How Do Speakers Work?

by Robin Lanier

Even the person who calls an electrician to change a light bulb needs some knowledge of what makes speakers operate if he is to choose the right system for him.

WHEN YOU COME right down to it, you don't *need* to know how speakers work. But understanding can tip the balance of dangers and rewards in your choice of speakers toward rewards, and your use of speakers can be made more productive. Then there is the pure pleasure of knowing what an audio device or system is up to when it performs its transmutations—its re-creations.

In choosing speakers you will want to know the rationale behind each of the main types of speaker and the principal technical features that are the common currency of speaker promotion. The amateur can do a thoroughly valid job of evaluation by putting together his knowledge of general expectations with the information he receives through his own ears. Some aural training is vital, to be sure, but it is both pleasurable and extremely useful.

A basic examination of speakers must start with the stream of electrical power coming from the amplifier, power which represents the music or other sound we are calling on the system to reproduce. Electrical power is not sound; it resembles it only in that the two vary—in time and in intensity—in the same way.

The variations in air pressure that we perceive as sound actually are tiny. The trick is not so much in building a device that will produce these variations as in making one that will translate electrical power into mechanical energy and mechanical energy into radiating waves of air-pressure variation without losing too much in the translation. A loudspeaker is hence not just a transducer, but an electro-mechano-acoustic transducer.

The most common motive force for accomplishing the two transformations—the speaker that has dominated every form of sound reproduction since its invention in 1925—is electrodynamic. The basic plan of this workhorse of modern communications is sketched in the first drawing. A coil, the "voice coil," is suspended near a strong magnet; the coil is firmly attached to a broad cone or diaphragm. (There has been a good deal of experimentation with flat diaphragms recently, though cones are used in the vast majority of speakers.) The diaphragm is free to move a short distance back and forth. When the pulsating power from the amplifier is fed through the voice coil, the coil will be pushed back and forth along its axis by the magnet, in step with the pulsations of the electricity. The cone follows and pulsates against the air. The resulting air-pressure waves travel out in all directions, reaching a listener's ear at a speed of about eleven hundred feet per second. They therefore take about one-hundredth of a second to cross the ten feet of an average living room.

The relation between electricity, magnetism, and mechanical motion used here is a fact of nature: the basis for the millions—or perhaps billions—of electrical motors that make our civilization go. And a reasonably good dynamic transducer is inexpensive, rugged, and a cinch to design, does a solid, no-nonsense job, and has enough fidelity to make highly acceptable music in many situations. These easily attainable virtues explain why the dynamic speakers have had such a hold on sound reproduction for so long.

Good Is Not Enough

When we want the speaker to reproduce the *entire* musical range, including lowest bass and highest

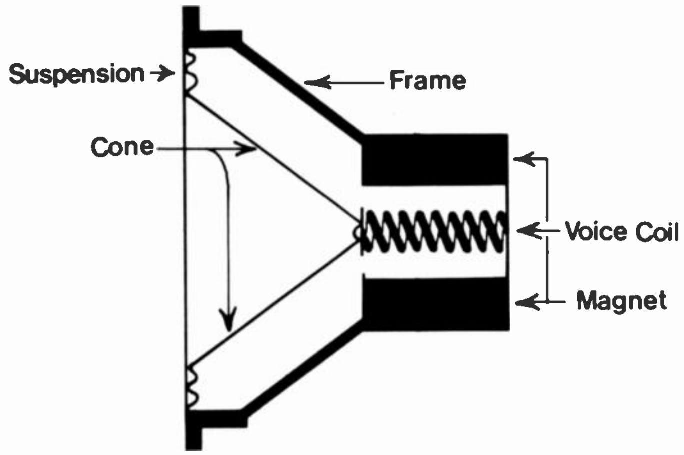


Diagram of basic operating parts in dynamic speaker.

overtones and with distortion so low it is not perceptible in the most careful listening, the weaknesses of the dynamic speaker crowd in upon us. In one sense, all speaker developments of the last several decades have been attempts to overcome these weaknesses, and we can survey the field rapidly by considering each of the main weaknesses and the remedies devised.

Speakers fall from high fidelity grace for three main reasons: failure to reproduce the low bass and high overtones; *unevenness* of action through the range, with some frequencies sharply overemphasized ("peaks"), or whole ranges out of balance with others; and harmonic and intermodulation distortion that blurs the sound by altering the input wave forms.

It is obvious what a lack of low bass does to the music: low organ, drum, or tuba notes, for example, will be much weaker than they should be or missing altogether. Weakness of high overtones makes the music sound soft or muffled—lacking in natural sharpness and bite.

Peaks, a besetting sin of speakers, should be discussed along with high and low weakness, because design approaches to the two sets of problems usually are interdependent. Peaks in the bass lend the music a boomy, "one-note" quality; peaks in the mid-frequencies make it "honky" or hornlike; peaks in the highs make it too sharp, harsh, hard, or scratchy.

Distortion also contributes to boomy, false-sounding bass by adding harmonics—the artificial "doubling" of the fundamental frequency fed into the speaker coil, producing audible output one or even two octaves above the fundamental. And this is not the only kind of distortion that afflicts loudspeakers. The means for reducing distortion are as various as its causes, but the success of each depends in large part on how well integrated the overall design is. For example, larger magnet structures tend to reduce distortion by providing a firmer "grip" on the voice coil (that's one reason why so many speaker ads mention a "heavy magnet"), but a hefty magnet *alone* is by no means a guarantee that distortion will be low.

Always keep in mind that one grand "feature" does not a fine speaker make. Any high fidelity speaker is a very complex mechanism, and successful design means handling a hundred interacting factors. No matter how brilliantly the designer may handle some factors (or how brilliantly his ad writers may describe his handling), his failings elsewhere can be all too audible.

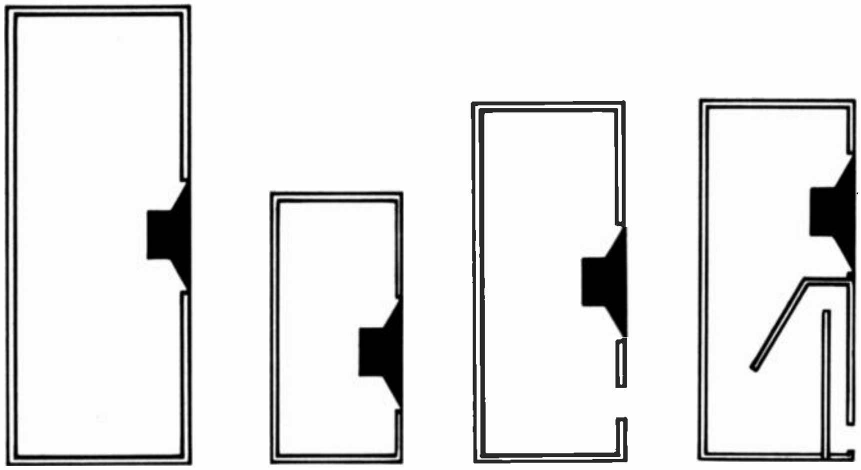
In Search of Big Bass

The output of a dynamic speaker tends to fall off in the low bass for several reasons. A cone of moderate size gradually loses its "grip" on the air as the frequency goes down the scale. This effect can be postponed by making the cone larger, but not eliminated within the audible range for a cone of any feasible size. It can be offset, too, by making the cone "pump" over a greater distance (its "excursion") for lower notes, and this is the approach taken in most of the better bass systems today. Speakers that can move very far have come to be known as "long-throw" types, meaning that the suspension they have allows the cone to move widely without significant restraint.

The question of the best cone size is fairly complex. Generally speaking a good bass speaker—often called a "woofer" or a bass "driver"—must be ten to twelve inches across, because of the air-gripping problem. Making the bass cone extremely large—drivers two feet across and even larger have been built—while it does improve the low-bass "air grip," raises other problems. Such speakers can be used for a narrow range of frequencies only, because they are likely to be poor at handling the mid-bass and higher frequencies. They are very expensive and take up a lot of room, especially if they require extra drivers to handle the mid-bass. For these and other reasons, it is more convenient to use only moderately big speakers with a greater throw.

One important reason why very big cones are not recommended for mid-bass and middles is "cone breakup," a general and most serious difficulty for all dynamic speakers. When a cone made of a thin, flexible material is pushed at its apex and held at the outer edge, it will tend to ripple and bend during vibration, rather than pulsate as a single surface. Such ripples introduce peaks into the music, giving it the false color of honk or harshness, or a tendency to cling to one particular note. Breakup is kept reasonably low in a good driver, but the larger the cone, the more difficult this is to do. It may prove impossible when the cone also is called on for mid-bass and middle frequencies.

