a sort of combination of them.

The bass response of speaker systems is no longer proportional to size. Most of the book shelf type systems go down as far or farther than the older horns, bass reflex and big infinite baffles. A response down to 35 cycles or so can be obtained readily in these smaller enclosures.

There is pretty wide agreement that very little is lost if the speaker response stops at around 30 cycles. Except for the pedals of the organ, no instruments produce fundamentals lower than 30 cycles, and it is difficult to record the last octave in any case. However, there are many transient sounds in this region which, while not part of the written music, accompany its generation by musical instruments, and contribute to the overall sound. Although there is no loss of musical value when these transients are not reproduced, there is a loss of the illusion of complete presence. The very few systems which have a respectable output below 30 cycles provide a really startling verisimilitude to the original experience. Very few people would be willing to pay the price in dollars and space needed to obtain the response in this lowest octave. Hence, even the finest of

commercial speakers have little clean and undistorted response below 30 cycles.

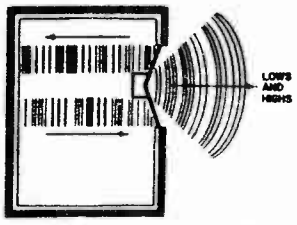
A saving of about 50% in cost can be achieved by being satisfied with a response to 40 cycles, and this type of system will provide a completely satisfying musical effect and a sufficient illusion of presence to satisfy most people. This response is easily achieved in the price range between $75 and $150 per speaker. Lower priced speakers manage to get down to 50 cycles on the fundamental and produce a fair illusion of hearing the lower frequencies by "doubling"—that is, generating second harmonics of lower frequencies.

In the past year or two there has been a revival of interest in larger speakers, since many people have no objections to big systems and many modern homes with large living rooms have plenty of space for them. However, the more dominant trend has been to smaller and, lately, to thinner speaker systems. The "thin" speaker is currently the fashion and no speaker manufacturer's line is complete without at least one thin speaker system. Frankly, the thin speaker has very little if any advantage in space saving, though it may be somewhat more decorative. What it gains in thinness, it gives up in area. And practically all thin speakers are inferior to some degree to book shelf sized systems using the same components.

It is quite possible to disregard entirely this business of suppressing the back wave and there are several speaker systems which make no attempt to suppress or delay the back wave and prevent cancellation; and they work and produce a good bass. It is true that in an entirely open space, such as a field, an open backed speaker would result in cancellation of the low bass frequencies. But when a speaker of this type is placed in any practical living room the back of the system and the front work into entirely different sets of conditions. The back wave is to some extent inverted by reflections from the walls and corners, and absorbed by them. Hence cancellation is not complete. Furthermore, the bass response of any speaker system is determined to a good extent by the room in which it is used. "Standing waves" are set up in a room at frequencies for which the room dimensions are multiples of a quarter-wave. At these frequencies the room is extremely efficient; it will produce the tone with very little excitation and hence will produce a sound even though the cancellation of front and back wave is quite large. Because there are no enclosure resonances, this type of open-

TYPES OF ENCLOSURES

INFINITE BAFFLE

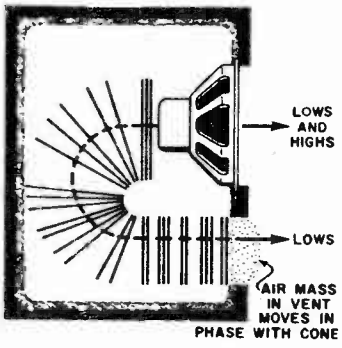


TRAPPED AIR "SPRING" PUSHES BACK ON AND "STIFFENS" CONE

INFINITE BAFFLE—If we mount the speakers in an enclosed box, the front and back waves will be isolated so they cannot cancel out. But the air trapped in such a box must be compressed by the back of the speaker and thus it becomes, in effect, a spring which pushes back on and stiffens the suspension of the speaker. This raises its resonont frequency. The smaller the enclosed box, the stiffer the spring and the more it raises the resonant frequency. A speaker generates very little power below its resanant frequency. Thus with a small box it is difficult to obtain a response below 60 or 50 cycles.

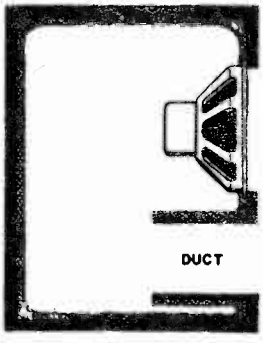
One way to minimize this is to use a large box and some very fine infinite baffle speakers, like the Bozak does. The Hartley *Baffle* uses another clever expedient. The *Baffle* is actually a box with an open back. But between the back of the speaker and the open back, there are a dozen curtains of sound-absorbing material. As the back wave goes through these curtains it is absorbed so that when it finally comes out the back, it is very weak and causes little cancellation. Because the box is not enclosed the air behind does not compress, and therefore, does not provide any resistance to the cone. Ed Villchur came up with a revolutionary solution for this problem in his "*Air Suspension System.*" He uses a speaker with a very loose suspension and a resonance in free air of around 10 cycles. When this speaker is put in even a very small box the resonant frequency is raised to not more than 40 cycles and can generate sound down to 30 cycles, or even lower. The stiff "air-spring" of the trapped air in the small box provides the restoring force for the speaker which, unlike others, has little restoring force of its own; and since air is a more linear spring than a mechanical spring, the motion of the speaker is more symmetrical and less distorted. By this combination the Acoustic Research speakers provide extremely good low bass response in a very small enclosed box. This principle is also used, under license, in the KLH and Janszen speakers. Since they make no use of the back wave, infinite baffle speakers are relatively inefficient. In wall mounted infinite baffles or large enclosed boxes, efficiency can be improved by using two or more bass speakers.

