Realism testing ◦ Diffraction unmystified ◦ Rx for cheap speakers

1/1980

SPEAKER BUILDER

US $3.00
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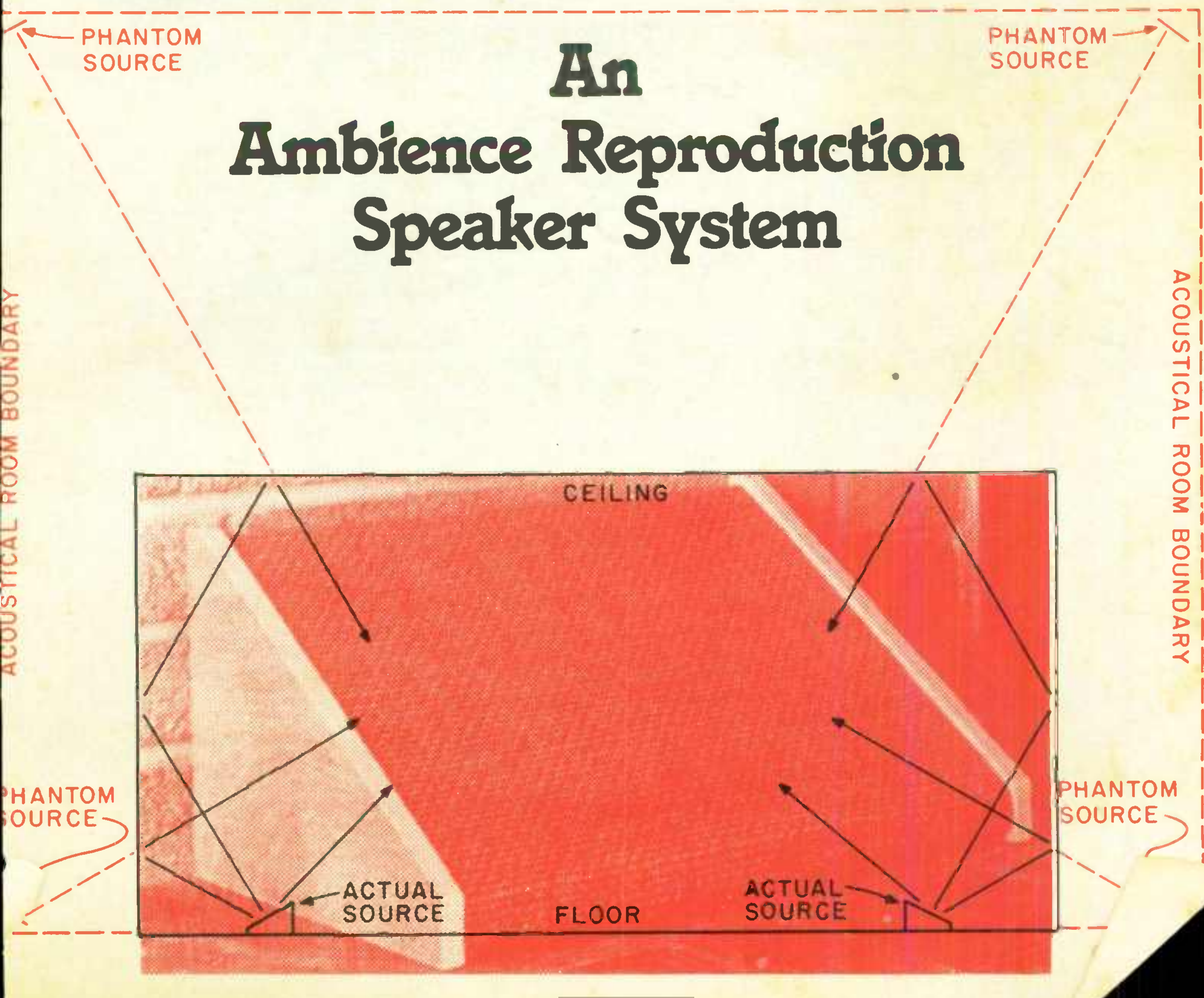
An Ambience Reproduction Speaker System



Good News

WOOD AND FINISHES, tools and veneers are basic to any serious speaker builder. We had never seen **Craftsman Wood Service Co.'s** catalog before it arrived a few days ago. Its 156 pages list a whole lot more for the woodworker than I had any idea was available. If you aim to build cabinetry yourself anytime soon I can't imagine you will want to get along without having this catalog handy for whatever you need. Tell them *Speaker Builder* magazine sent you. Craftsman Wood Service Company, 1735 W. Cortland Ct., Addison IL 60101.

IF YOU HAVE a new speaker system but no test gear yet, you may want to know about a good source of test gear for either short term rental—or to own. **Rag Enterprises** at 21418 Parthenis St., Canoga Park, CA 91305 (P.O. Box H, Eatontown NJ 07724 if you're in the East) offer new, used, reconditioned and rental test gear. They will rent with a purchase option as well. So if you're dying to know how your speakers are performing in your living room, you might consider renting appropriate gear for a month just to see how your system is doing. This list of prices and terms is available on request.

HARDLY ANYONE seems to stock more speakers—some seem orphans but no matter—than **McGee Radio & Electronics,** 1901 McGee St., Kansas City, MO. (816) 842-5092. They have a lot of other gear for sale too, of course. But I am sure that no one seriously interested in speakers and speaker building should be without their catalog. The bargains in all sorts of name-brands are genuine and well worth watching for. Tell them SB sent you.

Trusonic Speakers announce a series of auto speaker systems that include a three-way 120W unit with a five year warranty and a voice coil weighing 40 ounces. Kit systems for cars range from suggested retail of $90 to $150 per kit. The kits are said to be complete with grilles, crossovers, wire and even have removable jumpers in case the user prefers to bi-amp in his car. See your audio dealer.

A NEW 12 GAUGE sound cable from **DB Systems**, DBP-8 Speaker Wire,

minimizes loss of power and damping factor, and does not affect the frequency response of loudspeakers. Such considerations are especially important to systems utilizing 4 ohm speakers or runs of more than 20 feet. The heavy gauge wire is otherwise conventional dual conductor copper, with leads at both ends pre-tinned and cut to 16 gauge to easily fit any type of connector. As a convenience, solderless banana plugs are separately packaged for this purpose. DBP-8 Speaker Wire comes in 3, 6, and 9 meter lengths, which translates to 10, 20 and 30 ft.

WE'RE OFTEN ASKED where to find not only drivers, grille cloth, fiberglass and such other esoteric ingredients the avid speaker builder seeks but also where to find reliable information on speaker building. The **Speakerlab** people (P.O. Box 15780, Dept. SB, Seattle, WA 98115) have about as comprehensive an offering of goodies as anyone around. They don't sell fiberglass—but they are remarkably cooperative in helping the builder with what he needs. Say you want to build a couple of large corner horns. Speakerlab will sell you anything from the complete kit, or drivers and a set of plans—or the plans alone if that's all you need. Their catalog tells you a lot about speakers and how they work—and how to put one together. It also, of course, showcases the

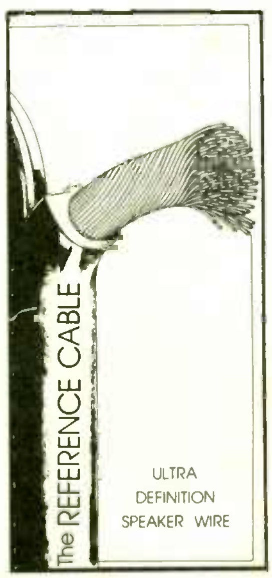
Speakerlab line of offerings but if offers more basic data at modest prices than we have seen elsewhere.

ANOTHER GREAT SOURCE of basic information, about theory most especially, is the interesting series of occasional papers published and distributed by **KEF Electronics, Ltd.** KEF are a British firm but unlike many British firms they are lively, imaginative, and extraordinarily innovative—even more so than the majority of US speaker manufacturers. Their publication, *Keftopics* is chock full of information about the basic rules governing the behavior of drivers in various sorts of enclosure. You will be glad, I am sure, that you asked to be put on their mailing list for these interesting publications. Send your request to: KEF Electronics, Ltd., c/o Intratec, Dept. E, P.O. Box 17414, Dulles International Airport, Washington, D.C. 20041.

Great America Companies, 2504 Freedom Drive, San Antonio, TX 78217 are manufacturing the first of a series of plastic cone drivers (the first made in the USA), an 8" woofer (8D12J1) which sports a 12 oz. ceramic magnet and a 1", four-layer voice coil. The specs on the unit supplied by the manufacturer show a response variation of approximately +7dB to −10dB over the 20Hz to 400Hz range. They argue that a plastic cone is superior to one made of paper (as most are) since it is not subject to humidity and temperature changes and does not deteriorate with age. Plastic cones have been viewed as a possible answer to the ideal cone design characteristic of stiffness which has not often been completely achieved in driver design. Great America says their driver is suitable for vented boxes or transmission lines in either two-way or three-way configuration. **SRC Audio** (3238 Towerwood Dr., Dallas, TX 75234) will, among others, stock the new driver. Great America have data sheets on request.

Gladstone Electronics offer Canadian speaker builders and audio buffs an excellent range of speaker kits and supplies including such names as Philips, Speakerkits, Peerless, JBL, KEF, Celestion and Decca. Indeed they stock a line of Philips kits that I have not seen readily available in the USA. Gladstone is willing, of course, to sell to customers south of the border. A card to 1736 Avenue Road, Toronto, Ont. Canada will put you on their list. They take MasterCharge, via telephone if you like, at 1 (416) 787-1448, but they are closed on Mondays. An interesting and different offering of supplies.

ULTRA DEFINITION is the name under which **Hartley Products** are marketing a 10 gauge wire for connecting speakers to their power amplifiers. They have a nice pamphlet on the subject with a series of spike and square wave oscillograms illustrating their reasons for considering their new speaker wire superior. Copies of the brochure, as well as information on their famous drivers are available by writing to 620 Island road, Dept. SB, Ramsey NJ 07446.



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SPEAKER BUILDER

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February
1980

SPEAKER BUILDER

EDITOR'S VIEW

WELCOME TO A NEW PUBLICATION and what I hope is a new era in audio craftsmanship. *Speaker Builder* is an extension of my original dream, conceived in the late sixties, that a significant growth in audio construction by amateurs would flourish and grow in the United States if a publication were offered to encourage it. By craftsmanship I do not mean mere do-it-yourself. The do-it-yourself movement appears to me to be "look at me I can really do it—and cheaper too." The prime impetus for do-it-yourself is saving money.

The sort of craftsmanship I am most interested in is one based in the love of doing the work and a knowledge of the inner workings and realities of the means of reproducing sound. This interest goes far deeper than many of the efforts of the commercial enterprises which manufacture the equipment people buy.

With that dream in mind I founded *The Audio Amateur* magazine in 1970, with a lot of help from friends. Ten years later, the magazine is a modest success and has, I believe, influenced and aided a growing movement among music lovers to find ways to make better equipment for reproducing music.

In 1970 the larger U. S. hi-fi magazines had turned away almost entirely from any technical articles of any kind and those they did publish were child's play.