Three other general facts about bass action in



Infinite baffle (left) is sealed enclosure large enough to prevent trapped air from affecting cone motion. Relatively small air-suspension system next to it uses trapped air as "spring" to control cone motion. Ported systems (the two at right) come in wide variety of configurations; that without duct is conventional bass reflex, that at far right represents labyrinth or transmission-line loading of back wave.

cone speakers must be borne in mind. The first is the necessity for separating the bass sound produced by the back surface of the speaker from that produced by the front. These two tend to cancel each other if they mix, because they are "out of phase"—the cone obviously *pushes* the air in front while *pulling* that in back. So the air pressure is raised in front while it's being lowered at the back and vice versa. A speaker is said to be "baffled" or "in a baffle," when front and back waves are separated by the enclosure.

Another important fact is the "bass resonance." It is an inherent characteristic of every mechanical device having both mass and elasticity to have a resonance—a frequency of natural vibration. The whole-cone or bass resonance in a cone speaker is most important because, with minor amendment, it is the bottom of the speaker's response range. Below the resonance, speaker action falls off sharply. Unless remedial measures are applied a note at the bass-resonance frequency will be exaggerated, boomy, and distorted. In typical cone speakers, the resonance usually is somewhere between about 25 and 150 Hz. The heavier the cone and voice coil, or the "floppier"—more yielding—the flexible suspension, the lower the resonance.

And finally, the box in which the speaker is mounted affects bass performance fundamentally, particularly in its effect on bass resonance, but in other ways too. In a comparatively small box the trapped air, pressing against the back of the cone, stiffens cone action and raises the resonance. This may be used in a positive way, as we'll see in a moment.

Let's run through the main dynamic bass systems now offered to the speaker buyer.

Infinite baffle. This is a very large box, or a wall with the speaker mounted in it, the back being open into the adjoining room. The idea is to give the energy from the back surface of the cone "infinite" space to radiate into, at the same time effectively preventing any mixing of the back wave with that from the front surface. For a twelve-inch speaker, such a box should have six to eight cubic feet of interior volume—the more the better. Sound-absorbing material inside the box helps to make it "neutral"; that is, prevents internal reflections that can "color" the sound. The result can be very good with a naturally excellent speaker, but the mounting as such does not substantially improve bass performance in the resonance region, as the next system does.

Bass reflex or vented. For a long time the most popular high fidelity bass speaker mounting, this one keeps coming back in one new form or another. Ducted-port or "phase-reversal" systems use this principle. In its simplest form an opening in the front of the box is dimensioned precisely so that the box becomes an open "tuned column" a little like an organ pipe. With the box tuned to the driver's bass resonance frequency, there are some good results. First, the resonance is thoroughly tamed—smoothed out, making tones near it solid and clear rather than boomy and distorted—and cone breakup is greatly reduced. Second, though the bass notes coming from the back of the speaker via the opening are out of phase with those from the front in the resonant-frequency range (and hence control the resonant peak), those a bit above this range are in phase as they come out of the port, so they reinforce the bass directly from the speaker.

When the bass reflex principle first "arrived" about thirty years ago, it made such an improvement in the bass that it seemed a miracle. But its weakness is that, below the resonance, the response falls off even more rapidly than it does without the tuned box. Some of the newer systems are significantly better in this respect. In some speakers the duct is shaped in such a way as to act like a "velocity transformer" for reinforcement of the deep bass. (The speakers are called Venturi after the principle on which the design is based.) Some designers use an array of holes for the opening, which introduces an "air resistance" or filtering effect for additional smoothing. Others use a large vent covered by what looks like another speaker cone—often called a "passive radiator." Its flexible edge design, similar to that of the woofer itself, allows this "seal" to vibrate in response to the motion of air within the box. But the physical properties of this otherwise undriven cone are chosen—again, according to a complex of interrelated variables—so that its "loading" will smooth response of the driven speaker in the resonance range, while its own motion will reinforce the sound from the driven speaker at other frequencies.

The meaning of all this for the prospective speaker buyer is that he must learn to listen critically to the low bass. When you shop take along an organ record with a passage that goes up and down the pedal notes, hitting all or most of them, not just one or two. (I like the Bach D minor Fugue, as recorded by Biggs on Columbia KM 30648, for this purpose.) This is vital for judging *any* bass system. Listen to the record on what you know is a superb system, noting that the pedal notes are all there, well differentiated and approximately equal in strength with no tendency to wide skips (octave jumps) in the scale. Try for the same result in any speaker you are considering.

Rear loading. In this design, also more than thirty years old, an internal tuned tube attached to the back of the speaker is crammed with sound-absorbing material. This does more smoothing, over a wider range, than the conventional bass reflex type.

A recent resurgence of the idea has borne interesting fruit (particularly among European manufacturers) in what are known as the "transmission-line" systems. Similar to bass-reflex designs in basic description, they use the port-and-duct system specifically as a way of loading the bass driver to control resonance properties, rather than to convert some of the back wave to front-radiated sound to "help" the front wave—a key aim of conventional bass-reflex designs. A correctly designed transmission line can produce very clean, tight bass.

Aperiodic. This very recent approach aims in a sense at the opposite of the bass reflex and is capable of putting excellent bass into small boxes. The objective is to produce a box-speaker combination that has no resonance in the bass at all, and fairly complex construction achieves this. Bass can be clean over a wide range.

Air suspension. This has become something close to the standard in the last decade and often is called acoustic suspension. Pioneered by Acoustic Research, it is used by dozens of speaker makers. The basic idea is simple: Using a speaker that is extremely floppy, for a very low bass resonance (say below 20 Hz), it is possible to use a relatively small box that raises the resonance to, say, 40 Hz. Advantage: The air in the box is now part of the "spring" in the cone. Over wide excursions, air is a much smoother spring than the plastic or paper suspensions used in dynamic speakers.

The result is extremely smooth, boomless response right down through the resonance and for some notes below. The air-suspension system revolutionized our expectations for bass that can be produced by boxes of three to four cubic feet and smaller. But the best air-suspension systems still are not perfect.

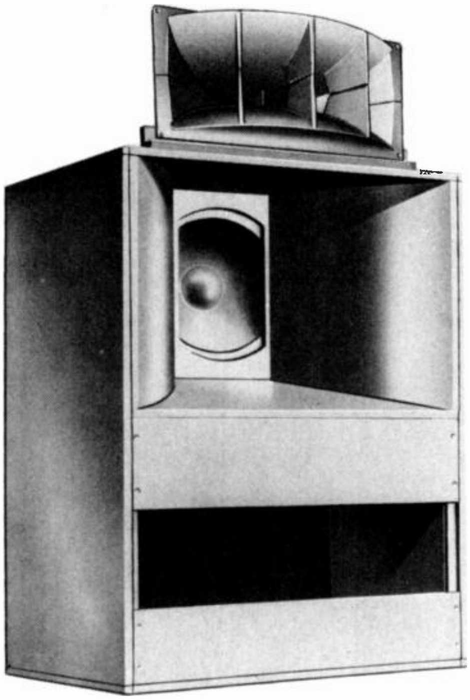
Slots, air couplers, and others. The pitfalls of going all out for just one big idea are devastatingly demonstrated by the remains of bass speaker systems dotted across the high fidelity landscape of the last several decades. We have had a parade of trick boxes that were going to bring hi-fi glory—enclosures with slits, slots, V-cuts, internal horns, "air couplers," and a lot more. Survival is the test; careful listening is the audiophile's way to assay survival value.

The horn. The horn is an idea that never dies. It has been used for music reproduction since Edison's day and was used with loudspeakers at the very beginning of electrical reproduction.

A horn can be added to any dynamic speaker; it's a question of making the throat (entry) big enough to accommodate the speaker. A horn does for a loudspeaker just what it does for a human voice: It provides a "grip" on a much larger volume of air than could be controlled without it and so greatly increases the volume of sound that any given effort will produce. As an engineer would say, the horn "matches the speaker to the air." The horn is, in short, an acoustic transformer.

This means that the speaker cone has to work much less (move a much shorter distance) to produce loudness, which in turn means lower distortion. In addition it needs less power from the amplifier, also making for lower distortion. Further, correct design of the horn will tame the bass resonance of the speaker for a firm, clean sound.

But horns are scarce in high fidelity today, for two main reasons. Every efficient horn has a bass cutoff, a note in the bass below which practically no sound comes through. The frequency of this cutoff depends on the dimensions of the horn. To get the bottom low enough to reproduce the whole bass range down to, say, 40 Hz—the horn has to be huge: 12 to 14 feet across the mouth (outlet) and 10 to 12 feet long. Second, even above the cutoff frequency a horn imposes peaks and valleys that color the sound—to give it a "horn character."