BASS REFLEX



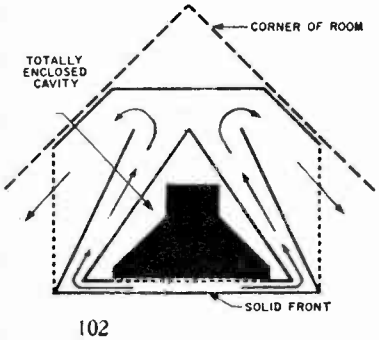
THE BASS REFLEX—The back wave can be used to augment the front wave by cutting on additional opening or "vent" in the box housing the speaker. With this opening the phase of the back wave is inverted or "reflexed" at bass frequencies so that the air coming out of the vent is in phase with the air pushed by the front of the cone, and thus augments the front wave.

DUCTED PORT



DUCTED PORT—If we turn the vent into a duct by adding a tube behind it, the resonant frequency of the enclosure is made lower. Thus we can reduce the size of the cabinet for a given resonant frequency. By using high compliance speakers with low resonance as well as long ducts, we can get a good bass response with much smaller cabinets than is possible with a bass reflex enclosure. Most of the new compact speaker systems use the combination of high compliance speakers and the ducted port.

FOLDER CORNER HORN



THE HORN—If we talk through a megaphone or a rolled up taper of paper, our voice will carry much farther because, first, our voice is coupled to the air more effectively and, second, because the megaphone concentrates the power of our voice in a narrow angle. Horn speakers work on this principle and are very much more efficient than other types. However, to be effective horns have to be very long and have a very large mouth area. The problem of length can be solved by folding the horn as the horn of a trumpet or tuba is folded. To radiate 40 cycles a horn should have a mouth area between 6 and 10 feet in diameter. This is obviously impractical for home use. However, this can be approximated by coupling the end of a relatively small horn to the corner of a room. The walls, floor and ceiling of the room then become extensions of the horn and the room itself becomes, as it were, the mouth of the horn. The most famous of the folded corner horns is the Klipschorn, still considered one of the finest of all speaker systems, and it is certainly the most efficient—28 per cent as against the 1 to 7 per cent efficiency of infinite baffle, bass reflex and ducted port system.

backed system, like a true infinite baffle system, has less coloration. So that, all in all, if fine speakers are used, these open-backed systems can produce a fine sound. However, their performance does depend a great deal more on their position in the room than is the case with the other types of speakers, and a good deal of trial and error experimenting is needed to find the best position.

The speaker itself, is, of course, extremely important and designing and producing a really fine speaker is a great art which only a few people have mastered. Good speakers are expensive and the best are quite costly. The performance of a speaker comes from a combination of many factors—the size of the cone, the length of the "throw," the size of the magnet and voice coil, the type of suspension, the shape of the cone, and the material of which it is made. Various combinations of these several factors can be used to achieve comparable performance, and every designer has his own.

Although the most familiar speaker uses a round cone of paper or other materials, it does not need to take this shape. EMI uses an oval speaker to achieve a respectable piston area in a compact enclosure. The most revolutionary speakers do not use a cone at all. The Biphonic Coupler and some University speakers use a more or less conventional type motor to drive a thin wood panel which forms the face of the "cabinet," to achieve a very large piston area. The ADC speakers have a rectangular piston made of styrene foam, driven by a fine British motor. The Bi-Coupler is an "open-back" type system. The ADCs are heavily damped bass-reflex systems. Partly because of the inertness of the styrene piston to sound and partly by careful design of the enclosure the ADC is almost entirely free of resonance in the bass range. The largest model produces a respectable output to below 30 cycles, with an excellent transient response.

The use of such unusual pistons is dictated by another consideration. The piston of a speaker ought to remain a rigid piston all the time. Unfortunately, when it is made of rather thin paper, it tends to "break-up" in the mid-frequency range as various sections of the cone resonate. This not only produces resonant peaks at these mid-frequencies, but keeps the piston from being really efficient at the low frequencies.

In the past two or three years other

manufacturers have worked in the direction of preventing cone break-up and producing a really stiff piston. One of the earliest was a plasticized paper cone in the latest models of the superb Hartley speakers. Leak uses a "sandwich" of plastic foam and aluminum in a very rigid though still light cone. Electro Voice uses foam plastic in its very large woofers.