The situation has altered radically in ten years. *Audio* has become a much more technical magazine and occasionally publishes fine construction projects. The electronics magazines stay with relatively simple projects for the most part—at least in audio matters—and follow whatever the fad of the moment may be, whether CB radio, computers and whatever will come next.

I am pleased that so many of you want to set out with us on this new journey into the special world of loudspeaker construction. I have high hopes that by giving special attention to the matter of speaker construction and design, we can find new answers to one of audio's most complex problems: how to get the sound back into the air again after storing it in an electronic form.

We will naturally be spending a lot of time on cabinets. Their design is the prime matter, but constructing them well and finishing them beautifully are also details to which we'll give much space.

Driver manufacturers are, happily, becoming more and more aware of the number of individuals who want to build their own speaker systems. They are sharing unprecedented amounts of information on the performance of their drivers and how to use and enclose them well. We will try to relay some of that information but also to provide articles showing the speaker builder how to make some types of speaker drivers for himself. Three sorts are prime candidates: the electrostatic, the air motion transformer developed by Oskar Heil (manufactured by ESS), and the Magneplanar-type speaker.

Not only do we want to explore new ground, but we will re-print some of the really valuable material which was published when the high fidelity movement was in its infancy. Some of the basic information about speaker behavior appeared over fifty years ago. We hope to begin that survey of the past by reprinting some excellent articles to give us all some perspective on what has been done and when.

Speaker Builder is primarily committed to helping you enjoy constructing the very best speaker system you can build for yourself. We will try to bring you accurate, authoritative information. But at the same time keep in mind that much of what is at issue about speakers is not a matter of scientific certainty. In these gray areas opinion prevails and people of high reputation disagree about quite important matters. As *Speaker Builder's* editor, I will attempt to bring together the best representatives of differing points of view without bias toward any one of them. In my opinion periodicals should provide a forum for differing views and insights. I encourage every subscriber to read carefully, do his own homework as objectively as he can and to report what he finds in our "Letters" columns. We have no gilded thrones around the editorial sanctum of this publication—and the editor wouldn't have time to sit on one if we did have them. So you need not expect pronouncements from on high. We are a forum for ideas and the more testing, and communication we do about those ideas in these pages the better.

I hope every *Speaker Builder* reader will consider that he or she is a potential author. We need good accounts of the sort of work you do with speakers. Write to me with a brief outline of what you think you wish to write about and I will reply promptly.

Our articles will report your journey and not merely your results. We need to hear about failures, what did not work, as well as the final triumphs. We like personal writing and are not fearful that the use of the personal pronoun will detract from the ideas you wish to communicate.

We hope you will send us items for *Tools, Tips & Techniques* for which we will pay modest honoraria—and always enough to pay for your year's subscription to this magazine. We need to know about your shortcuts, useful tools, and solutions to tough problems you have discovered in your work on speakers.

Problems are welcome too: *Bafflements and Breakthroughs* will contain your puzzlements and the answers others may have found for those problems.

Speakers have been around for a long time. The first were horns riding the arms of phonographs. In the late 19th Century one London music lover had an exponential horn of over 60ft length mounted atop his listening room and connected to the phonograph in the next room via a tube. The late Percy Wilson advised a Norfolk, England devotee of acoustical gramophones, Douglas Fitzpatrick, in building a horn for an antique reproducer whose mouth opening was six feet square—as shown in the photo below. We'd like more such photographs for future issues. Send them to the editor for the *Heirlooms* collection. We will return them carefully packed, and insured.

We'd also like photographs of your speaker systems—inside and out if possible. We prefer black and white photographs but are sometimes able to use color prints if they are smooth finish and have adequate contrast. Send them to *Craftsman's Corner.*

We'll be offering a wide assortment of basic information in issues to come. *Data Base* will contain such things as crossover coil winding values, R-L-C charts and other information. If you have such information to share please write us about what you have and we'll let you know whether we can use it.

We are looking about for a good columnist on woodworking. There are more tools, for less money these days than ever before. But basic skills are really the result of information plus practical experience. If you think you'd like to write such a series for us, or know someone who would, let us know.

A WORD ABOUT ADVERTISING and advertisers is in order. We have long since recovered from any deep seated fears editors seem heir to about undue influence of advertisers. Some companies strike fear in my vitals but not those who advertise in the magazines I have the pleasure to publish—not as yet anyway. I have no problem refusing such and have done so in times past. Advertisers in this magazine appear to me to be a wide range of enterprise, and those I know personally are honorable. Many of them are small operations, often a moonlight effort on the part of an enthusiast to launch himself on an independent career.

If you have trouble with an advertiser, please give him or her the benefit of the doubt and a generous amount of patience. Delivery has become very problematical even with the efforts of United Parcel. If

you are not kept informed about back-ordered or lost items, let us know and we will try to get an answer for you. If an advertiser proves to be unreliable we will cancel his advertising and advise readers about the problems encountered.

When you write to us about such problems, however, try to avoid taking up a Ralph Nader/vigilante posse role. The facts and dates plus copies of relevant documents will do the trick. We advise anyone buying by mail to keep good records of transactions. It doesn't help to tell us you ordered something from some vendor "several weeks ago..."

Speaker Builder is a reader supported magazine, which means we do not depend on advertisers for the major support of the publication. But advertisers and advertising are a vital part of the life of any avocation. The special interests of audiophiles, like most other groups of enthusiasts, are best served by fellow enthusiasts who decide to go into business to supply what they often best understand the devotee needs. Some quite large businesses began in that fashion. Such enterprises stay helpful and producing good products as long as they get, and heed, good feedback.

Speaker Builder is not primarily a marketing tool for advertisers. No advertiser will get a product review in our pages because he is an advertiser, and vice versa. But at the same time, your hobby interests will be better served if the people who make the supplies you need know you are a speaker builder and that you read this publication. A healty hobby inspires good vendors. We will cooperate with you as consumers in keeping retailers and manufacturers honest and we will not knowingly slant editorial reports or reviews to keep an advertiser happy. At the same time we will not allow our columns to be used by an unreasonable consumer who wants a convenient medium for dumping on a vendor.

The last thing this editor wants from readers is false enthusiasm about what appears in *SB's* pages or false reactions to advertisers just to encourage them to advertise here. But your honest reactions to advertisers can let them know how well their dollars are being spent on their message in *SB.* Your honest reactions to their products can help them make better ones—just as our reviewer reports can assist in the same effort.

Contrary to popular wisdom about "Madison Avenue" I do not believe advertisers and consumers are natural enemies. I think the hobby we love is likely to profit most from a more cooperative and rational set of assumptions all round. I have come to believe that the good vendors need encouragement quite as much as sloppy, venal ones need firm opposition. We will try to tread such a path and we hope that you will too.

We begin this journey with high hopes. *Speaker Builder* we trust will become a deeply satisfying reading experience and meeting place for every music lover who wants to discuss this many-sided avocation. We will give it our best and we hope that you will too. □

The Unobtrusive Stage

Sage advice on the end result we seek using loudspeakers—and some simple tests for knowing when we have—or haven't—arrived

by ALAN G. WATLING

SOME 35 YEARS AGO I was standing in a room in a German telephone exchange, looking at some of the line amplifiers which relayed Berlin studio programs to other centers. A German voice said something behind me, and I turned to see—nobody. There instead was the monitor loudspeaker on its short pillar, a 12" cone unit with a chamois leather surround mounted in a plain baffle board about three feet square. Behind it was an enormous DC energised magnet.

There it stood, talking at me with a positively uncanny naturalness. It started a trail for me that still intermittently fades out, restarts in another direction, gives a glimpse of a repeat performance which tantalizes or for all the wrong reasons improves on my memory of that brief glimpse of natural sound reproduction. Such is the fascination of hi-fi. It is instructive to recall some of the technical facts behind that event, if only to compare them ludicrously with the current parameters considered essential to any approach to reality.

The source was almost certainly a moving-coil mike, although just possibly an early capacitor type was pressed into service. The line from the studio was, I can guarantee, 3dB down at 50Hz and 8kHz with a few dB bumps in between. The noise was a little better than 45dB down. After the monitoring tap off the line amplifier transformer (rather loose laminations and a nasty peak at 12kHz) the signal went to a valve amplifier that would have made a useful trailer heater. Six watts triode output at 5% distortion—and that's about all the available measurement of its shortcomings.

It was well supplied with wirewound resistors and paper capacitors and had fixed bias. It did boast a splendid output transformer (and one on the input too!), and it was beautifully bolted together in the fashion of the day. Lots of grey and silver paint and a smell of hot shellac. I have no doubt that on music it would have revealed a few aberrations, but that source was not available then. After all this time, I am still convinced a modern loudspeaker of comparable sensitivity could not have worked the miracle under those conditions.

MORE IS LESS

A modern transducer would certainly have shown up the line noise, the distortion on peaks, and some coloration on mid-bass (maybe even added some), and would have made me aware, by its obtrusive nature, that I was in its presence before I had even turned round. And the frustrating thing is it will still do it today with a super-quiet distortionless amplifier and undreamed of source equipment.

If you're wondering what I'm getting at, my point is that an unobtrusive loudspeaker that does not come between you and reality is very, very rare—and when you find it, it will change with the source material. That, is your Holy Grail, somewhere through the paths of chipboard and trees of long-fibre wool, hidden perhaps in the labyrinth, or a mirage in the shimmer of electrostatic diaphragms. Certainly nothing can make the adrenalin flow like the first sound from that magic box—especially if the box is still warm from the sandpaper held in your own hands.

NATURALNESS RECIPE

What did the German monitor speaker have that was so good? Well, first of all, it did one thing we now do electronically, if we are sensible: its response favoured the signal bandwidth and ignored the hash. Then it was working well within its power capabilities. Next, the added coloration due to an open baffle was negligible. The damping on the voice coil was very good due to the enormous magnet, and the amplifier, though not a negative feedback design, helped along this road with a low triode impedance and a well-matched output transformer. The cone material was probably quite linear over the speech bandwidth, and the soft surround did not set off too many break-up resonances. Finally, the whole thing was well away from reflecting walls and a couple of feet off the floor.

If we built this speaker today, and kept to the same rules, the result would be the same. There's nothing really magic about pushing the air about with an electro-mechanical-acoustical transducer—it's a matter of knowing the physical laws that govern the process and establishing their relevance to the particular sounds you intend to produce. I don't say it's easy, but it is a predictable exercise and the results, emotional as they may be, respond to good engineering and intelligent analysis.