This Altec system uses horn loading both for tweeter (atop system) and woofer. Note port at bottom; horn loading can be used for back wave, front wave, or both.

The awkward size of bass horns often has led to their being folded: wound back and forth within the speaker box and open at the bottom or back or sides. The most successful of the bass-horn systems over the years is the Klipsch corner-horn speaker, which uses the walls of the room as extensions of the folded horn to increase its effective size. This system has survived for so many years because it does produce very solid bass of tremendous power.

Even with the recent, and striking, advances in bass-speaker design, a certain minimum of size—cone size, box size, magnet size—is needed for the lowest bass. If you buy a very small speaker, one cubic foot, for example, don't expect to hear the lowest one or two octaves. A very small speaker may be a valid choice if space and budget are limited, because music still can be enjoyable without that last octave, which is needed for only a handful of instruments and then only for the lower extreme of their ranges. A speaker that handles those extreme bass notes will have several times the size, and the price, of a one-footer.

The Trouble with Treble

The problems in high-frequency reproduction are, like those in the bass, getting good response at the extreme of its range and maintaining smoothness of response throughout the range. Peaks are especially distressing in the treble, because they make the music hard, sharp, offensive. And there is a new problem: directionality, or beaming, which is peculiar to the propagation of high frequencies.

Sound waves of about 500 Hz and below spread out almost equally in all directions, no matter how they are produced. But from about 2,000 Hz up, the sound tends to concentrate into a beam traveling straight out from the speaker and becoming progressively narrow as the frequency increases.

The aural effect of severe beaming of highs is this: The sound may be well balanced, with treble fully reproduced, for a listener directly in front of the speaker but may be seriously lacking in highs—muffled, dull—if he sits a little to one side. You can hear a distinct change in quality as you walk across the front of a beamy speaker.

There have been several remedies for beaming, and most of them can work well if properly handled. The smaller the cone, the less air beams at any given point in the scale; so very small "tweeters" (high-frequency drivers) are preferable on this count. Many systems use two or more tweeters pointed in different directions, which also can spread the highs. Everything else being equal, a dome tweeter has better "spread" than a cone. And a horn can be so shaped that it spreads the highs out widely.

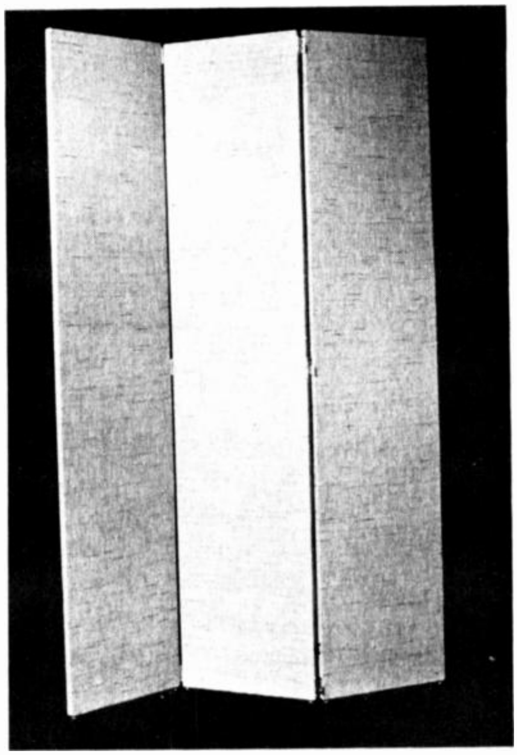
Successful dynamic tweeters have taken a variety of forms. The intimate complexities of the design—cone materials, magnet design, and a score more—are more important than the over-all configuration in keeping peaks low. Among the better tweeters, however, a fairly high proportion have been of the dome type.

Horns can be used with special drivers for the treble range. They help to spread the sound horizontally but may have more coloration than the best open-cone tweeters available as alternatives at around the same prices. A sensible approach for the prospective buyer is careful listening with an awareness that strong highs aren't necessarily pure highs.

Note that highs need spread only wide enough to cover the seating area, which means from about 90 to 150 degrees in most living rooms. If you hear roughly the same strength of highs wherever you sit, the design is a success on this score.

Great virtues have been claimed for omnidirectional speakers, which really means omnidirectional tweeters because the bass is omnidirectional in any case. There are many ways to achieve uniform propagation in all directions—in the horizontal plane at least—the most obvious probably being the use of separate tweeters facing in different directions. The highs projected toward the walls bounce back into the room a small fraction of a second behind the highs radiated directly from the

A number of recently introduced systems, like the Jans-Zen below, use electrostatic elements for higher frequencies plus conventional cone woofers. Full-range electrostatics must be relatively large in area and can look very much like the speaker at right—which is, however, the Magneplanar. It applies the electromagnetic principle to drive a large, flat diaphragm similar to that in a full-range electrostatic speaker.



speaker. This design does spread the highs well in the room, but it does not, as some proponents imply, create a concert-hall effect by having some highs reach the listener later than the highs directly from the speaker. The sense of space we get in a concert hall is produced by reverberations, delayed many times as much as the bounced sound in a living room. It is purely a question of distance: An echo may have to travel 150 extra feet or more in a large concert hall before it gets to the listener; in a moderate-sized living room the delay path seldom is more than a few yards. The effect on the listener's perceptions is totally different.

Nondynamic Speakers

Speakers need not be electrodynamic, of course. So far most nondynamic speakers have been more successful in producing high fidelity sound in the treble range than at very low frequencies.

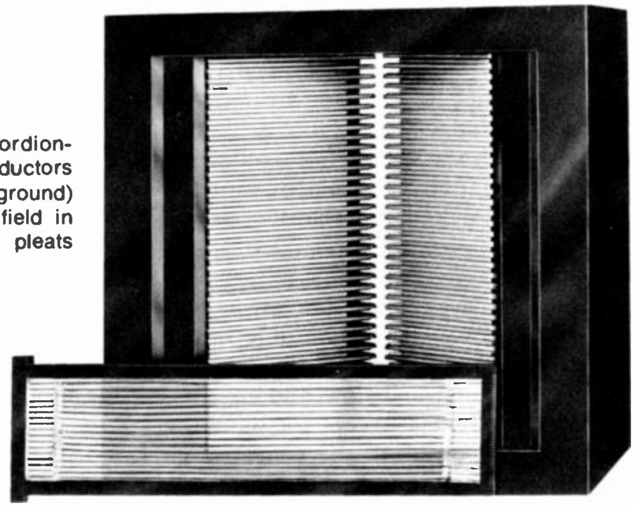
The electrostatic. By far the best known "other" speaker is the electrostatic, which is almost as old as the dynamic. It has had spurts of commercial success, including some use in theaters, especially in Europe. But it occupied a relatively small corner of the high fidelity scene until the last several years. We now are seeing a renaissance of the electrostatic in very large speaker systems, almost entirely as a means of covering the treble.

The "motor" in an electrodynamic, as described earlier, uses the reaction between a current-carrying coil and a magnet. The motor in an electrostatic uses a different relation between electricity and mechanical force: The attraction and repulsion between two conductive members carry the high voltages. If the voltages on the two conductors have the same polarity, they are pushed apart; if the voltages have opposite polarity, the two are pulled toward each other. The forces involved are proportional to the electrical charges of the members.

In the electrostatic speaker one member can be a fixed metal grid, the other a flexible, metalized plastic membrane. The fixed member must have openings to allow passage of the sound generated by the moving one, and there may be fixed members on both sides of the moving one. If high voltage, rising and falling to represent the music, is applied to the plastic member, it will be alternately attracted to and repulsed from the fixed grid, in step with the electrical pattern. So the flexible member acts as a diaphragm. The grid or grids are polarized by a constant electrostatic charge for the fluctuating charges to "work against."

The great advantage is that every point on the diaphragm is pushed equally, with no breakup like that in a conventional cone driven only at its apex. The diaphragm can be made to have very little mechanical resonance to further reduce peaks. Hence an electrostatic's sound *can* be extremely pure.

But the members have to be very close together if their electrostatic fields are to interact correctly, so



The ESS Air Motion Transformer has an accordion-pleated diaphragm (removed, foreground) with conductors running in folds. Large magnet structure (background) has pole pieces at center that focus magnetic field in conductors, alternately squeezing and opening pleats when alternating audio current is applied to it.

the diaphragm can't move far. Thus the bass is weak unless the diaphragm is very large—perhaps twenty square feet or more. For this reason only a few full-range (bass and treble) electrostatics have lately had much success, despite their inherently low distortion. And those whose response extends into the deep bass generally are both large and expensive—over $1,000.