Jensen in its fine 3-P/K speakers also uses foam plastic but with a flat piston, coupled to the motor with a cone made of the same material. The Jensen speaker systems using these speakers, particularly the largest one, the 3-P/3, produce a very impressive sound. These speakers are very shallow and hence particularly adaptable to the "thin" type of speaker and Jensen offers two thin systems using these speakers.

Another radical design with excellent performance is the British IMF which also uses a foam plastic cone with a unique center suspension which produces a very high compliance.

There is more imaginative research and development today in the speaker field than in any other branch of high fidelity and even more radical departures from conventions are in the works and can be expected to reach the market in the next few years.

All speaker systems are individual and differ from each other far more than the fiddles made by one maker differ from those made by another. Also the performance they deliver will vary with the amplifiers by which they are driven. Ideally, the speaker and amplifier should be designed to complement each other. J. B. Lansing has provided the first such integrated combination of amplifier and speaker, using transistorized amplifiers built right into the speaker enclosure and part of it. Lansing calls the amplifier an "energizer." The amplifier is a two-channel stereo amplifier and hence only one is necessary for a stereo system. The energizers have equalization for the individual speakers and can be used with any standard preamplifier.

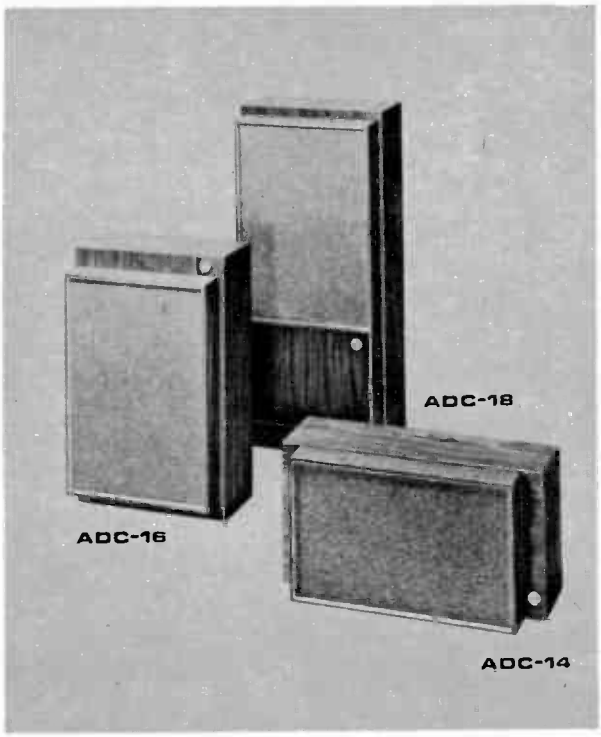
There is another type of speaker mechanism—the electrostatic. If two pieces of foil are suspended parallel to each other, and if a varying voltage is applied to them, they will repel and attract each other, depending on the phase of the voltage. With an alternating voltage like that of the audio wave, they will vibrate back and forth and thus produce sound waves in the air in which they are suspended. The electrostatic motor has many virtues. For a given piston area it has very little mass and therefore can be set in motion—or stopped—very easily and quickly. It is thus capable of extremely fine transient response. On the other hand, it cannot move as far back and forth as the motor driven piston of a cone speaker, and thus requires a very large piston area. For this reason, it is difficult to reproduce the lowest bass octaves with an electrostatic. There are several full-range electrostatic speakers—notably the Quad and the KLH. The KLH is very large, the size of a Chinese screen and also very expensive. But it produces a sound which some people believe is as nearly free of coloration as any speaker so far produced. The Quad is much smaller and does not have quite the efficiency at the very low frequencies. Both of these are of the "open back type" and part of the inefficiency at the lowest octaves is due to the cancellation which occurs with open-back systems.

Because of these limitations the electrostatic speaker has been used largely as a tweeter for reproducing the highest frequencies. Electrostatic tweeters are very clean, with a superb transient response, and many people prefer them to any other.

Practically all hi-fi speaker systems use two or more speakers; although the number of speakers used is by no means a measure of quality. It is quite possible to design a single speaker capable of covering most of the audio range; as, for example, the Hartleys do; but it is easier to divide the range into at least two parts and cover each with a separate speaker. The division is made by "crossover networks." In the lower priced systems it is usual to use two speakers, a woofer and a tweeter. A woofer, mid-range and tweeter combination is quite common and is usually quite sufficient, though some systems use as many as five speakers.

The most obvious to the ear differences in the sound of different speaker systems come from the differences in the speakers covering the mid- and high-frequency ranges. Some are shriller, some brighter, some have a metallic tone, some a very nonassertive high end. This is where individual preference can play a very large part in the choice of a system. Most systems have a control or two of them so that the high end, and possibly the mid-range, level can be adjusted to suit individual preference and to provide a proper or ear-satisfying balance to the bass response.