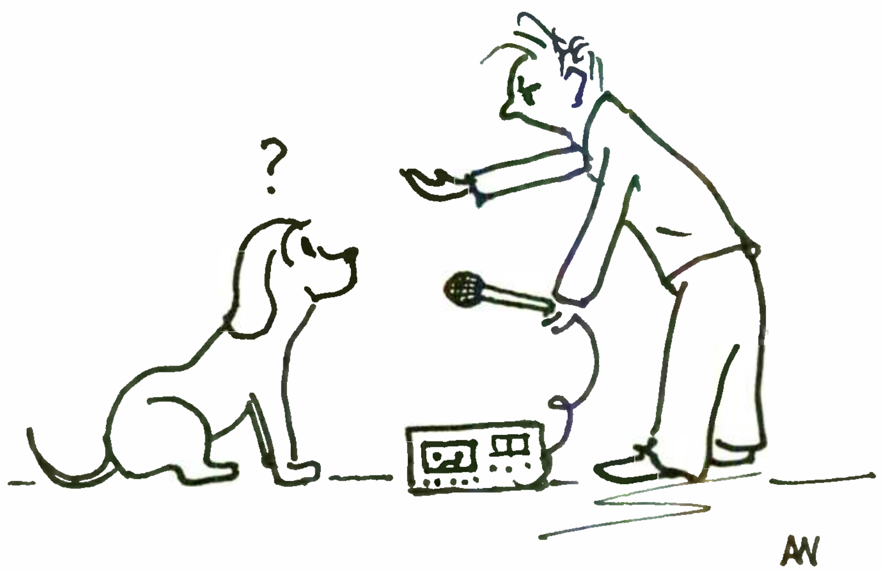
AMATEUR VS. MANUFACTURER

The problems of making good speakers are different for the manufacturer and the amateur. Apart from a large capital investment in machinery, staff, and test gear, the manufacturer has an enormous quality control task. Practically everything he puts into his product affects the sound: cone material, wire, chassis, damping material—even the finish on the cabinet. Consistent results over a long period become a major occupation. Manufacturers like KEF try to factor out the variables by using more stable materials for diaphragms and complex testing techniques to check the final response against a standard. At the other end of the scale Peter Walker of Quad relies on a electrostatic design which is more predictable than the moving coil, but faces a completely new set of problems in sensitivity and power bandwidth. Good and consistent results don't come cheaply in the top brands.

The amateur has only to put together two or, at the most, four assemblies, and he has time on his side. Usually lacking the complex testing equipment, he nevertheless can do wonders with reliable source material and a good pair of ears. The debatable quality of the source probably causes the most heartache. If you lack access to master tapes or discs which have not been equalized out of sight, you could do a lot worse than make a home recording with as good a microphone as you can lay your hands on.

TAPING A TEST

Taking the greatest possible care not to over-record, tape a series of simple sounds which can be repeated live for comparison when you test the speaker. Notes on a musical instrument are fine, but sounds like two bits of sandpaper rubbed together, knocking on a plank of wood, and of course speech are all revealing tests. Record out of doors if you can, to avoid the additive effect of room acoustics. If this is impossible, make an absorbent studio by draping a comforter over a couple of chairs and do a bit of close miking. You will probably be appalled at the first results, but they'll teach you a lot about live and reproduced sound levels. Ignore the background noise for the moment and concentrate on the absolute quality.



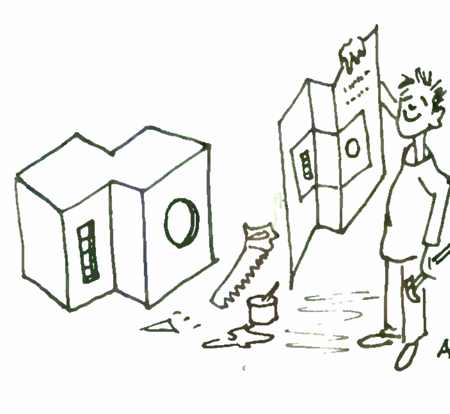
SIMPLE SOUNDS . . .

Your first tests are best done in mono with one speaker. Then use two in double mono, which is a severe test of matching equality. Your ears are a little bit more critical of small colorations when they are not busy sorting out clues for stereo. Some so-called linear phase designs give peculiar results in double mono, and all but a very few of the best do not give a central image when the listener stands off the central line. More of this later.

If you are going to follow someone else's design, then do him the courtesy of following it closely. In particular, use the model and make of unit he specifies. It doesn't matter if you have heard a superb tweeter in some other speaker—that may have resulted from a host of unrelated conditions. The designer must at least have taken the sensitivity of his chosen unit into consideration when he burnt the midnight oil. If he has done his job properly, he has also matched the natural cut-off frequency of his unit to that of the crossover network and to the units above or below the bandwidth it covers. You may think he's a bit nuts to have mounted the tweeter in the middle of the baffle with the mid-range on top; it will take you two weekends and a lot of sawdust to prove him wrong.

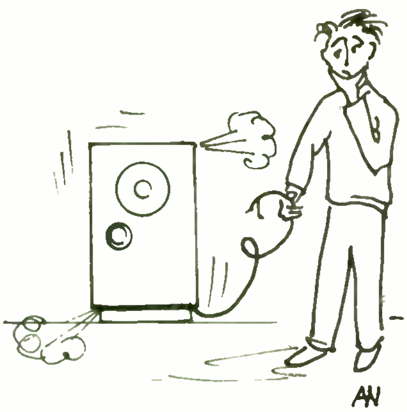
JUDGEMENT DAY

Perhaps you are a real beginner, with no recorder and little theoretical knowledge; this is your first effort at providing a worthy outlet for the expensive record player and amplifier which have made you a poor man before your time. OK, you will have to judge your efforts by the degree of satisfaction you get from your records, which will be your kind of music and your kind of sounds. Don't be put off by unimpressive results: that's perhaps the best indication you could have that



FOLLOW IT CLOSELY . . . .

About the author: *Alan Watling is a confirmed devotee of most of the craft disciplines of audio-including building speaker housings. With pen and camera he is equally adept. He lives with his wife in a countryside John Constable made famous, near Colchester, England.*



RESIDUAL FAULTS . . .

THE UNOBTRUSIVE STAGE

you are on the right path.

By all means play a familiar disc, but remember your brain will be comparing it with images laid down over many repetitions through different equipment. "I heard things I have never heard from my discs before"—but are they worth hearing? Are they some new resonance that will take you the next two years to program out of your memory banks? That's what the ads don't tell you. Also your design was put together by some fallible human being with his own favorite source material. It is absolutely shattering to discover what some reputable manufacturers use as reference material. Wherever possible, go for the most natural recordings without synthesizers or amplified instruments. Direct-to-disc issues are one way of avoiding the studio alterations, but check a few reviews before you go raving mad.

All my previous observations apply even more stringently to final testing on stereo characteristics. If you read the current articles on image positioning you will realize much more is still to be learnt on producing an illusion which is stable over a wide listening area. In many ways the design which produces the best power bandwidth and off-axis response is not the best for that subtle qualtiy of depth in a stereo image. In fact, I have not yet found the best combination, despite bashing holes in walls (see *TAA* 1/74, p. 16) and eliminating the worst faults in small speakers. Again, the most reliable tests result from using the simplest microphone arrangements; Blumlein coincident-mike technique may not suit all the hi-fi ears, but it does produce consistent and reproducible image positioning.

BEFORE SMASHING

At about this point in the proceedings you will be feeling a bit dispirited. The nearly-finished design (minus its feet, grille, and a good deal of cosmetics) sounds just like a lot of other loudspeakers, only more so. For the fiftieth time you put on the bass drum in *Limehouse Blues* and feel you are missing something.

Pack up the tools, light a pipe, talk to your wife (will she be surprised!), have a drink—do whatever makes you forget about loudspeakers. Put the whole thing aside for a couple of days and allow your ears to recover from listening fatigue. More loudspeakers have been smashed to bits just when they were near the end of the road than at any other time. Even if you think you have reached the ultimate, sleep on it and have a crafty listen before breakfast the next morning. The residual faults will shine out like beacons.

What you then do about them will set you off on the best thing that can happen: a reading and learning session that in my experience lasts years and years. Whom to read? The old school first, because there's nothing so new as the oldest you can find. Perhaps the editor can help here, as I don't know what is easily available in the U.S.A. Olson, Rayleigh, Meyer, Briggs, Moir are all cheek-by-jowl on my bookshelf, with a good fat selection of technical magazine articles over the last 20 years from engineers who have made their reputations in the development of this most elusive of devices.

YOUR OWN STAGE

Back to the title, if I may. The Unobtrusive Stage is the one on which your private hi-fi fantasy is performed. If you are sensitive enough to respond to that dB of unwanted sound, don't you want the visual aspect to be satisfying too? I personally can't understand the trend for full frontal nudity in speakers. To see all the works flapping away in plastic and aluminum trim is, to me, psychologically devastating.

In my last home I was able to use white net curtains for special occasions like the performance of a complete opera for a group of friends; they made sound reproduction into an experience. While you needn't go to those lengths, the finish and placing of speaker cabinets are worth a bit of consideration. When they combine with reproduction that detaches itself from all that hardware and floats Bach, Tippett, or Pink Floyd into your personal space you have a contact with the source nearly—but never exactly—as good as the original sound.

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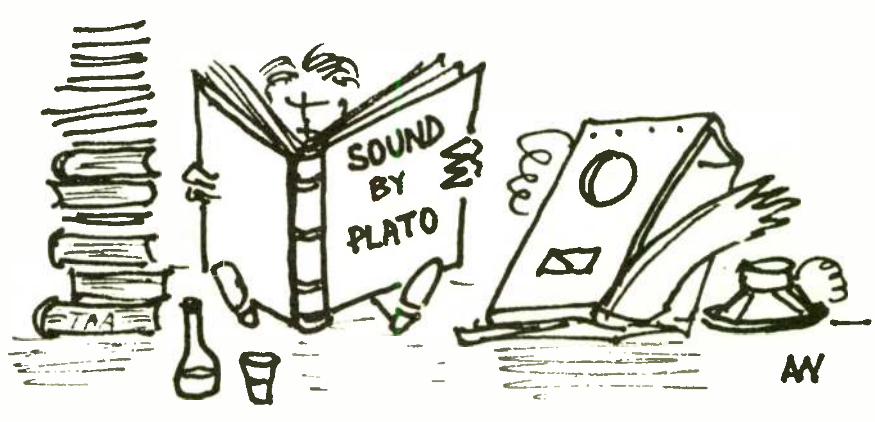
BACK TO THE BOOKS . . . .



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CBS Laboratories' STR Professional Test Recordings

For over ten years, the original series of these high-precision test records set a standard for the audio industry. Now the new series sets an even higher standard. It's been revised, recut and expanded.

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STR 112 SQUARE WAVE, TRACKING AND INTERMODULATION TEST RECORD. Enables detailed study of tracking capabilities of stereophonic phonograph pickups. The square wave modulation allows a rapid appraisal of stylus-tip mass, damping, and tracking. Low frequency compliance and tracking are determined by means of 300Hz bands of progressively increasing amplitude. Intermodulation distortion measurements are made possible by graduated 200Hz intermodulation test bands. The STR 112 has been cut with vertical angle approximately 15°, which is representative of current recording practice.

STR 120 WIDE RANGE PICKUP RESPONSE TEST RECORD. Makes possible the measurement of pickup response at frequencies far beyond the audible range, where elusive distortion elements can cause audible distortion. The low-frequency range includes glide-tones at twice normal level for the detection and elimination of arm resonance, loudspeaker cone and cabinet rattles. Other tests include: silent grooves for measuring rumble and surface noise characteristics; and standard level bands at 0dB for overall system S/N measurements. This record is suitable for use with a graphic level recorder to provide permanent, visible records for precise evaluation.