Electrostatics are making more of an impact as the treble partners of cone bass speakers in a number of hybrid systems. The rationale of the hybrid is that you get the extreme purity of the electrostatic where it is needed most, in the mid-highs and highs, and the strength of the dynamic where that is needed, in the bass.

And it works well in a number of cases. Just keep in mind that the designer of such a system has to balance an unusual number of complex factors. Thus the fact that he is using the electrostatic-electrodynamic combination is not in itself a guarantee of excellence. It's rather the opposite, because more things can go wrong.

The Magneplanar. There is one type of speaker that closely resembles a full-range electrostatic without being one. The Magneplanar has long strip magnets within its panel-like construction, which is only an inch thick. The current from the amplifier follows a conductive path on a membrane comparable to the metalized plastic member in an electrostatic. But it is the interaction between the magnets and the magnetic field caused by the current in the conductive path (rather than electrostatic fields) that produces the necessary attract/repel action.

The design has more than mere physical resemblance in common with the big electrostatic panels, however. It also is relatively expensive and offers much the same virtues and limitations in terms of sound output. For example, the excursion distance is limited (for much the same reason as in electrostatics), again requiring compensation by an increase in the total radiating area (which is, in fact, the reason for the physical resemblance).

The Air Motion Transformer. Just in the last year a radically different kind of tweeter has appeared, to general applause: the Heil Air Motion Transformer, named for its inventor and built by ESS. The diaphragm of the speaker has deep vertical folds; on the sides of the folds are metalized strips that are in a strong magnetic field. With the current going back and forth through the strips, alternate pleats move toward each other, squeezing the air alternately toward the front and toward the rear.

It works well; highs are notably strong and free of distortion. At this writing, the design has become known as a tweeter for use with cone dynamics for the lows, but a full-range unit is said to be in the planning stage.

Perhaps I should point out that, to the extent that both the Magneplanar and the Air Motion Transformer still operate on the principle of an alternating current passed through a fixed magnetic field, they are comparable to conventional drivers. In the Heil design it is essentially the driven membrane and the way this membrane moves the air in contact with it that are different.

The Walsh driver. Even more like the conventional cone speaker is the Walsh driver used in some of Ohm Acoustics' speakers and, in modified form, as a tweeter by Infinity Systems. In turning electrical energy into mechanical energy, in fact, the Walsh driver uses the same elements as a conventional cone: a voice coil moving in the field of the speaker's magnet and driving a cone whose outer edge normally is connected to the speaker's superstructure by a compliant, airtight ring. But there the similarity ends.

The Walsh driver radiates from what would be the back of a conventional cone, and the cone faces vertically, rather than out into the room. Sound is produced not by air "held" within the moving cone, but by shock waves (so to speak) that travel from its apex to its outer edge. The cone material is chosen so that these waves will move diagonally along the surface of the cone with a speed whose horizontal vector is equal to the speed of sound moving in air; hence the wave in the cone stays in step with an ever-growing and ever-expanding cylindrically propagated sound wave in the air around the driver. The compliant edge serves more as damping to prevent the "shock wave" from reflecting back toward the apex (which would disrupt the neat formation of the cylindrical acoustic waves) than to allow the pumping motion inherent to a conventional woofer.

Ohm's speakers are large (and relatively expensive at present) and cover the full audible range, with the cone driven from the top. Infinity's tweeter is much smaller, is driven from below, and has a periphery that is unterminated except for damping material within the "mouth" of the cone—which doesn't function as its mouth, of course.

The sound from such a driver is said to be "coherent," meaning that the sound propagated in every direction is exactly in phase with that propagated in every other direction. This is not inherently true of conventional cones, whose back wave is out of phase with the front wave. But, as we've seen, the back wave can be thrown away (as it is in an infinite baffle system), suppressed (by damping material), or held back by what might be called an acoustic delay path (in a bass reflex system, for example) so that it emerges in phase with the front wave at certain frequencies and hence reinforces them.

In some systems—specifically, the Air Motion Transformer, the Magneplanar, and typical full-range electrostatics, as well as some "panel" speakers in which flat diaphragms are driven by conventional coil-and-magnet transducers—the sound radiated by the back of the speaker is identical to that from the front except in being out of phase with it. These are known as bi polar radiators. The sound from the back surface (half of the driver's total output) reflects from walls and furniture and back into the room, of course. What you hear will depend even more on the nature of the reflective surfaces with a bipolar speaker than with a conventional one.

It's a moot point, however, how the phase relationship between the front wave and the back wave will affect what you hear. Because of what is known as the "precedence effect," our perception of sound "locks onto" the direct radiation—which precedes the reflections, with their longer travel paths, in reaching the ear. Again, you must listen for yourself.

You must know what you're listening *for*, of course; and I hope this article will help you in that respect. With some practice you can train your ear to spot promising new directions and avoid dead ends in loudspeaker design. The general rules of testing speakers by ear are: have two or three recordings that are totally familiar (organ music and orchestra à la Strauss or Mahler are excellent); hear them on many kinds of speakers, including some of the very best; keep renewing your memory of how they sound. You will not only become expert, but also enjoy yourself in the process. ●

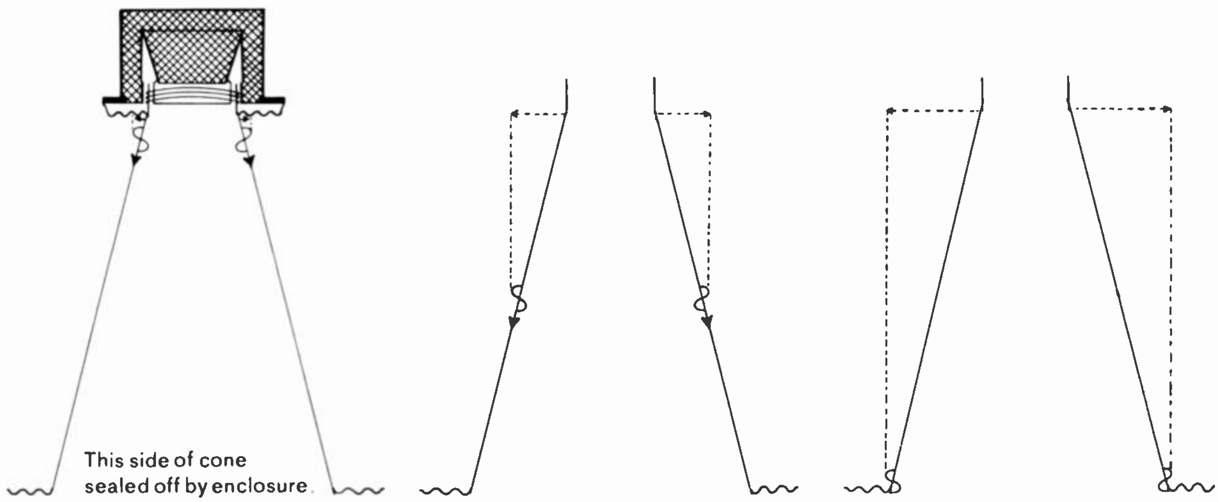
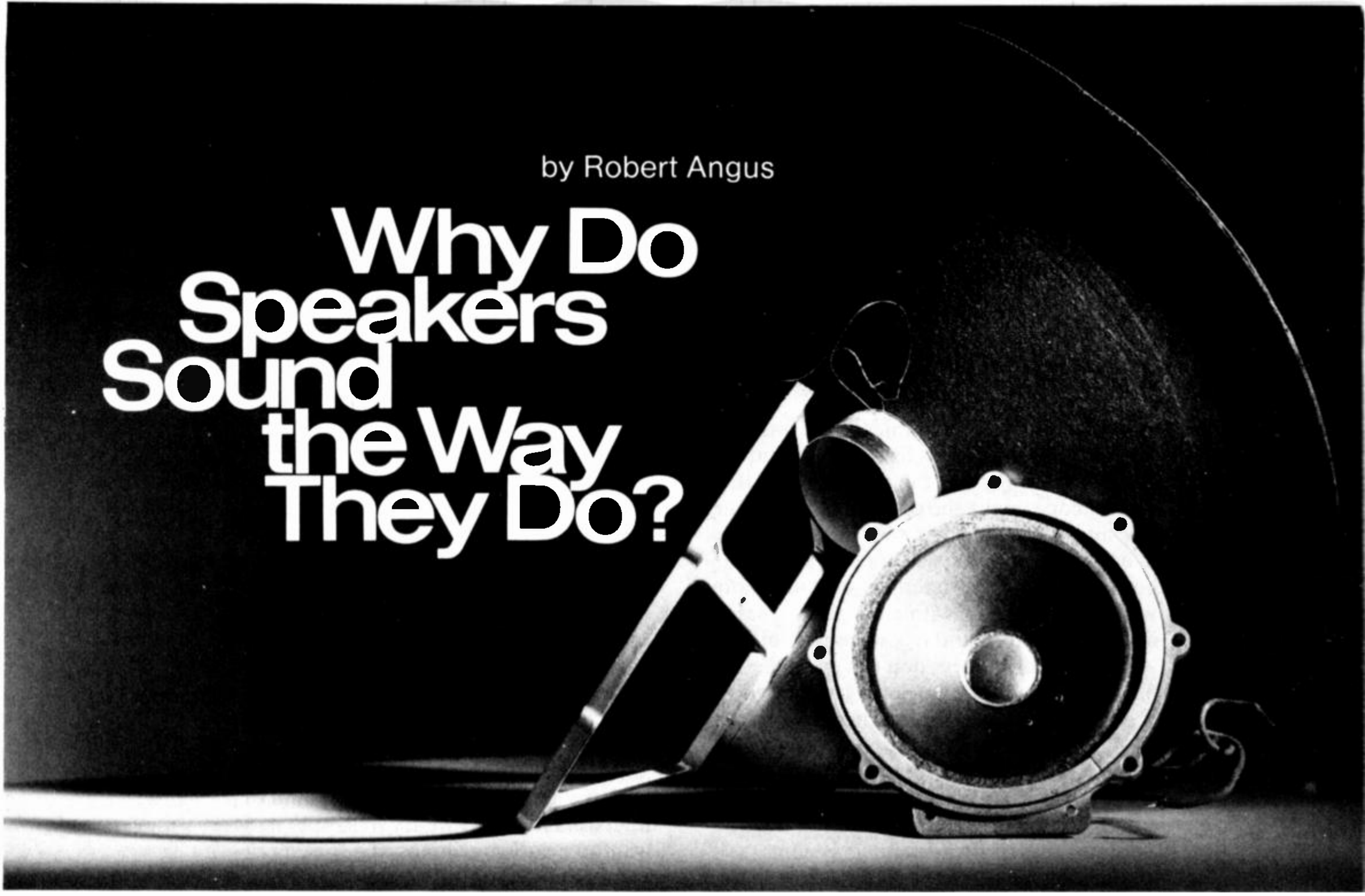