The speaker system makes the biggest difference in the sound of high fidelity systems. Hence, this is the point at which the buyer of a system has the greatest op-

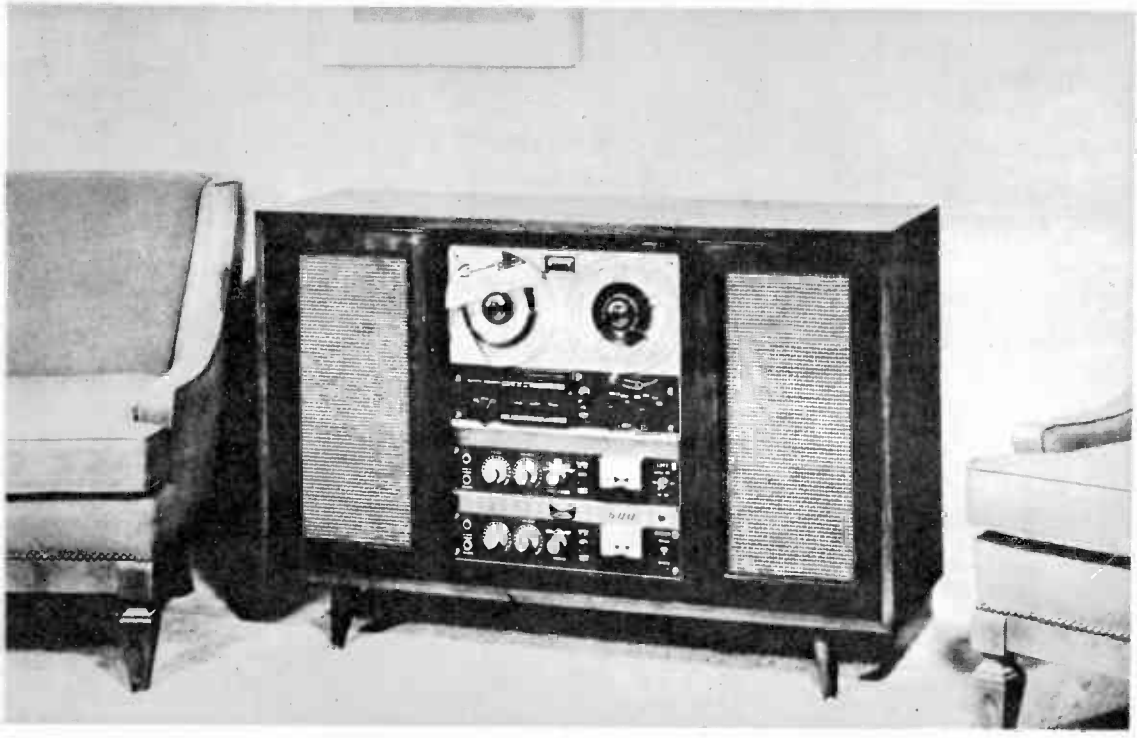


All of these ADC speakers with rectangular foam plastic pistons produce exceptionally clear sound.

portunity to suit his taste. While speaker systems can be measured, the measurements mean very little because they have little correspondence to the sound that will be produced in any room. Two systems can have precisely the same measured curve and yet sound as different as the voices of people. The ideal way to choose a speaker is by actual trial in the room in which it or they are going to be used. Some dealers will permit such trials.

The best way to prepare oneself for judging speakers—or for that matter, the entire hi-fi system—is to listen to as much real music as possible before you set foot in a store. Go to the concerts of your symphony orchestra a few times or your high school band; or, if you prefer jazz, listen around the jazz emporiums—provided there is no microphone in sight. Listen carefully to the bass, the fiddles, drums, double basses, triangles, etc. Remember the function of a high fidelity is to bring you a sound as nearly as possible like the original. When you go shopping, choose the speaker or system which sounds most like the live orchestra or jazz band. •

All About Tape Recorders



Freeman 600 shown above offers semipro performance and features at the modest price tag of $400.

FROM the point of view of sound quality, tape can be the best source of stereo program material. For one thing, tape does not suffer from pinch-effect distortion which is unavoidable on stereo disks. For another, since the process of tape recording is entirely electrical, problems of mechanical inertia or momentum do not arise, as they do with a mechanical cutter or a disk pickup. Consequently, the ability of tape to reproduce transients sharply and cleanly and without hangover is superior. Also, two separate heads are used in stereo tape recording for the two channels whereas in stereo disks, a single needle is necessary for both channels. Therefore, stereo tapes are capable of much better channel separation and less interaction between the two channels. Finally, there is no rumble problem with tape. There are problems of flutter and wow to be sure, but even when these problems are not completely solved, the effect on reproduction is not as damaging as turntable rumble can be in the stereo hi-fi system.