STR 130 RIAA FREQUENCY RESPONSE TEST RECORD. Provides RIAA frequency characteristics for the calibration of professional recording equipment and for testing the response of professional and consumer record reproduction equipment. This record is suitable for use with a graphic level recorder to provide permanent, visible records for precise evaluation. Spot frequency bands for use without automatic equipment are included.

STR 140 RIAA PINK NOISE ACOUSTICAL TEST RECORD. Designed for acoustical testing of systems and loudspeakers and for psychoacoustic tests on reproduction equipment. With the STR 140 it becomes possible to test loudspeakers in the room in which they will be used. Spot frequency tones with voice announcements facilitate the testing procedure. Continuous glide-tones in ⅓-octave bands cover the frequency range from 30 to 15,000Hz and are synchronized with a graphic level recorder.

STR 151 BROADCAST TEST RECORD. Developed especially to meet the needs of broadcast engineers, audiophiles, and other professionals seeking a convenient signal source for the testing and adjustment of all audio equipment. Tests include: phonograph pickup response and separation, speed accuracy at 33⅓ and 45 rpm, wow and flutter, rumble and hum detection, ballistic test of V. U. meters and many others.

STR 170 318 MICROSECOND FREQUENCY RESPONSE TEST RECORD. Provides pickup designers and recording studios with a high-level, easily-equalized signal for frequency response and channel separation measurements. The STR 170 employs a 318 microsecond characteristic corresponding to the "test" or "flat" mode common to most disc recording equipment. Constant amplitude recording is employed in the region below 500Hz with constant velocity recording in the region above. The transition is smooth, in contrast with the STR 100 which employs a sharp breakpoint at 500Hz. The record is suitable for use with a graphic level recorder to provide permanent, visible records for precise evaluation.

SQT 1100 QUADRAPHONIC TEST RECORD. Designed for calibration, verification, and adjustment of SQ® decoding equipment. The record provides test bands for pickup measurements, for adjustment of decoder electronics and for channel identification and balance. Each band is described in terms of recorded characteristics and its intended use.

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. . an Ambience Reproduction Speaker System

by David L. Clark *and*
Bernhard F. Muller

Photgraphs by David Carlstrom

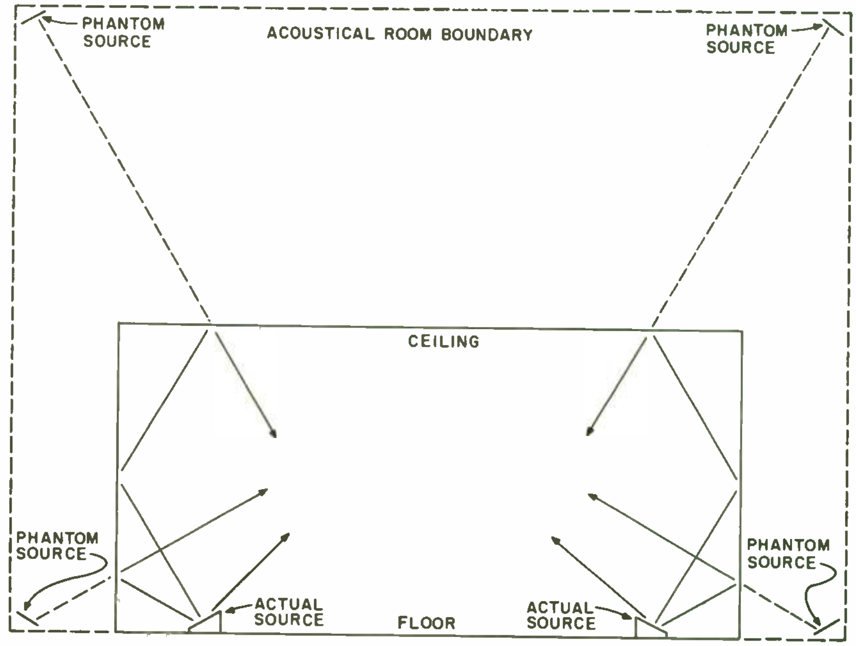

Fig. 1. Expansion of acoustical room boundaries due to phantom sources produced by wall and ceiling reflections.

"Ambience", as applied to sound, means the sensation of the acoustical space in which a sound is produced. This is generally an enjoyable sensation, and audiophiles have spent much effort over the years to reproduce it. While stereo sound systems can reproduce the recorded ambience quite well, the addition of side and/or rear speakers fed by a delayed version of the signal can dramatically improve ambience reproduction. This is not to be confused with quadraphonic sound and there should be no awareness of sound coming from behind the listener.

Ambience systems are still in an experimental stage and proponents do not yet agree about how they work. Two basic philosophies can be considered: 1) *Extraction* of ambience information already existing on most two-channel discs and tapes. 2) *Synthesis* of an ambience by production of a series of delayed "echoes." When synthesis is used, it is usually combined with the extraction technique. In either case, a delay of 10 to 100 milliseconds (ms) is used and the signal emanates from speakers to the sides or rear of the listener.

The delay allows the signal from the front speakers to arrive at the listener first. This is important for two reasons: 1) When any two speakers are reproducing the same sound, the ear tends to perceive the sound as emanating from the nearer speaker even if the loudness of that speaker is much lower. This is the well known Haas effect. The time delay to the rear speakers insures that their sound will arrive after that from the front speakers. Thus rear speakers can be operating, but not heard as independent sources. 2) One of the most important properties of concert hall ambience is the time required for the first reflection to reach the listener. If the delay time is set to approximately match this hall characteristic, an important element of ambience reproduction is achieved.

STEREO AND AMBIENCE

In a natural recording, the delayed reflections are picked up by the stereo microphones, but the stereo speakers do not reproduce the *direction* from which the reflections came. The listening room wall has reflections from all directions, but they are so closely spaced after the initial sound that they only produce "living room" ambience and partially mask the concert hall's delayed reflections. Side or rear speakers can approximate the direction of arrival of the important first reflection. Thus delay and direction combine to "extract" ambience while preserving a frontal sound. It is important to note that no precise acoustic phasing is used. Therefore, precise listener positioning is not required.

When the audiophile uses delay only to feed the rear speakers of a "quad" system the quality of ambience reproduction is usually only fair. Most manufacturers of delay units incorporate some recirculation which produces multiple echoes to partially synthesize ambience. This helps, but in the authors' opinion, always sounds a bit faked. In any case, it strays too far from an ideal approach to be intellectually satisfying.

speakers or even rear speakers for quad. Good localization and imaging are exactly what we do not want, as this would tend to make the listener aware of the ambience speaker as a sound source. Smooth response is, if anything, even more important than in the "main" system as any coloration tends to call attention to the speaker.

We have experimented with a number of ambience systems and have found two channel delay feeding ambience speakers to give the most natural results. The authors' experiments included using difference information undelayed and delayed, sum information delayed, and stereo delayed. The optimum delay depended on the type of music being played, and a reverb effect with recirculated delay only "muddied" the sound. Whether

situated to the side of and behind the listener. "Pointing" away and slightly upwards toward a wall. We achieved good results in this manner, but the optimal listening area was small and level adjustment was critical to avoid "hearing" the ambience speakers. We decided to adopt the angled wall reflection principle for the final design, but further experimentation was clearly necessary.

The wall reflection aiming of the ambience speakers works so well, we believe, because it produces "phantom" sources outside of the room boundaries. The phantom source effect, illustrated in *Fig. 1*, is much like the visual images which would appear if the room had mirrored walls. The larger number of sources reduces the ability to localize any one source and

Fig. 2. Preferred orientation: reflecting off wall.

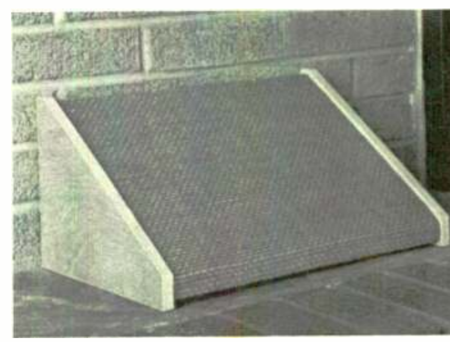

Fig. 3. Next best: aiming upward.

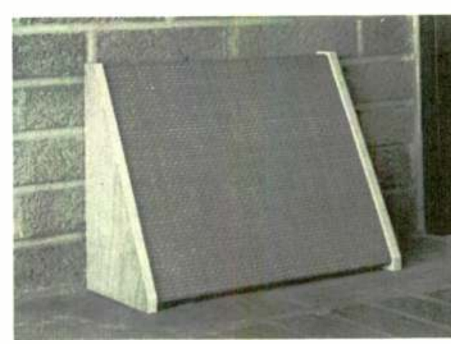

Fig. 4. Minimum floor space orientation.

REALISTIC AMBIENCE ELEMENTS

It appears we need not only a solid "first reflection" from one direction, but additional reflections and from other directions, more closely duplicating the concert hall experience. This thinking and subsequent experiments leads us to propose the specialized ambience system of six to eight speakers arranged around the listening room walls, which we describe in this article.

Speakers designed for ambience reproduction must meet a different set of requirements from those for stereo

the ambience speakers were connected in phase, out of phase or in random phase resulted in different effects, but all were pleasant.

WHERE DO WE AIM?

During listening evaluations in the design stages of the ambience speakers we used a delay of difference information fed to all speakers in phase. Source material was primarily classical music from disks. Initially we used a pair of conventional high quality bookshelf type speakers. The most satisfactory results were achieved with the speakers

also increases the number of directions from which the sound arrives. Both effects, in our judgement, more closely approximate the reflections one receives in a good concert hall.

In our next experiment, we distributed ten small speakers about the walls of the room including the one in front of the listener. Things got very interesting because level setting and listener position both became noncritical. It was possible to be anywhere in the room, even very near one of the ambience speakers and not be sonically aware of it's presence. It became almost painful to turn off the ambience and listen to the lifeless sound coming from the front speakers alone.

WHICH SHAPE BOX?

Haing decided on a system of multiple speakers reflecting from walls, we next optimized the design of the small speakers. The Phillips AD5061 5-inch full range driver was chosen on a price/performance basis. A sealed enclosure was chosen for its smooth low frequency rolloff and hence good transient response. A cabinet volume of 8.21 liters (500 in^3) gives a critically damped response down to 125Hz and controlled cone excursion below that.

We first constructed a nearly cubical box of 8.21 liters with the driver firing at a 20° angle from the top. This shape's deficiency in bass and considerable coloration made it unsuitable. We traced both problems to diffraction around the baffle. At certain frequencies the sound bounced up from the floor and combined, out of phase, with the directly radiated sound.

We then designed a thin, wedge shaped 8.21 liter cabinet with the driver facing upward. The bass was restored and the coloration disappeared. Apparently the speaker was effectively "flush mounted" in the floor. We noticed that as the speaker was moved toward the wall (<0.3M) to get the desired reflection, another coloration would develop and become severe at very close spacings. As we altered the wedge angle to make the speaker fire more directly at the wall, the coloration became worse. With large angles from the wall, such as aiming straight up, the reflection action disappeared. By experimentation we chose as ideal an angle of 60° from the wall. This gave a desirable reflection path with minimum coloration at a reasonable distance from the wall.