Diagram from Ohm Acoustics indicates how Walsh driver works. Conventional magnet-and-coil driver (top) produces wave in cone, which in turn excites air in contact with it. As wave moves down cone (second and third diagrams) it stays synchronized with acoustic wavefront (dotted vertical lines), progressively reinforcing it.



by Robert Angus

Why Do Speakers Sound the Way They Do?

In America, designers start with a goal—whether it's a new concept in sound reproduction or merely a desire to beat the competition.

PROBABLY NO OTHER component in the audio chain is subject to a mystique like that surrounding loudspeakers. The average audiophile may regard his cartridge or amplifier as an inanimate piece of hardware to be selected with little more care than in choosing a waffle iron or power lawnmower. But when it comes to loudspeakers, he's more likely to make his choice with all the care of a concert pianist selecting his Steinway for the evening. For some men, choosing a loudspeaker is almost as complicated as choosing a mate.

Perhaps that explains why there are at least ninety manufacturers of component high fidelity loudspeaker systems hard at work filling the almost insatiable demand for more speakers in the U.S. Last year Americans bought some $255 million worth of loudspeakers, and the industry expects to do better this year. At an average price of $100 per speaker system, that works out to about one stereo pair per year for each eighty families in the country.

With so many companies producing speaker systems, it's not at all surprising that there are differences in objective, basic philosophy, and technique as well as in the finished product. A physicist from Massachusetts Institute of Technology may start manufacturing loudspeakers to prove his theories about direct vs. reflected sound. A hi-fi dealer in southern California may start making speaker systems in the back of his shop because he thinks he can match the sound of a name brand at a fraction of the price. An audiophile on Long Island may start assembling speaker systems for friends who admire one he designed for himself. An audio engineer in southern New Jersey may simply want to see how good a speaker he can build for his own enjoyment.

All have different objectives, making generalization problematic. Particularly where new technology is involved (one thinks immediately of Ohm Acoustics and the Walsh driver, ESS and the Heil Air Motion Transformer, and similar projects), all rules of thumb go by the board. The loudspeaker industry has many fine craftsmen and more than a few visionaries, who may work in unique and even "unapproved" fashion.

But the vast majority of the speakers sold in this country are not the products of such offbeat efforts. Including both so-called private-label speakers—which account for a large and generally uninnovative portion of the market—and brand-name products, perhaps eighty per cent of the systems sold today are of conventional design: bookshelf systems or somewhat larger models that are similar in basic type. These models are the bread and butter of the American loudspeaker industry, and it is primarily the manufacturers and designers of such systems that I investigated in preparing this article.

Who's a Manufacturer?

Not all of the ninety-odd companies in the business actually make speaker systems from the ground up. Only a handful stamp or cast the metal baskets that hold a woofer cone, make the cone itself, create the voice coil, and fabricate their own magnets. The majority buy parts from outside suppliers. In some cases the "manufacturer" operates nothing more than a woodworking shop, with a few employees to install woofers, tweeters, and crossover networks in boxes. A few manufacturers don't even make the boxes but order them from a local cabinet shop. Some of the best names in the business buy tweeters from Peerless (a Danish supplier) or Matsushita, woofers from Jensen or Electro-Voice, and so on. Companies like CTS and Utah make drivers for other manufacturers and use only a small fraction of their output in their own branded systems.

Obviously some speaker companies have better facilities for designing and testing their products than others do. About twenty U.S. and foreign manufacturers have both scientifically designed listening rooms and their own anechoic chambers, permitting accurate evaluation of the systems they produce. In addition, another twenty or so have access to somebody else's anechoic chamber–perhaps a chamber at a nearby university engineering school or at an independent testing organization, or one maintained by a supplier. Actually some anechoic chambers are available, for an hourly fee, to anyone who wishes to use them. To that extent, any speaker manufacturer can lay claim to having "his" anechoic chamber.

Sound vs. Sales

In theory each designer is after the best sound he can possibly get in his speakers. But is he really? And just how close is it possible to come to the ideal?

Once I started talking frankly to speaker manufacturers, I discovered that the obvious goals are by no means universally accepted. "We're in business to sell loudspeakers," said the president of a large company. "We design speakers that sell." But in admitting that good sound is not the beginning and the end of loudspeaker design, he–and the other manufacturers I spoke to–declined to have his name, or that of his company, used in print.

One manufacturer of speakers that are sold under the "private" brands of several large audio chains in the East explained: "In order for a speaker to sell, it must sound exciting. The sound must excite the dealer, to persuade him to stock it in the first place; the salesman, so that he'll push it; and the customer when he first hears it, so he'll buy it." Translated into performance terms, this means a bass that booms and a peak in the upper midrange.

"Most people who go into a store are impressed by lots of bass and a bright midrange, so that's what we give them," he continued. "The bass has to be reasonably clean, but we emphasize all we've got. Then we add a boost in the midrange to make those frequencies sound brighter."

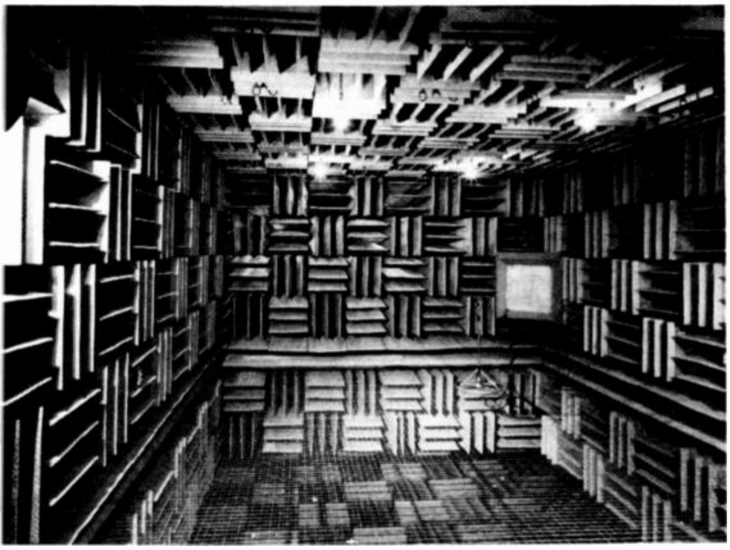
A small East Coast manufacturer of quality speakers said, "We live by reviews. We don't have the money for lots of advertising, and we're not in every store. So we have to depend on getting our products favorably reviewed by magazines."