On the other hand, tape has its disadvantages. It is more expensive. The process of duplicating tape is more costly and has certain imperfections. Duplicated tapes do not deliver the full quality of performance of which tape is capable. Although the top quality tape recorders used for making original recordings are capable of the best frequency response so far attained in any recording process, this does not carry down to the playback tape machines used in most home hi-fi systems. Almost all modern disk records have a response at least to 15,000

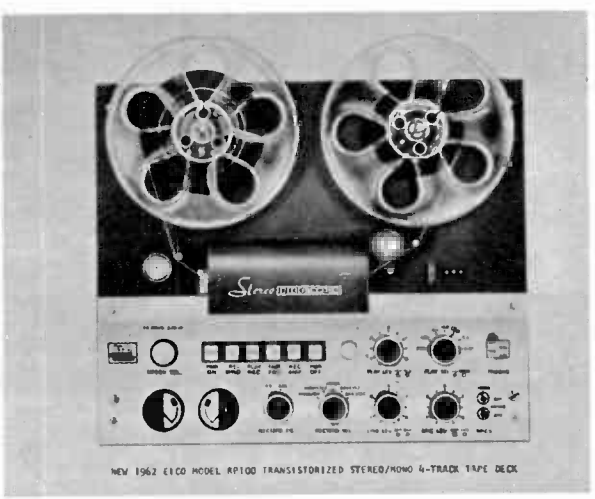
cycles and many to 20,000. There are any number of disk pickups capable of response to 15,000 cycles or beyond at 33 rpm. But only the better and more expensive tape playback machines are capable of this response. Most home type machines do not have much useful response beyond 10,000 cycles, and many are really flat only to 7500 cycles.

In short, the higher capabilities of stereo tape are realized only when first-class equipment is used; whereas pretty good results can be obtained with medium quality disk equipment.

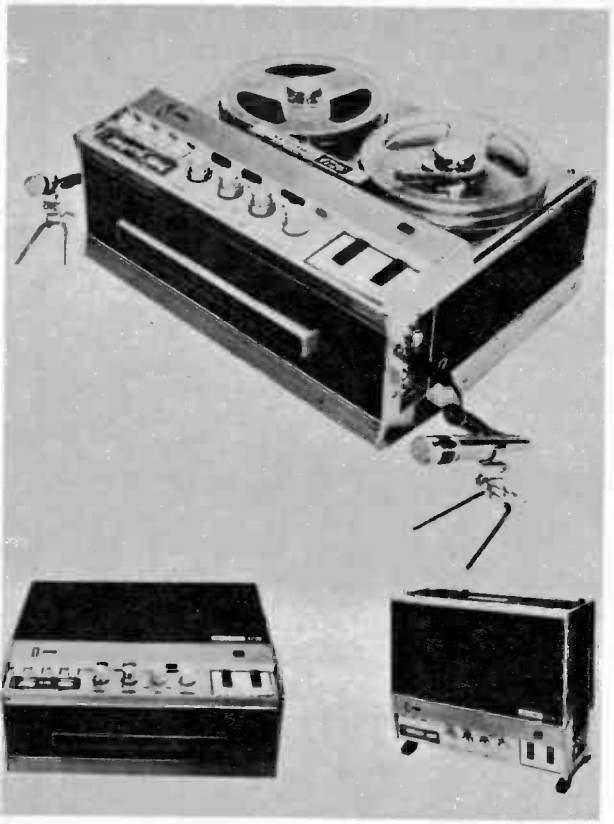
Some, but by no means all, of the recordings on disks are also available on four track stereo tapes at prices a dollar or two higher per reel than the equivalent disk.

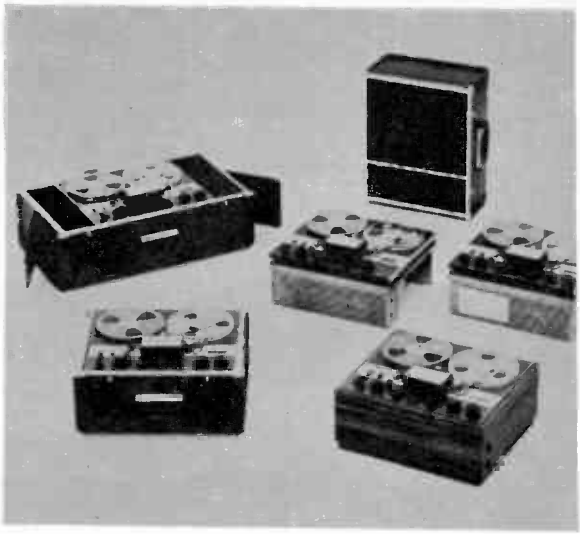
From time to time attempts have been made to produce "magazine" tape recorders that would permit the tape to be placed on the tape player as simply as a disk on a turntable. However, these have not been successful because, first, the quality has generally been poorer; second, the improvement in convenience is not great; and finally because magazines require special tape players and recorders, and generally these cannot be used with regular reels of tape.

If you are interested only in playing back commercial tapes, the cost of a tape installation can be modest. There are several "tape decks" available at prices ranging from around $75 to $200, including several of high quality such as the Ampex, Tandberg and Sony. They cannot be used for recording and are less expensive than



Transistorized Eico recorders in kit form are one of the finest stereo buys at around $300 per unit.