In some rooms it may be impossible to fire all the speakers at the wall. *Figs. 2, 3, and 4* show other possible orientations. In practice some of the speakers may have to be "stored" flat against the wall and brought out only for "serious listening." *Fig. 5* shows the response curve with eight units operating. It is smooth with a "natural" looking high frequency rolloff due to room absorption.

BUILDING THEM

Construction is straightforward (see *Figs. 6, 7, and 8*). After gluing, the front panels may be fastened together with an insulation stapler and the brace

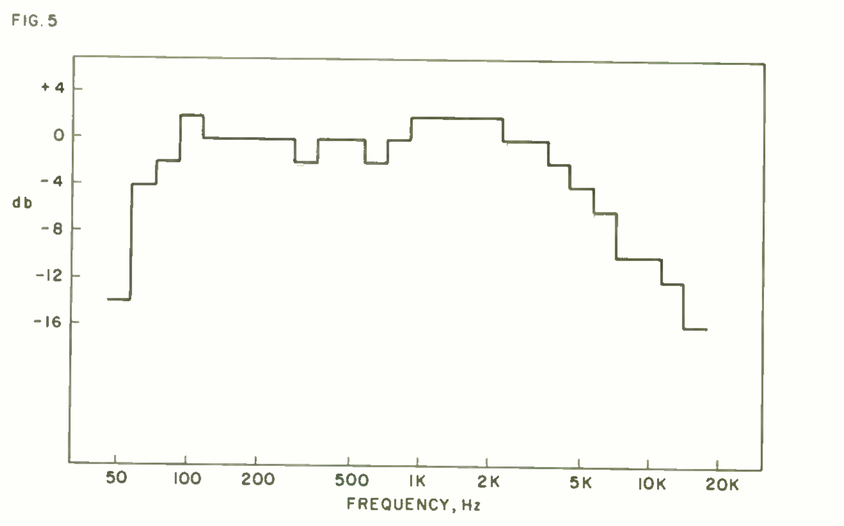

Fig. 5. Typical frequency response of 8 units in 3500 ft^3 living room. Measured with pink noise and ⅓ octave analyser.

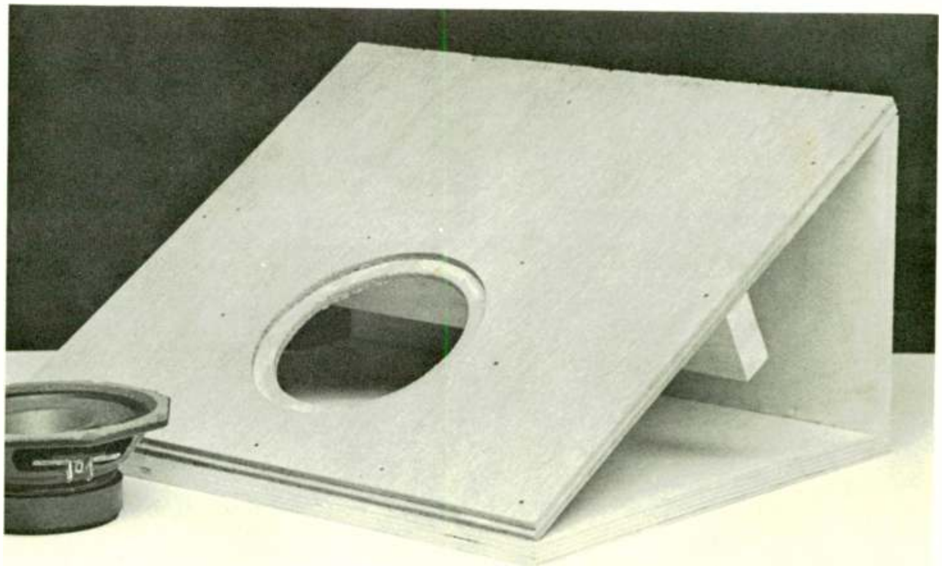

Fig. 6. Assembly detail. Exact location of the brace is not critical.

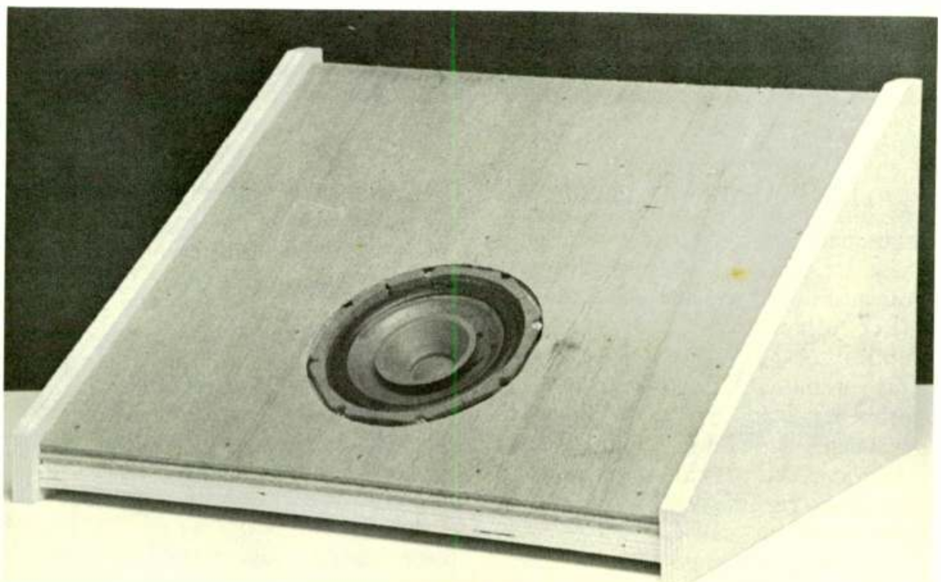

Fig. 7. Finished unit minus grille cloth. Sides overlap ¼" all around.

added as shown. The easiest procedure is to assemble the bottom, back and sides first. After the glue is dry, the front panel is added and glued. If you have a router, it is better to make the front panel out of a single piece of ½" plywood and rout out the speaker recess. Fill the entire cabinet loosely with 1ft² of 3½" thick building insulation fiberglas® . Make sure the box is airtight.

Continued on page 16

Time Delay Devices For Ambience Speakers

ANY TYPE OF TIME DELAY will work with the ambience speakers as long as it has reasonable fidelity and a delay time of 15 to 30 milliseconds. Tape delays are usually much too long and should not be used. Make sure the particular device is capable of operating as a pure delay with no recirculation or echoes. Desirable but not essential features are:

1. Two separate, independent left and right channels.
2. Variable delay of 10 to 100ms.
3. Superior audio quality (response to 10kHz or over, low noise and distortion.)

If you choose a single channel delay, it will probably accept left and right inputs and delay the difference signal. If it is a mono in, mono out, device, (such as the Delta Lab) you should use a difference signal matrix. The Williamson Super Quadpod (*Audio Amateur* 1/77, p. 14) should work well for this (see also *Audio Amateur* 1/71 for an earlier version.)

You might try no delay at all. Surprisingly good results can be obtained using a rear channel output from a quadraphonic matrix or the Quadpods.

ASSORTED DELAY DEVICES

Delta Lab DL-1 Professional, Digital Mono $1200.00
Delta Lab Research, Inc., 25 Drum Hill Rd., Chelmsford MA 01824 (617)459-2346.

Advent Sound Space Digital $595.00
Advent Corp., 195 Albany St., Cambridge MA 02139 (617) 661-9500.

Southwest Technical Products 2AS-A Analog, 2ch, kit $250.00
Southwest Technical Products Corp., 219 W. Rhapsody, Dept. SB, San Antonio TX 78216.

Preis Homebrew *TAA* 4/75 Acoustical, 2ch, pts approx. $100.00

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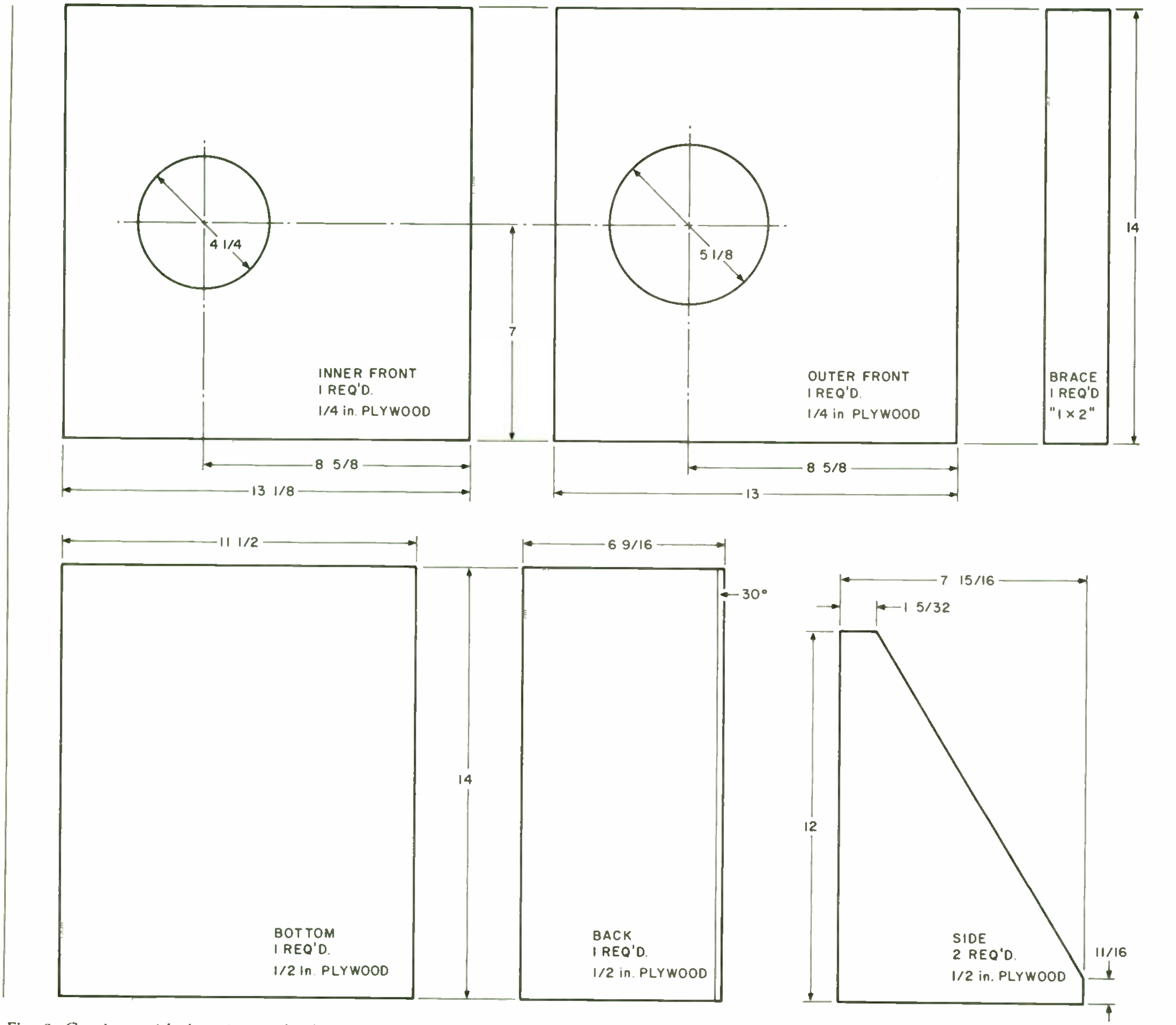

Fig. 8. Cutting guide for pieces of cabinet, one enclosure. If the builder has a router the speaker front panel can be made from ½" plywood and routed deep enough to mount the driver flush with the front face of the cabinet. Baffle board should be stained or painted black so speaker is not visible after grille cloth is mounted.