Then does he tailor his product to please the ears of the reviewers? "Oh absolutely," he replied. "We read all of the reviews of other people's speakers and compare them carefully with the products until we have a pretty good idea what kind of sound the reviewers like, and we try to supply it. Most critics want to hear lots of highs. If a speaker doesn't have plenty of highs and isn't able to disperse them reasonably broadly, it'll draw bad reviews. I suppose you could say we're designing our product to please a very small–but very discerning–group of listeners.

"Is that so terrible? After all, these are supposed to be the most carefully trained . . . ears in the country. They act as proxy ears for hundreds of thousands of others around this country."

Although none of the speaker manufacturers I interviewed admitted doing so, several suggested that their competitors "soup up" speakers for the benefit of reviewers. "What Brand X sends out to the reviewers isn't what they sell to their customers," was the general feeling. "They hand-make a few units strictly for the critics." (The interesting thing about the comments is that the same brand was never cited twice as an example.) Reviewers seem to have suspicions as well, though I know of no instance in which an equipment critic was able to prove that his sample had been tampered with.

More to the point is the manufacturer who produces a sensational-sounding speaker and wins raves from the critics but later changes the ingredients inside his box. Most good loudspeaker systems remain on the market for several years, during which time the ingredients used in them change–due to rising costs, unavailability of some parts, or perhaps an improvement by the designer. As a result, some audiophiles are discovering that, when they upgrade a stereo system to quadriphonics, the XYZ-4 bookshelf speakers they buy today don't sound exactly like the XYZ-4s they bought in 1970.



Though it is an important technical tool, not all speaker manufacturers have an anechoic chamber. This is E-V's.

In most cases, the changes represent improvements—at least in the mind of the manufacturer. Sometimes, however, he may keep ahead of rising costs and the rest by using cheaper woofers, tweeters, and crossovers or by changing the construction of the cabinet in a way that affects bass response. But the manufacturer may continue to hand out reprints of a review praising his original speaker system.

Yet another nonmusical consideration in loudspeaker design is what might be called regional taste. Although most of the companies doing business in the U.S. claim their products are available nationally, many confine their sales mainly to one geographic region. Several factors can be involved: Bulky speakers are expensive to ship over long distances; a good sales force may be available in one area but not in another; purchasers themselves may display preferences in sound.

One speaker manufacturer confessed to tailoring his product primarily for the New York City market. "They like lots of bass in New York, so we give it to 'em," he said. "Every time we introduce a new speaker, one of our New York dealers asks if we can't do something to beef up the bass—and we usually do."

The chief product engineer for another major manufacturer said, "I design speakers that sound good to me. We do most of the things other people do—check frequency response, dispersion, and the rest; and we invite listening panels to evaluate the speakers. But if a system doesn't sound good to me, it usually doesn't get as far as the listening panel. If it did, and if the panel liked it while I still didn't, it wouldn't be put on the market." The engineer, a regular concertgoer, said his goal "is to design a speaker that sounds as much like what I hear in the concert hall as I can make it—for a price."

Still another approach is taken by another producer of private-label loudspeakers. "There's my 'JBL L-100' model," he said, pointing out a system. "And here's our 'Dyna A-25.' Over there's our 'Advent.' "

I asked if he seriously meant to imply that each of these Brand X speakers was intended to compete directly with the name-brand model. "Listen for yourself," he suggested, setting up a direct comparison between his "Advent" and the real thing. "You'll hear the same bass qualities. And our midrange matches theirs, note for note. The only difference is that ours is $30 less."

Speaker design in this factory, he said, involves buying a best-selling speaker and pulling it apart to find out what's inside. He explained, "If the box measures 11¼ by 10 by 20 inches, we build a box 11¼ by 10 by 20. If there's a 10-inch woofer inside, we put in a 10-inch woofer. We match the tweeter and the over-all construction. Then we listen to see how close we came to the original sound." If there are differences, the president of the company (who is not an engineer) makes whatever alterations may be necessary to produce a fuller bass, tone down a squawky tweeter, or jack up a sagging midrange.

Back to the Sounding Board

But that still leaves a handful of companies that are serious about designing a musical instrument. Said the chief engineer for one of these: "Price always is a factor. I can make the most marvelous-sounding speaker you ever heard. But it'll cost you $1,200, and it may stand eight feet high. We're more likely to start out with the intention of making a speaker to sell for $99 or one of a certain size—or both. So I begin by trying to figure what ingredients I can put into a box that size or how much I can *afford* to put in. Because the laws of physics apply to loudspeaker design, once we've set the size of the box, a number of other decisions have been made for me. If it's a small box, I'm limited in how much bass I can get from it. If I use a speaker with a very heavy magnet, then I need a thicker wood for the box. And so on."

Actually the list of variables in speaker design is almost endless. A single loudspeaker in a simple bookshelf enclosure can produce satisfactory sound reproduction at very low cost, free from such problems as the need for crossover networks or matching of two or more speakers. But what type of speaker?

As any audiophile knows, it takes a large heavy cone moving comparatively slowly to provide rich, full bass. Such a speaker requires a fair amount of power to drive. And try as it might, it simply can't reproduce treble tones—those in the range from 4,500 Hz up. For that, you need a small, lightweight cone moving at high speed. The more conscientious speaker designers shop as carefully for these ingredients as the chef of a fancy restaurant does for green vegetables or prime cuts of meat.

Using a two-way or three-way may simplify some problems of selection, but it also multiplies others. Drivers must be matched not only in frequency response, but in efficiency as well—and very carefully. A treble reproducer that's more efficient than the woofer can produce a forward or bright sound—considered desirable under some circumstances, undesirable under others. If the woofer's response curve drops off before the tweeter really gets rolling, there's a gap in the midrange. Adding a midrange driver may help, but as one designer commented, "Each time you introduce a crossover network, you face problems with phase and intermodulation distortion."

"Actually, some sixty-five per cent of all the music occurs in the midrange—roughly from 500 to 5,000 Hz," observed another designer. "That's why it's so important to make sure that there are a minimum of complications here. Everybody hears it when you goof."

He noted that most two-way systems cross over somewhere within this range. "That's why I much prefer to design a three-way system. It avoids the problems," he said.

He observed that the tweeter handles only about fifteen per cent of the music "and thus can have a low power-handling capacity. The woofer handles the remaining twenty per cent, but because the electromagnetic system and cone must work so much harder, they're usually of heavier construction, with greater power-handling capability."

Let's suppose the designer has elected to build a three-way speaker in a standard bookshelf enclosure, approximately two cubic feet in size. His first attempt sounds fairly good in the midrange and treble, but the bass leaves something to be desired. This is a typical situation. According to the textbooks he can (1) use a bigger woofer, but that requires a bigger box; (2) use the same woofer in a bigger box; or (3) increase the stiffness and mass of the woofer cone. An alternate version of the third solution involves sealing the box so that the speaker cone rides on a cushion of air trapped inside. This is the principle used in the acoustic suspension loudspeaker to obtain good bass response from a small box.

Each of these options implies changes in cost as well as performance. If the enclosure size is to be increased, for example, woodworking costs go up and must be offset by a saving somewhere else. Perhaps using a different tweeter will result in a simpler crossover design without seriously altering performance. But if the selling price has been decided, the designer must juggle costs as well as electrical and acoustic performance factors while he works. And that juggling act is basically what loudspeaker design is all about.

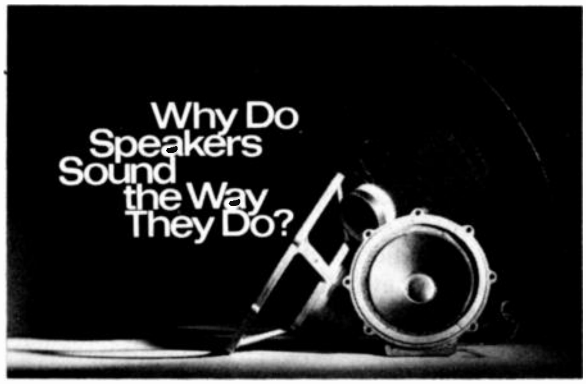
Not all of the choices involve serious cost factors, however. In choosing just the right tweeter, for instance, the designer must consider that the harder the cone, the more efficient the speaker and the brighter the over-all sound seems to be. A cone that's too hard sounds shrill (or is said by engineers to be crying). A soft cone has a tendency to absorb high frequencies, making them subtler and the tweeter less efficient. The trick is to find one that will match the sound in the rest of the system.