New "44" series in tape recorders is latest in the world-famous Ampex line; they come in variations to suit various applications at prices from $550 up.

Vernon offers unusual convenience in operation and very high performance in $600 semipro class.

recorders because they have no electronic elements in them. Practically all current hi-fi preamplifiers permit the connection of play-back tape heads directly and provide the necessary amplification and equalization.

However, the investment in tape facilities is most justified when it is desired to make recordings as well as to play back commercial recordings. Tape offers a simple, convenient, and high quality means of recording for the amateur. With the better recorders only a minimum of skill is needed to make recordings as faithful as high-fidelity disk recordings. The capabilities of tape recording for fun, enjoyment and even profit, are almost limitless. Many people, nowadays, for example exchange tapes instead of letters. Many also use the tape recorder, as they use a movie camera, to record the progress of the family from the first lusty bellows of the baby to the reminiscences of grandfather. Camera fans use tape recordings to provide an accompanying commentary or background music for slides and home movies. A new breed of candid tape recording fans is recording the sounds of the world around them and portraits in sound of the memorable personalities they meet. Some of these have even found their way into commercial recordings on disks.

The first decision you have to make in choosing a tape recorder is how serious you're going to be about tape recording. You're faced here with a Hobson's choice. The recorders in the $75 to $200 class found in appliance, music, and discount stores are playthings suitable for casual use, noncritical recordings of voice and generally, for fooling around with, but not for high-fidelity playback or recording. On the other hand if you want high-quality recordings and are serious about recording, you have to be prepared to pay at least $250 and more likely four or five hundred dollars for a really good machine.

There used to be a very large gap between the home-type machine and the semiprofessional type. But now there is a medium quality class that does meet minimum hi-fi standards at prices ranging from just over $200 to $400. This includes the Heathkit, the Viking, the Bell and the

Tandbergs with their high-quality, three-speed performance in the $400-500 class have fine reputation.

higher priced Knight recorders. The Eico transistorized recorder is in this price class but is semiprofessional in performance.

In the semipro class you will find the very fine made-in-US Ampex, Concertone, Crown, and Newcombe.

The finest American tape recorders—notably Ampex, Concertone and Crown—are acknowledged to be the finest in the world, and are used by broadcast stations and for original tape masters everywhere. They are expensive, however, because the skilled craftsmanship required for such high precision is more expensive here than anywhere else. The lower cost of precision manufacture in other countries has brought many fine tape recorders into the market at prices within reach of the home tape recording or hi-fi enthusiast. Particularly outstanding in small, moderately priced recorders with extremely high performance are the Swedish Tandbergs. The Japanese have been particularly successful here, as in the camera field, in producing units of very high performance at moderate prices; and as in the camera field, the made-in-Japan label on a tape recorder is by no

Inexpensive at $180 in kit form and easy to put together, this Heathkit AD22 delivers quality.

For reproducing tape, a playback deck like this Sony at $120 is considered an economical buy.

means to be sneered at. Quality is high in the best lines and rigidly controlled. In recent years the Japanese have taken the lead in the transistorization and automatic or semiautomatic operation of tape recorders. The Roberts in its several models has been an outstanding value for several years. The Sony line offers high values in quality and performance in a line which covers the entire field from inexpensive to semiprofessional. The Freeman and Vernon also offer high performance in the upper middle priced range.

In the past year great strides have been made in improving the quality at the two slow speeds—3¾ and 1⅞ inches per second. The Tandbergs have been notable for their excellent response at these slow speeds. The Roberts Crossfield head and the Crown narrow gap head in the latest models, produce a frequency response at 1⅞ inches which many recorders previously did not provide even at 7½ inches, though at some sacrifice in response at the very low end below 50 cycles. Thus, they offer an extremely economical means of high fidelity recording—allowing as much as 8 hours of program on one 7-inch reel.

The basic factors in choosing a tape recorder are summarized on our chart. You can have an extremely wide variety of combinations of speed, reel size, number of heads, semiautomatic operation, etc. It is well to study catalogs carefully and examine recorders in the stores to get the combination of features best fitting your needs.

There are many accessories for tape recorders, such as foot switches which let you use the recorder for dictation and secretarial purposes. Special models, or accessories for standard models, are available for synchronizing sound to slide programs, so that recorder and slide projector work together automatically. On some recorders you can duplicate tapes. Most smaller models, especially the transistorized ones, can be used equally well at home with 60 cycle power, in the car with an accessory power supply, or portable with batteries.

Because in most instances the tape recorder will be a secondary source of program material for the hi-fi, it is best to choose a tape recorder in terms of its value to you as a recorder rather than a reproducer. If your interest in recording is

Sony 600 series offers semipro performance and very high versatility at the modest $450 price tag.

not great a relatively simple and inexpensive recorder will probably do. On the other hand, if you are interested in making fine recordings, the more complex and costly recorder may have a greater appeal.