FIG. 9A FIG. 9B

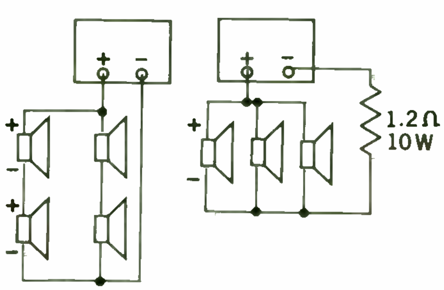

Fig. 9. Speaker hookup diagrams. A. Four 8Ω speakers per channel in series/parallel. B. Three 8Ω speakers per channel, parallel with an added 1.2Ω resistor to raise impedance to 4Ω, the minimum most amplifiers drive comfortably.

The speaker can be mounted without screws using "silicone seal" but may be troublesome to remove later. A better, more flexible alternative is non-hardening "weather caulk" and screws. If you install insulated spade type solderless connectors you will be able to experiment more easily with phasing and channel reversal.

Ten to 15 watts per speaker should be sufficient. An integrated amplifier with tone controls would be ideal since this would allow broad spectrum balancing. Eight speakers should be hooked up four to a channel in series/parallel. If only six speakers are used, they should be hooked up three per channel in parallel. Since some amplifiers become unhappy with a 2⅔Ω load, a 1.2Ω 10 watt resistor can be used in series with the speakers, (see *Figs. 8a and 8b*). This reduces damping slightly but has a negligible effect on sound.

FINAL RESULTS

The end result of our work is a system which has produced the only spectacular improvement in the authors' sound systems in over ten years of reducing "TIM", sub-woofing, time aligning and dozens of other "upgrades." □

Not because we say so, but because they say so. . .

"The *'New Yorker'* of audio magazines"

—ESS, Input, Sacramento, CA

Audio Amateur is a magazine that continues a great American tradition—a tradition that loves tinkering and experimentation and embraces rather than eschews technology. Readers of this magazine, I suspect, don't simply discuss the latest heavily advertised "quantum leap" forward. **TAA** subscribers are impressed more by an interesting project they can build from scratch. They love to extract, by modification, the greatest possible perfection from classic and recently introduced audio products.

Like the **New Yorker,** the **Audio Amateur** publishes articles that are measured and thoughtful, articles that are beyond superlatives by the bushel basket found in most of the mass circulated audio magazines. The reasoned tone results in part from the considerable contributions made by English writers, including the late B.J. Webb. Edward T. Dell, Jr., the editor, almost always includes a thoughtful editorial that, alone, is worth the cost of admission. Unlike some of the little audiophile magazines, **TAA** is generally beyond clannish allegiance to a few manufacturers. Articles on projects to construct and modify appeal to the fondness of its readers for a wide range of projects.

Audio Amateur has served up a smorgasbord of projects over its ten year existence. How to properly adapt a Grace arm to an AR turntable, build a record cabinet, modify a Formula-4 tonearm to improve low frequency reproduction, or build a 10 dollar three-element Yagi antenna have all been offered as appetizers, projects that require some familiarity with tools and a few nights of your time. The main course offerings demand various degrees of more sophisticated electronic skill. If you've only assembled a one tube radio (twenty years ago), many of the electronic projects are going to more than you can chew. Numerous past articles have shown how to improve classic Dynaco products. Recently, Nelson Pass of the Threshold Corp. discussed how to build a 40 watt per channel class A amplifier. Electronic articles typically assume an ability to find the parts necessary to build the projects. Chances are you'll spend some time searching through parts catalogs and local surplus houses before you can begin to wade into the actual construction.

Sophisticated articles that examine specific audio problems but do not involve building projects also abound. Walt Jung, contributing editor, has discussed slewing induced distortion in amplifiers in a series of articles. How we actually perceive sound and how many speakers may be necessary to recreate the closest possible approximation of the live event has also been discussed.

If speaker building is your forte, past articles have dealt with horn loaded and transmission line designs. Instructions on how to build electrostatic transducers from scratch, and box fabrication for sub-woofers with an accompanying active crossover have also been features. It's a measure of **TAA** contributor ingenuity that a complex driver like the Heil air-motion transformer has been built by an amateur — complete instructions on how to build a home version of the large Heil appeared in the magazine in 1977.

An excellent analysis of recently introduced audio kits is a regular feature. Kit reviews are technically very thorough and are often more objective than you find elsewhere. A regular feature, "Audio Aids," offers all kinds of informative hints from readers. A letter section from readers comments on past articles and present concerns and lends a thoughtful and inquiring tone to the magazine. Advertisements, themselves, are often helpful to the reader since many of the ads list parts that are vital for project construction. Most of the better kit manufacturers also advertise in **Audio Amateur.**

If you are already an audio craftsman, or would like to become one, **Audio Amateur** is an excellent touchstone. For less than the price of a good meal and a movie ticket, you can receive four issues a year.

—**George Hortin,** Staff Writer
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How to improve that small, cheap, speaker

Author's two modified speakers and his disassembled central bass speaker. The modified units cover all but the very lowest bass, below 40Hz.

by Paul J. Stamler

For the audiophile of average means the pursuit of high-quality sound is frustrating. Prices are going up like helium balloons, and the number of genuinely low-priced, natural-sounding components can be counted on one hand.

My own system can best be described as "rock-bottom audio amateur"—AR turntable, homebuilt Quest preamp, modified Dynaco Mark IV power amps, and a battered Teac reel-to-reel deck—representing a total cash outlay of around $200, exclusive of speakers. The signal sources are OK, if not spectacular; the electronics are top-notch.

The speakers, however, are another story. They were a high school graduation present back in 1967 (is it *that* long ago?) and were far from the state-of-the-art even then. Time has not improved them. I've known they were the weak point in the system for quite a while, but put off replacing them because I could not afford anything I liked.

I took the speakers apart a few times to replace loose mounting screws (acquiring some nicely magnetized screwdrivers in the process), and noticed the cabinet itself was well made. When W. J. J. Hoge's excellent article on vented-box speaker design appeared (*Audio*, August, 1978, pp. 47-55) I decided to take the plunge and replace the drivers. (I was also egged on by a persistent buzzing in one of the tweeters.) The resultant speaker systems, while nowhere near the cosmically unaffordable state-of-the-art (Quantum Reference Sources, Double Quads and the like), are nonetheless quite easy to listen to, and I venture to say they outdo in naturalness any other system in the $70-apiece range—which is what they cost.

DRIVER SELECTION

I first established the box's approximate internal volume. With due measurement I came up with about 36 liters; now to check out some bass drivers.

In his Table I Hoge lists appropriate specifications for a number of available woofers: diameter, free-air resonance (f_s), total system Q (Q_{TS}), equivalent air mass (V_{AS}), and reference efficiency. Since my cabinet is limited to drivers of 10' diameter or less, my choice was narrowed to six drivers: the KEF B110 and B200, the CTS 6W10C and 10W18C, the Eminence EM40 and the Australian Magnavox 8-30.

The next question was fundamental: what did I want the speakers to do? Here let me emphasize an important fact: with the exception of pipe organs, synthesizers, and the seldom-used lower eight notes on a piano, virtually no music has sounds below 42Hz, low E on a bass fiddle or bass guitar. In fact, on most available records, if anything below 40Hz is audible, it's likely to be cutting-lathe rumble, air-conditioning noise, or warp—not music.

I can sense the "hall-ambience" fanatics out there gearing up for conniptions at that last statement, so let me hastily rejoin that while they may be right about some of the better classical recordings, I listen most to recordings of traditional folk music of one sort or another; most of this is recorded with multi-mike close-up techniques, eliminating hall ambience. (An exception is Missouri Friends of the Folk Arts' marvelous recording, *I'm Old But I'm Awfully Tough*—field recordings of Ozark vocal and instrumental music, recorded using coincident microphones and mastered with exceptionally high quality. For details write Missouri Friends of the Folk Arts, Box 307, New Haven, MO 63068.)

So for most purposes, a cutoff frequency (f_3) of 40-45Hz is entirely adequate. But an adequate cutoff is not enough: the frequency response must also be reasonably flat, free from major dips and peaks. Hoge gives two equations, derived from the pioneering work of A. N. Thiele and R. H. Small, that make these calculations relatively simple:

$$(1)\ f_3 = f_s \sqrt{\frac{V_{AS}}{V_B}}$$

where V_B = the internal volume of the box.

$$(2)\ \text{Ripple (dB)} = 20 \log \left[2.6\, Q_{TS} \left(\frac{V_{AS}}{V_B} \right)^{0.35} \right]$$

So let's haul out our log tables and do some computations. (I do *not* own a calculator!) Given an approximate V_B of 36 liters, we come up with the following figures:

TABLE 1

Bass Driver	Cutoff Frequency (f_3-Hz)	Ripple (dB)
KEF B110	26.8	− .75
KEF B200	42.0	7.54
CTS 6W10C	45.0	−2.71
CTS 10W18C	55.6	3.48
Eminence EM40	52.4	7.82
Magnavox 8-30	50.1	.10

Clearly we can eliminate the KEF B200, Eminence EM40, and CTS 10W18C for high cutoffs, high ripple, or both; the CTS 6W10C might be acceptable, but it still has almost 3dB of upper-bass dip (the negative sign denotes a dip well above f_3, whereas a positive sign means a peak just above f_3). And although the Magnavox is very flat, it cuts off at 50Hz—besides being hard to get. So by process of elimination we arrive at the B110.

Note the various possible compromises: we could have sacrificed some bass response with the Magnavox and gained efficiency (its reference efficiency is .86%, as opposed to .18% for the B110). The B110's response is a bit lower than I'd like, leading to its lower efficiency (see Hoge for the cabinet size/frequency response/efficiency tradeoff).

We must consider one other factor. The B110 was designed to cover both bass and midrange frequencies, and is known to be a very high-quality performer in the midrange; it is used in the Webb transmission-line speaker and the LS3/5a, among other fine systems.

Much of the driver's lack of midrange coloration can be attributed to its small size and to the fact that its cone is fabricated from Bextrene. This doped-plastic material allows a cone to be made both stiffer and lighter than an equivalent-sized paper cone, thereby achieving better transient response with less cone breakup. Bextrene is also more opaque acoustically, meaning that sounds reflected within the cabinet will be less audible through the cone, and it is less susceptible to changes in temperature and humidity than paper.