As we've noted previously, while some manufacturers actually produce their own drivers—or at least their own paper cones and suspensions—a large number buy ready-made tweeters, woofers, and crossover networks from outside suppliers. If many designs use the same driver—say, the Peerless tweeter—don't the finished systems tend to sound alike? The answer, surprisingly, is no. One characteristic common to all bookshelf systems using Peerless tweeters is very wide treble dispersion. But some Peerless-equipped systems seem to have very bright highs, while others seem subdued. The reason: The balance achieved between each of the elements in the system affects its over-all sound. An overprominent woofer, for example, or a system in which the tweeter and midrange overlap, tends to make the highs seem softer and more diffuse.

"We've been using speakers from an outside supplier since we've been in business," a producer of brand-name speakers told me. "They're quality units, made by a quality source. But they differ in sound characteristics by as much as 1 to 2 dB. We match ours within ½ dB, so that a customer buying a pair won't hear any difference between them. But another manufacturer buying from the same supplier and putting the same tweeter into a system similar to ours could get a different sound."

When all is said, the biggest differences in the processes by which various speaker systems evolve stem from disparities between the premises on which the products are planned. Some designers begin with an abstract concept, like omnidirectional radiation, and explore the means toward this end with little (initial) regard to costs. Others begin with a successful system (say, the AR-3a) and look for ways of beating it at its own game, so to speak—perhaps by shaving $50 from the cost or by increasing its efficiency. Obviously the variations are endless.

Once the premise is established, there follows a complex process of selection, compromise, and evaluation to reconcile opposing forces of cost, physical design, and acoustic performance. Some designers establish and pursue the realization of their objectives with the perfectionism of an Antonio Stradivari. When a real craftsman is in charge, the result can indeed be compared to a fine violin; the surprising thing is that, even with an amateur or a cost accountant at the helm, the results are successful as often as they are.



by Hideo Eguchi

In Japan, a listening panel often decides on the final sound.

Over the past few years HIGH FIDELITY has become increasingly aware that Japanese speaker designers have been using computers and statistical-analysis techniques in ways almost unheard-of in the West.

One paper from the Acoustic Research Laboratory of Matsushita Electric Industrial Co. Ltd. (Panasonic) in Osaka, for example, described the collection of data on several sound sources using a panel of ten girls from the factory (presumably chosen on the basis of hearing acuity) and applying a methodology worked out in previous tests with scores of subjects and sound sources. The girls were asked to make value judgments on each of three speakers, presented only two at a time, in terms of ten "bipolar" pairs of adjectives (bright/dark, clear/unclear, etc.) selected from among hundreds of Japanese adjectives on the basis of the previous tests. The girls' preferences in each pair of sounds, and with respect to whatever adjective-pair they were asked to apply, were registered on punched tape and the results collated by computer.

While these particular tests concerned themselves primarily with the over-all sound of the speakers in question and were unrelated to technical performance characteristics as such, tests carried out at the Toshiba Research and Development Center sought to analyze actual performance factors as well as those associated with aural perception. An article published in 1971 by one member of the research team said the company's total listening panel consisted of 644 persons, though in one group of tests only nine (presumably handpicked) members were used and the data for only the five "most reliable" were collated.

Closer to home, U.S. Pioneer has told us something of the research that it did on American audiophiles' tastes and preferences before making some of the final design decisions on the R series of loudspeakers. This seemed particularly significant because of the snide attitude that some have taken toward the Japanese statistical approach, apparently believing that Japanese speakers were built "for Japanese factory girls—not American music lovers."

Obviously a lot more is involved than simply whether a group of Japanese factory workers happens to like or dislike a given speaker. So for this special speaker section we have asked our Japanese correspondent to fill us in on just how and why manufacturers are using group listening tests and statistical analysis as design tools in Japan. He surveyed the field, and this is what he found.—ROBERT LONG

IT WOULD BE no exaggeration to say that through the years fifty million Japanese have lent their ears to help their country's audio industry improve its loudspeakers.

In Japan during the early days of hi-fi, when the term was misread as "high fee" at Tokyo's famed Akihabara radio center, scores of open-front stores were offering raw speaker units (and separate enclosures) at I-can-get-it-for-you-wholesale prices without the national commodity tax. Invariably these driver units were demonstrated at each stall through a horn enclosure made out of an upended soapbox with a speaker opening cut into the top, rather than the front. In this way, would-be purchasers could compare the sound of different brands as the retailer placed each unit over the hole, with the cone looking into the box.

In upgrading to the high fidelity speaker system that we know today, it became obvious to the Japanese manufacturers that the Akihabara soapbox could no longer be used for consumer listening tests. But it has been possible, from the beginning, to classify Japanese manufacturers of high fidelity speaker units and systems into several highly competitive groups. And, as it happens, these classifications are closely related to the way the manufacturers use statistical analysis today and to the extent to which they incorporate the results of group consumer listening tests into commercial design.

The Specialists. . .

The most competitive group consists of the manufacturers who first established themselves as mass producers of loudspeakers. Among them are Pioneer and Onkyo, which is now a Toshiba subsidiary. Both companies have helped put group listening tests to direct use in high fidelity speaker-system design.

Pioneer makes constant use of three distinct listening groups in evaluating the cost-performance of each new prototype. "Blindfold" tests pit two competitive brands of speaker system (typically, American Brand X and Japanese Brand A) against Pioneer's own, using each of the three listening groups. In addition, Pioneer uses up to three different sources of sound (perhaps a phonograph record, a music tape, and a live performance) for comparison. There also are three kinds of music used: say, symphonic, international popular, and Japanese rock.

The first listening group is usually composed of Japanese consumers whose names are listed at the Pioneer Audio Specialty Stores (PASS) as buyers of the manufacturer's products. The second group includes interested Japanese distributors and retailers of the company's high fidelity speaker systems. Last but not least, Pioneer has its own listening committee of twelve or thirteen members representing all sections of its speaker manufacturing and marketing divisions. The hearing characteristics of each member of the committee are analyzed and the information used for evaluating the results of tests in conjunction with all other technical data. The consumer-group listening tests usually are conducted in a hotel room whose acoustics have been measured.

The Giants. . .

At the start of the high fidelity boom in Japan (the Japan Audio Society held its first annual fair in 1952), loudspeaker manufacturers found themselves competing against household electrical appliance manufacturers, including Matsushita (National/Panasonic), Mitsubishi (MGA), Sanyo, Sharp, Toshiba, and—more recently—Hitachi. Generally speaking, the electrical giants became involved in the manufacture of high fidelity speakers because they already produced audio equipment for the broadcasting industry. The heavy electrical manufacturers like Hitachi, Mitsubishi, and Toshiba have been working with the General Research Laboratory of the Nippon Hoso Kyokai (NHK)—Japan's counterpart of the British Broadcasting Corporation (BBC)—in the field of sound reproduction. They maintain central research laboratories equipped with sophisticated testing apparatus.

These manufacturers have greatly expanded their mailing lists of consumers available for group listening tests, while NHK maintains a list of close to 25,000,000 households paying the mandatory radio/TV receiving fee. The light electrical manufacturers like Matsushita, Sanyo, and Sharp have a firmly established place in the consumer market through their sales of major appliances and TV receivers.

Besides conducting consumer-group listening tests, the electrical manufacturers attract potential buyers of high fidelity speaker systems through their plush showrooms, where the products can be tested on the spot by the visitor. These showrooms serve as a source of statistical data. In terms of pure numbers, the Technics showroom in the Ginza Core building draws up to 25,000 visitors daily.

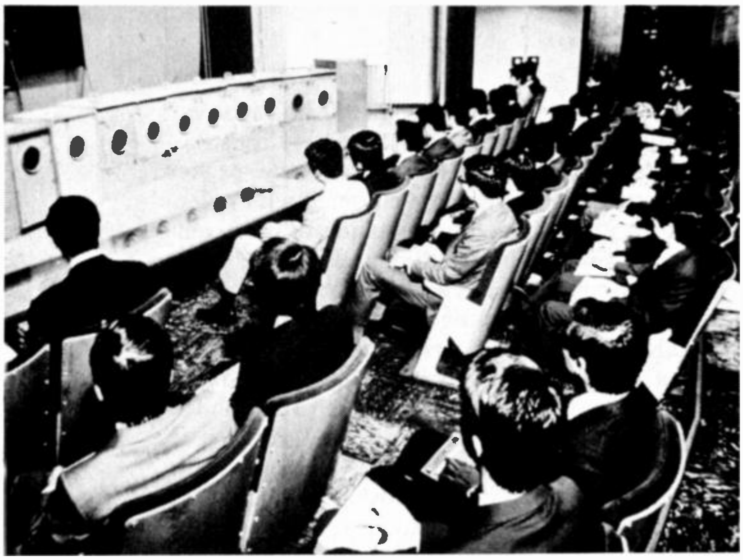
. . .And the In-Betweens

The speaker specialists and the electrical giants are, however, merely the extremes; there are many other companies between these extremes. Some started out as manufacturers of other components.