Some recorders come with built-in amplifiers and companion speaker systems and form a complete playback system. You can connect a record player or a tuner to these and use them as the basic reproducing system, although generally the quality of reproduction will not meet genuine hi-fi standards because amplifiers and speakers are not as good as the independent ones specifically designed for hi-fi systems. Most of these recorders, however, can also be connected to a hi-fi system and will provide good quality. The semipro and pro models usually do not have built-in amplifiers. Headphones are used for monitoring.

When you buy your tape recorder by all means also buy the accessories needed to guarantee the maintenance of high quality and to make the process convenient and skillful. You should have a tape splicer so you can edit and put together various takes. The Robins Gibson Girl splicers are especially convenient and effective as well as modest in price. A tape threader is a convenience that will repay its cost of around 75¢ a hundred times over. A head demagnetizer, like the Robins HD6 at $7.50, will insure the maintenance of the high-frequency response and signal-to-noise ratio. If you plan to do a lot of recording a bulk tape eraser is a good investment. Get also a kit of cleaning accessories to keep the heads and drive clean and operating properly. •

POINTS TO CONSIDER BEFORE BUYING A TAPE RECORDER

● **SPEED.** There are four standard tape speeds: 15, 7½, 3¾ and 1⅞ inches per second (ips). The slower the speed the more recording time on a given length of tape, but the poorer the high-frequency response. Fifteen ips is used only in broadcasting and for making original masters for records. Seven and one half ips is the standard speed of commercially available stereo and mono tapes. It provides good frequency response and double the playing time of 15 ips tapes. Three and three-quarter ips permits 1 hour of playing time per track on a 7 inch reel of tape. With the best available heads response to 15,000 cycles can be obtained. The speed is adequate for home recordings of speech and unimportant music. One and seven-eighths ips provides 2 hours of recording per track but except in finest recorders is suitable only for voice work. Most recorders provide a choice of 2 or even 3 speeds.

● **TRACKS.** Single track recorders are now used exclusively for broadcast work and when making master tapes. Two tracks permit recording one program on upper half of tape and another program on lower half, thus doubling playing time. Current stereo tapes are four-track; one pair is used for one travel direction and another pair is used for the opposite travel direction to provide playing time equal to two-track monophonic recordings. Four-track recorders can also be used to record 4 tracks monophonically to provide up to 4 hours of program on a single 7-inch reel at 3¾ ips and up to 8 hours at 1⅞ ips. For home use a 4 track recorder with either 7½ and 3¾ ips, or 7½, 3¾ and 1⅞ ips speeds is most useful and economical. A four track head will also playback two track and single track tapes.

● **MOTORS.** Top-quality recorders use three motors to assure constant speed, low wow and imperceptible flutter. It is hard to do as good a job with one motor but it can be done with good design and precision construction as in the Tandberg, Ampex, and Roberts recorders. Inexpensive recorders use a single motor. Hysteresis-synchronous motors result in less flutter, wow, and hum; inexpensive recorders use four-pole induction motors.

● **HEADS.** At least two heads are necessary for playback and recording—an erase head and a combined record-playback head. This is the most common arrangement in less expensive recorders. Separate heads for recording and for playback permit monitoring the recording as it's being recorded. Separate heads also permit many trick effects such as sound-on-sound recordings, echo effects, etc. Most semi-pro machines use three heads and it is possible to obtain them and professional machines with as many as five heads for full, half-track and quarter-track playback or recording.

● **FREQUENCY RESPONSE.** The critical response area is beyond 10,000 cycles. Most machines below $200 do not provide a flat response to this point even at 7½ ips. Good semi-pro machines will provide response to 15,000 at 7½, to 10,000 at 3¾ and 6,000 at 1⅞ ips.