So, taking all these factors into account, I settled on the KEF B110 for the bass driver and the KEF T27 for the tweeter (why break up a proven combination?).

DESIGN

Now it was time to begin working more exactly. I found the box's internal volume to be 25.0 × 27.5 × 54.0cm., for a volume of 37.125 liters. The corner blocks and braces inside the box added up to 1.142 liters, the speaker magnet occupied the equivalent of two cylindrical sections totalling .151 liters ($V = \text{Height} \cdot \pi r^2$) and the speaker's truncated cone occupied .082 liters

$$\left(V = (r_1^2 H_1 - r_2^2 H_2) \cdot \frac{\pi}{3}\right)$$

where r_1 and H_1 refer to the base radius and height, respectively, of the cone untruncated, while r_2 and H_2 refer to the base radius and height of the truncation. All these items added up to 1.374 liters, so the net internal volume was 37.125 − 1.374 = 35.751 liters.

I realize these calculations, particularly those involving the cone volume, may seem to be a bit hairsplitting. And so they are, but they're fun—and in the case of a bigger driver than the B110, they would make considerably more difference.

Using 35.75 liters as my calculated box volume (we'll let that 5th significant figure drift away), I computed f_3 as 26.94Hz, and the ripple came out as −.73dB—not bad. The next step was to calculate f_b, the frequency to which I had to tune the box:

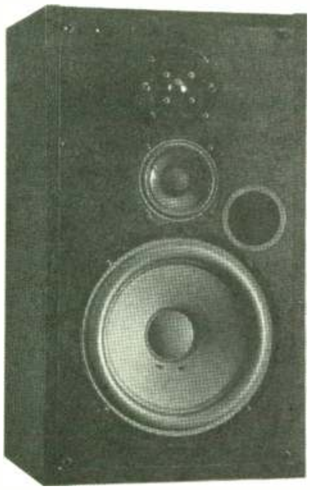
$$(3)\ f_B = f_s \left(\frac{V_{AS}}{V_B} \right)^{0.32}$$

which came out to 28.34Hz. To achieve a tuned box, one can either use a simple port (hole in the wall of the box) or a ducted port, of greater length and diameter. I decided to try the simple port first. Given V_B, f_b, and l_v (the thickness of the panel—in other words, the length of the port), the necessary diameter (d_v) is given by the following ghastly equation:

$$\text{Eq. (4)}\ d_v = (1.8 \cdot 10^{-5} f_b^2 V_B) + \left[(3.25 \cdot 10^{-10} f_b^4 V_b^2) + (4.23 \cdot 10^{-5} f_b^2 V_b l_v) \right]^{1/2}$$

Continued on page 22

SEAS PROFESSIONAL SOUND



Kit 223 is a three-way system at a reasonable price, designed for use in a 20 - 25 litres closed cabinet. The 5 cm tweeter is viscously damped by magnetic oil in the airgap. This ensures a smooth frequency response and a low distortion level at high frequencies.

Kit 253 is designed for bassreflex cabinets. The 1" dome-tweeter has a vacuum formed, high loss plastic diaphragm, with a shape optimized for the high frequency range.

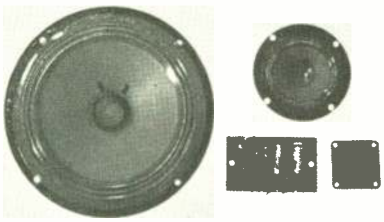
Kit 403 is a 3-way system with a 10" woofer, a 4.5" midrange unit and a 1" dome tweeter. In a 40 litres, ported cabinet this system delivers smooth and effortless reproduction of the entire audible sound spectrum.

Kit 603 is a 3-way system, built for a 60 litres bassreflex cabinet.
High efficiency and excellent reproduction of transient characterizes this system.

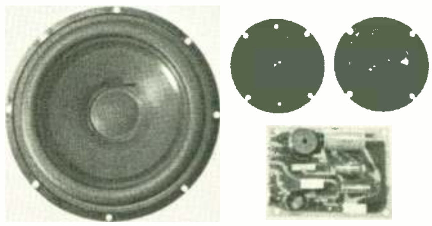
CABINET KITS. If you prefer not to build your own boxes, SEAS CABINET KITS are available for all loudspeaker kits. Cabinet kits for 223, 253, 403 and 603 are supplied as ready cut chipwood boards, with a brown laquered ash-veener finish. The front baffle has a dark brown finish. Everything the home constructor will need is included in the cabinet kits, such as damping material, cloth, glue, and front grille. They are designed for ease of construction and require no special tool for assembly. A detailed building instruction is enclosed. The SEAS cabinet kits are acoustically optimized to each loudspeaker kit. This is an easy way of building professional loudspeaker cabinets to a reasonable price.

LOUDSPEAKER KIT		223	253	403	603	DISCO-47
Enclosure type		Closed box	Bassreflex	Bassreflex	Bassreflex	Bassreflex
		3-way	3-way	3-way	3-way	7 units 4-way
Frequency range[1]	Hz	50-20 000	35-25 000	35-25000	30-25 000	40-20 000
Nominal power[2]	W	30	60	60	80	120
Music power[1]	W	45	100	100	150	160
Operating power[1]	W	2.5	5	3.2	3.2	0.4
Characteristic sensitivity	dB	92	89	91	91	100
Recomm. enclosure volume	litres	25	25	40	60	100
Recomm. amplifier power	W	6-45	10-100	8-100	8-150	6-160
Drive units		21F-GW 10F-LG 5F-HF	21F-WB 10F-M 1" Dome H107	25F-WBX 11F-M 1" Dome H107	33F-WB 11F-M 1" Dome H107	2x30F-A 2x15F-BR 2x10F-LG Horn-Tweeter
Crossover frequencies	Hz	1500-5000	800/4000	700/3000	600/3000	1000/3000/8000
Crossover network		D 082 P	D 083 P	D 084 P	D 085 P	D 086 P
Impedance	ohm	8	8	8	8	8
Ext. measures (cab. kit)	mm	488x284x263	488x284x263	575x330x298	660x400x317	1005x496x343

1) DIN 45500 2) DIN 45573

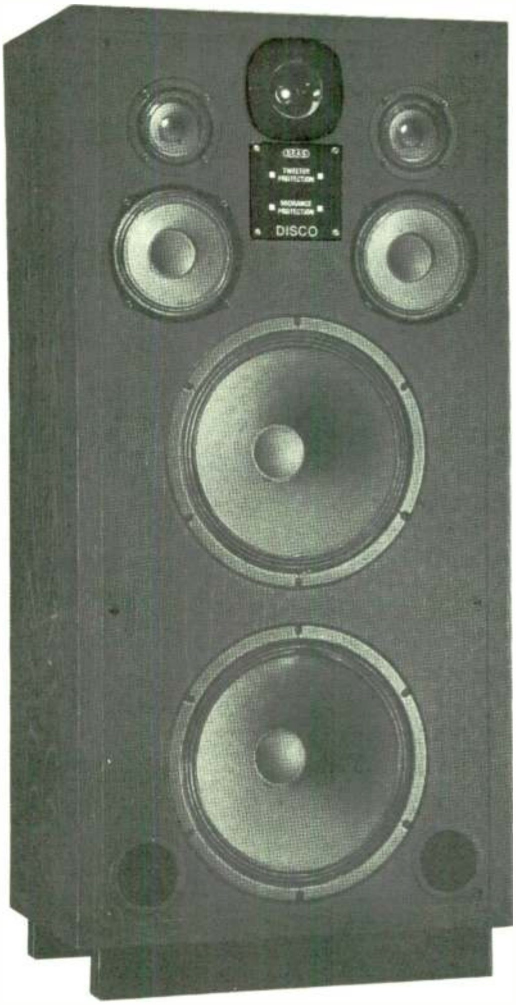


223



253

DISCO 47



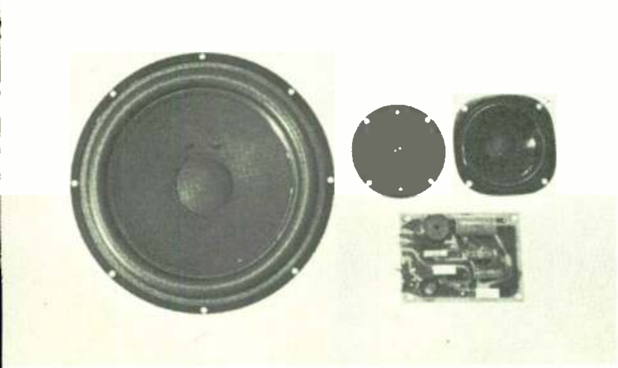
This is a loudspeaker kit designed to reproduce high sound levels with little distortion. DISCO-47 is a 4-way system, consisting of 7 units. Two 12" woofers, two 6" midrange units, two 4" tweeters and a horn loaded supertweeter. The system is designed for use in a bass reflex cabinet of about 100 litres internal volume. This secures a very good transient performance, especially in the low frequency area.

The system has a power handling capacity of 160W and the almost unbelievable low operating power of 0.4W.

The system is equipped with an automatic protection device for the midrange and treble units. At high power levels the protection circuit will be engaged and the warning lights marked «tweeter protection» and «midrange protection» will light up.

Empty cabinets for DISCO-47 are available. They are supplied in black veener finish. Damping material, cloth, frontgrille and cabinet stands are included.

SEAS FABRIKKER A.S has many years of experience in designing loudspeaker kits. Much effort has been made in making the kits easy to assemble, without special tools or equipment. The use of push-on connectors eliminates the need for soldering. All necessary material as screws, gaskets, DIN-cable, bass reflex tube and rear chamber are included. Also a metal badge for mounting on the front. For Kit 403, 603 and Disco-47, a decoration ring for mounting in the bassreflex port is enclosed. The specifications for every kit are included as the last page in the extensive instruction leaflet that comes with all kits. This page can be glued on to the back of your cabinet to give the finished product a professional look.



03

603

SONIKIT
1173 65th Street
Oakland, CA 94608

C.C.S. DISTRIBUTING
5070 E. 22nd Street
Tucson, AZ 85711

IMPROVING A SMALLER SPEAKER

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Gulp! After wading through this mess, I came up with a vent diameter of 2.1cm—awfully small. A hole this small tends to create air turbulence and whooshing noises—more realistic with pipe organs and calliopes, perhaps, but not generally desirable. So I decided to try a ducted port instead. If d_v now is used to denote the internal diameter of the duct, and 1_v is the length of the duct then:

$$(5)\ 1_v = \frac{2.36 \cdot 10^4\ d_v^2}{f_b^2\ V_B} - .74d_v$$

For a tube with an inner diameter of 4.6cm, the length worked out to 13.99cm, not bad at all. (A larger diameter yields a longer duct.) The design was now almost complete, except for one thing. We calculated the volume of the box to be 35.75 liters, taking into account the volume of the drivers, bracing, etc. But we must also take the volume of the vent into account as well. It does not form part of the box volume. The vent's volume works out to .232 liters, so the new box volume is 35.52 liters. If we recalculate we have f_3= 27.03Hz; f_b=28.39Hz; 1_v=14.04 cm, and Ripple = −.71dB. Since 1_v changed by a mere half millimeter it is probably not worth it to go around again, but some designs may make enough difference for the third iteration. The design is now complete.