JVC is one example. In its audio research laboratory a computerized "sound quality evaluation system" records the data derived from blindfold listening tests by three separate groups. One listening panel includes thirty professionals; another is made up of twenty audio specialty dealers; the third comprises at least twelve consumers, though it also draws on JVC employees at the Yamato plant, where the lab is located.

Each of the twelve seats in the JVC listening room, whose acoustics are accurately known, is equipped with a pushbutton device; each listener can indicate his reaction to the sound quality of the speaker system under test. Thus the results of each phase of testing is immediately recorded on punched tape.

Nippon Columbia (best known to Japanese audiophiles under its Denon brand name) takes quite a different approach. It has long been engaged in the production of loudspeakers, but it does not use consumers in its group listening tests. Members of the company's recording division—as well as the design and production staff—monitor



Toshiba is among the companies using closely controlled group experiments to determine speaker-design criteria.

prototypes of its high fidelity speaker systems. Nippon Columbia does not believe that laymen can contribute significantly to the design of its speakers. It says that typical rooms—either Japanese or American—do not provide an appropriate environment for speaker tests, even though high fidelity systems may be designed to match the acoustics of such rooms. Comparisons of speaker systems in consumer group tests set up by distributors and retailers in "typical" rooms certainly cannot be considered objective, the company adds.

Though both JVC and Nippon Columbia today operate as subsidiaries of giant parents—Matsushita and Hitachi respectively—both carry out their loudspeaker programs independently. The engineers (understandably) prefer charting their own courses; but it should be pointed out that the objectives of the relatively small and specialized subsidiaries are not necessarily consistent with those of the giant, mass-market-oriented parents.

Competing against the Japanese manufacturers who started out with loudspeakers, the electrical giants, the audio-specialty manufacturers, and the two major phonograph record/music tape producers are at least two others: namely, Yamaha and Sony. The Yamaha brand of Nippon Gakki, the world's largest piano manufacturer and Japanese exporter/importer of musical instruments, was associated in the initial days of high fidelity with sets assembled from the leading brands of audio components. Yamaha's consumer-group listening tests have concentrated on the tastes of Japanese music lovers rather than dyed-in-the-wool audiophiles. But with Yamaha's unusual promotions at recent All-Japan Audio Fairs, where it has used two types of listening rooms, and its growing line of quality components, this situation is changing.

In testing its prototypes, Sony discovered that the reactions of consumer groups can be misleading because of the myriad subjective factors involved. Its "consumer group" for its listening tests, therefore, consists of employees, who can readily be checked out and replaced in the event that they prove to be unsuitable. Sony believes the consumer tests held by some of its competitors are more or less publicity stunts, with little or no technical value to the designer of high fidelity speaker systems. While its own designers believe there is room for further development of speaker systems, they are confident that such improvements can be made through careful evaluation of data derived from technical experiments and listening tests in the lab. Incidentally Foster—a name long associated with speakers in Japan and now a Sony subsidiary—is conducting separate consumer tests under its new brand name, Fostex.

Generally speaking, however, the use of statistical analysis in determining criteria of merit is of greater importance to those Japanese speaker manufacturers that are interested in capturing a broader and bigger domestic market for their products, and there is some question whether such an approach would be of equal use in exports.

Another Japanese manufacturing group has been producing speakers and drivers for U.S. audio-store chains and mail-order houses for sale under their own brand names. Manufacturers in this, the so-called OEM business, tend to "design" speakers and enclosures by listening to U.S. brands instead of evaluating them through purely technical means. These listening experts are compared with Japanese tea and wine tasters, and their number is a closely guarded secret. Not only are they reputed to identify each particular brand, but they can also presumably "taste" the kind of material used for the cone and "smell" the species of wood for the enclosure.

The Meaning of the Tests

Basically, therefore, the "ear, not gear" approach is common in different ways to all Japanese manufacturing groups. Where the group listening tests are used—and depending on the outcome of those tests—it may take up to two years before a prototype is finally approved for manufacture and/or for export. In certain cases, prototypes are made available to audio specialists for individual testing. For example, JVC distributes up to thirty samples for such listening tests. Other Japanese manufacturers invite audiophiles, picked on a random-sampling basis, to try out new models a few months before they are marketed. A questionnaire comes with each sample speaker system, and the replies usually are evaluated by the designer and other personnel.

Speakers have improved to the point where, some believe, the residual distortion in the system cannot immediately be detected by group listening tests. One Japanese audio specialist recently ventured the opinion that a really fine modern speaker system will reveal any distortion in the amplifier; a correctly matched speaker will sound distorted, for example, when a transistorized power amp driving it is unable to handle short, sudden peaks.

Although it may be of little value to conduct group listening tests for harmonic or other distortion in a high fidelity speaker system, or for its frequency response from various listening positions, such tests have been found essential for manufacturing products to suit the musical tastes, financial situations, and living quarters of different consumer groups. Such obvious differences cannot readily be ascertained by laboratory test equipment alone. Broadly speaking, Japanese speaker manufacturers are primarily interested in producing the most accurate possible speakers at any given price level; at the same time they actually are turning to models tailored to the immediate needs and expressed preferences of the music lover. In this respect, statistical analysis as a design technique probably will be extended in Japan to other items of audio equipment.

The group listening tests also take into account the important factor of the listening room. At the JVC and Sony audio research labs, there are Japanese-style and American/European listening rooms as well as music rooms for rock groups and studios for classical music. Modern Japanese houses and apartments of ferroconcrete construction present new acoustical problems to the speaker designer; the rooms often are cluttered with reflective objects and, by Western standards, are comparatively small. The traditional Japanese room has plaster-covered walls and wooden ceilings and thick straw mats covering the wooden floor. The walls also have sliding doors framing panels of thin glass or paper. There is no furniture to speak of. Consequently, the older Japanese audiophiles, many of them doctors or musicians, are used to listening in a comparatively "dead" room, while the younger Japanese music lovers have come to expect more of a live room sound.

Thus, in using statistical analysis to determine criteria of merit, a Japanese speaker designer still must make two distinctly different evaluations. He is aware, too, that the Japanese manufacturers face rising competition from American and European speakers, since these may tend to sound better in the new Japanese homes—apart from their highly competitive cost performance. So although the Japanese speaker designers have the most sophisticated facilities for testing their products and the greatest number of "guinea pigs" for their statistical analyses, these techniques by no means supply all of the guideposts necessary in determining the directions they must take.

This report may reinforce in the minds of some American readers the image of the Mysterious Orient. Obviously there are many marked differences between Japanese and American practice in both the design and the marketing of high fidelity products. Does this mean that there is a Mysterious-Oriental sound in speakers in the same sense that one can talk of the New England sound in bookshelf speakers or a West Coast sound in speakers of relatively high efficiency? We think not. As Mr. Eguchi's report makes plain, there is no unanimity of approach among Japanese speaker manufacturers, and even superficially similar means can be used for strikingly different purposes. And our experience of Japanese speakers themselves, while limited to export models, of course, confirms that each should be taken on its own merits.

There is one notable parallel between *some* American speaker designs (as explained by Mr. Angus in his article) and some Japanese designs (the Eguchi report): the attempt to tailor the sound to regional or national tastes. But American companies have not adopted the consumer-testing approach for that purpose. Is that approach, as the spokesman for one Japanese manufacturer said, largely a question of "publicity stunts"? The companies that use the approach have indeed demonstrated their awareness of the publicity value of these tests. At the same time the tests provide the manufacturers who conduct them with valuable information about the way in which typical listeners actually perceive the sounds they hear—why measurably similar speakers don't necessarily sound the same and why listeners can disagree so sharply about the relative merits of some loudspeaker traits or designs.

The fact that our patterns of perception are only imperfectly understood helps foster the mystique surrounding loudspeaker design referred to by Mr. Angus. It puts a premium on the "golden-eared expert" in loudspeaker design—not because his hearing is necessarily more accurate than that of others, but because his perceptions lead him to design speakers that will satisfy other users. In this sense, loudspeaker design remains—as it has been all along—more of an art than a science. Perhaps the Japanese will change that.—R.L.