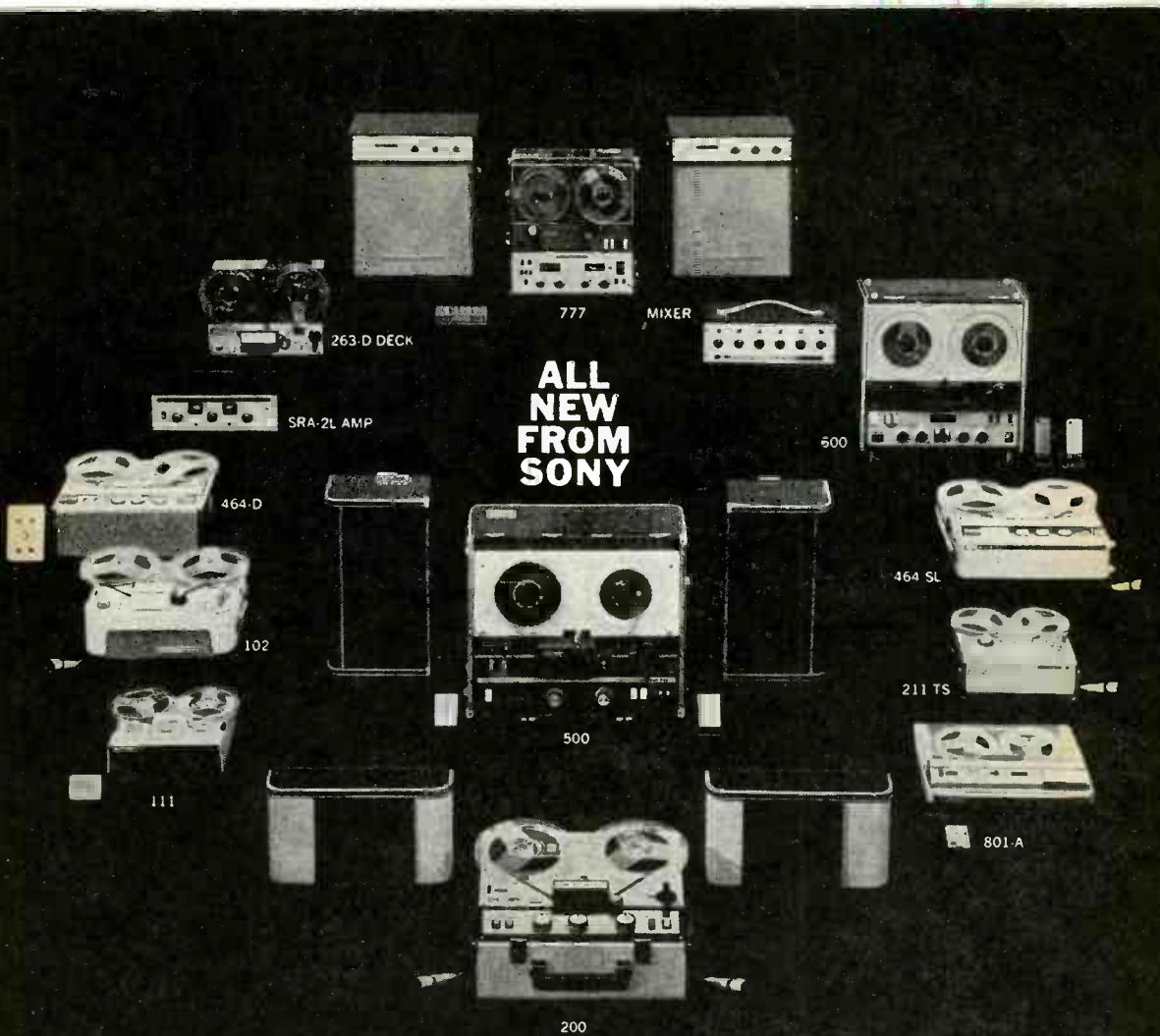
● **FLUTTER AND WOW.** Tape recorders do not have rumble but do have flutter and wow problems. Inexpensive recorders have noticeable flutter and wow and are not suitable for recording music. In semi-pro recorders flutter and wow are held down to .1—.15% at 7½; .15 to .2% at 3¾, and .25 to .3 at 1⅞ ips. Home-type recorders generally have more than .3% at all speeds.

● **NOISE.** The more tracks the poorer the signal to noise ratio. For good performance noise and hum should be no less than 50 db down. Only semi-professional and professional recorders achieve or surpass this figure.

● **LEVEL INDICATORS.** It is vital when recording to watch the signal level carefully to prevent overloading and distortion. Two types of indicators are used: "magic eye" and meter. Meter indicators give a more accurate indication, permit setting record level precisely, but may not indicate transient peaks. "Magic eyes" are better indicators of transient peaks but are not calibrated and therefore less accurate Generally, the better recorders use meters though Tandberg uses "magic eyes."

● **REEL SIZE.** The seven-inch reel is commonly used for all applications including broadcasting. In some broadcast applications, and when long recordings are to be made, a 10½-inch reel is available and it doubles the playing time. Most semi-pro and all home recorders accommodate only seven-inch and smaller reels. Some semi-pro recorders accommodate the ten-inch reel. Those that do are considerably larger and heavier.

● **TAPE TYPES.** Tape comes in several thicknesses. The thinner it is the more of it can be put on a reel. However, thin tapes may introduce "print-through"—a transfer of the recording from one tape layer to the next. Standard tape is 1½ mils thick and provides ½ hour of recording time per track on a 7-inch reel at 7½ ips. "Plus-play" tape is 1 mil thick and gives 50% more time per track. There is a "double-play" tape, only ½ mil thick, which affords twice the time of 1½ mil tape, but is especially subject to print-through. This tape permits as much os 16 hours of recording on four tracks at 1⅞ ips. For average use the normal tape is preferred but plus play is economical and suitable for casual home recordings. Most manufacturers offer several grades of tape at various prices. Second quality tape at less than $2 per seven-inch reel is good for most home use. There are also specialized tapes with high tensile strength that are more resistant to breakage from frequent use; some are less susceptible to print-through and are good for recordings that are to be preserved for a long time; and there are colored tapes that permit quick recognition of different recordings.



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