CONSTRUCTION

Building the speaker was fairly straightforward. I cut the new front panel from 1" Luan mahogany, but another well-seasoned hardwood would have done as well, as would hardwood plywood or top-quality chipboard. I chose the mahogany because I liked its looks. Bob Abrams, a fine St. Louis instrument-maker and musician, and Peter Lippincott, itinerant carpenter and contra-dance caller, helped me with the woodwork.

We mounted the baffle-board in the box with the same screws that held the old ones; I marked the spots from the inside of the cabinet with a gimlet, then drilled my ⅛" pilot holes. We cut out the speaker holes with a jigsaw.

The woofer mounted with bolts and T-nuts, and here I ran into a small problem: a 1" thick mahogany panel is actually ¾" thick (damn this nonsense!), and the fixing bolts supplied by KEF are ¾" long, not enough to clear the panel and engage the T-nuts. Since I discovered this at 11:00 on a Saturday night, I borrowed some longer bolts from a very good friend, screwed in the woofer to engage the T-nuts, then removed the long bolts and replaced them with KEF's originals which looked better.

The tweeter mounted easily with wood screws. I made the duct from a section of mailing tube, soaked in polyurethane varnish to improve its stiffness, and I mounted it in its hole with a somewhat unorthodox sealant, cornstarch-and-soda modeling clay. It seems to work all right, and should present no problems as long as no one spills beer on it.

The crossover's external mounting

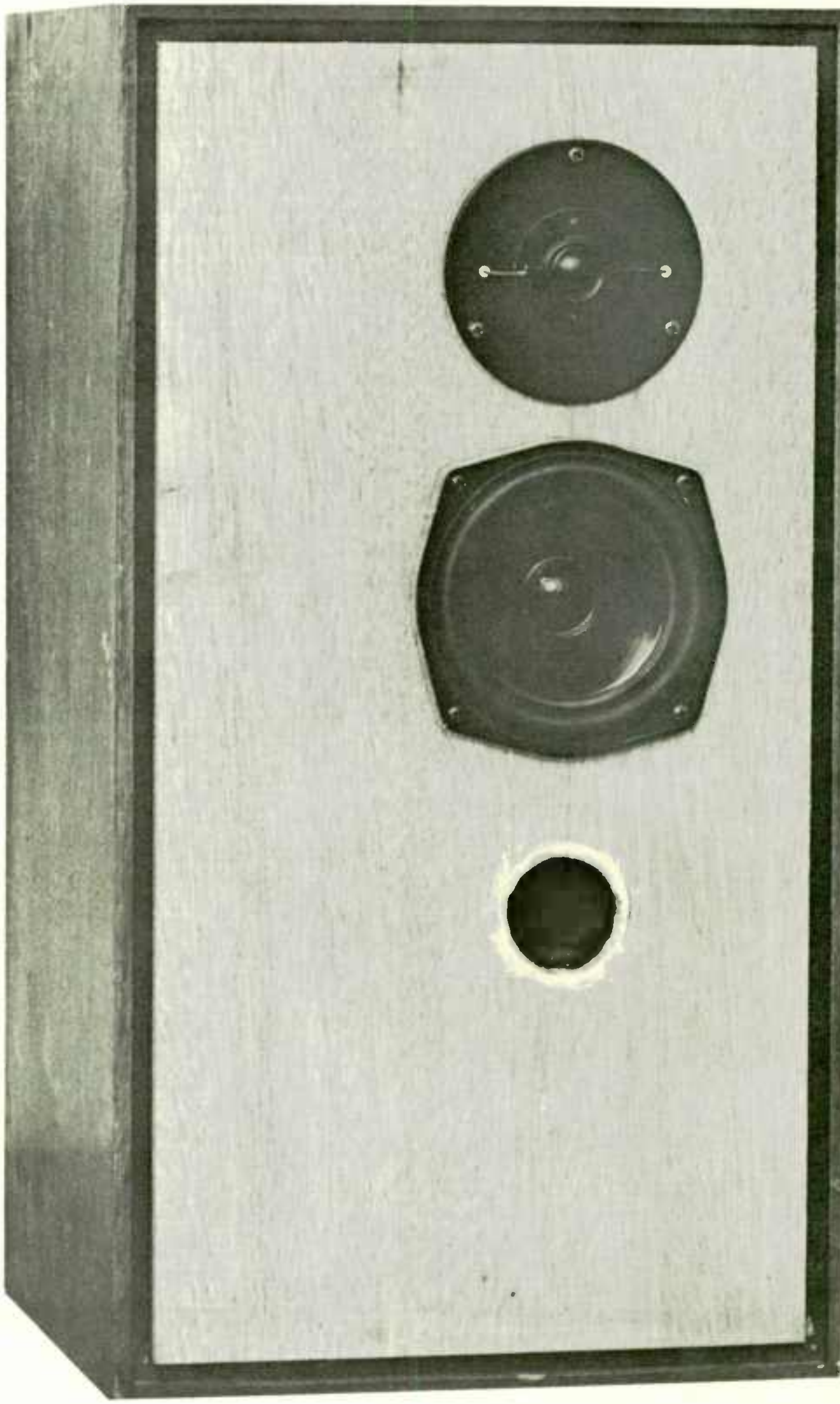

Fig. 4. Author's completed and upgraded speaker.

will facilitate possible biamping, should I get ambitious later on; I brought out the driver wires through small holes in the back, sealed with more modeling clay. I feel a bit more dubious about the clay here, and may replace it with epoxy one of these days. I first damped down the box's internal reflections with 1" fiberglass sheets on the walls, but I replaced them after a few days with a 6" batt of fiberglassfrom the local Speakercraft. The bass sounded tighter with the thin fiberglass, but there was an overall boxy sound that the 6" batts tend to diminish.

FIG. 1

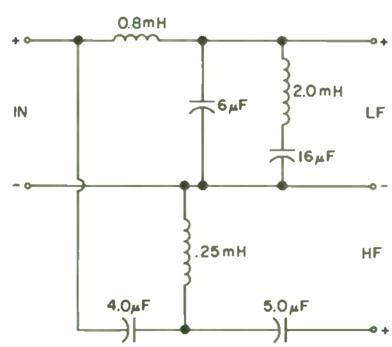

Fig. 1. KEF DN-13 SP1017 crossover network.

FIG. 3

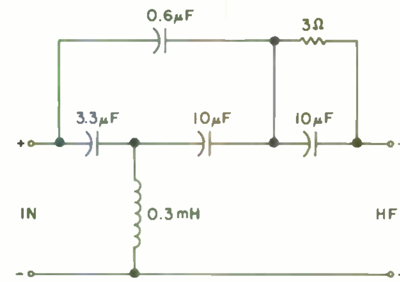

Fig. 3. Revised high pass section of crossover, KEF R-104aB. Note the reversed polarity.

CROSSOVER

As I was in a hurry to finish these speakers, I chose the route of least resistance (leaving capacitance and inductance aside) and used KEF's stock dividing network, the DN-13 (see *Fig. 1*). I discovered the T27 tweeter is pretty hot compared with the B110 woofer, and installed a simple attenuator between the tweeter

FIG. 2

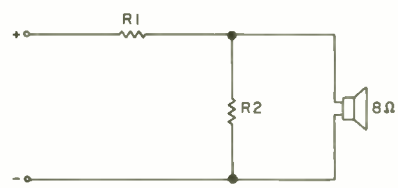

Fig. 2. Fixed attenuator for an 8Ω tweeter.

and the crossover. In this type of attenuator, known as an "L-pad" (see *Fig. 2*), we calculate the attenuation (A) by the formula:

$$(6)\ A = \frac{R_p}{R_p + R_1}$$

where R_p is the parallel combination

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IMPROVING A SMALLER SPEAKER

Continued from page 23

of R_1 and the speaker's 8-Ohm impedance. Since

$$(7)\ \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{8}$$

and $R_1 + R_p = 8$ ohms, in order to properly terminate the crossover network we can combine equations to obtain:

$$(8)\ R_1 = 8(1\text{-}A)$$

$$(9)\ R_p = 8 - R_1$$

$$(10)\ R_2 = \frac{1}{(1/R_{p1} - 1/8} = \frac{1}{(1/R_{p1} - .125}$$

To save a little work, Table 2 lists the appropriate values for various levels of attenuation. (I finally settled on 14dB.)

TABLE 2

Attenuation	R_1 Ω	R_2 Ω
.707 (3dB)	2.4	19
.500 (6dB)	4.0	8.0
.316 (10dB)	5.5	3.6
.250 (12dB)	6.0	2.7
.200 (14dB)	6.4	2.0

TABLE 3
VENTED-BOX SYSTEMS

Driver	Size (in)	f_s Hz)	Q_{ts}	V_{as} (liters)	Ideal f_3 (Hz)	Ideal V_B (liters)	Ideal Eff. (%)
KEF:							
B110 SP1003	5	38.0	.31	23.6	51	12.8	.42
B110 SP1057	5	38.0	.33	23.6	47	15.2	.38
B200 SP1014	8	24.7	.51	131.5	16	293.	.33
B200 SP1039	8	24.0	.45	130.0	19	205.	.36
B200 SP1054	8	24.0	.23	130.0	49	29.7	.86
B200 SP1063	8	24.7	.44	131.5	20	195.	.41
B139 SP1044	9x13	25.0	.37	164.0	26	148.	.66
Electro-Voice:							
SP-8C	8	55	.45	28.4	44	44.7	.93
SP-12C	12	45	.67	167.	20	827.	1.78
SP-15A	15	40	.45	283.	32	446.	3.59
JBL:							
2115	8	55	.48	35.	40	66.4	1.06
2215	15	20	.21	735.	46	130.	3.20
2231	15	16	.21	735.	37	130.	1.65
Altec:							
414-8C	12	34	.28	217.	52	87.1	3.15
411-8A	15	19	.35	830.	21	638.	1.59
416-8B	15	24	.28	677.	37	272.	3.47
CTS:							
6W10C	6	53	.43	27.2	21	37.4	.09
6W10R	6	40	.29	35.	59	16.	.79
8W16P	8	37	.45	68.2	29	107.	.68
8W16R	8	30	.45	80.	24	126.	.43
10W18C	10	24	.33	202.	29	130.	.83
10W20C	10	30	.46	158.	23	266.	.82
10W20R	10	25	.22	175.	54	35.4	1.40
12W32C	12	16	.23	702.	33	160.	1.39
12W38A	12	35	.32	233.	35	138.	3.12
12W54C	12	25	.25	240.	45	69.8	1.62
12FR54	12	31	.24	258.	59	66.5	3.48
15W54C	15	19	.19	943.	50	125.	4.02
Philips:							
AD-12200W	12	24	.33	314.	29	203.	1.30
AD-12250W	12	25	.33	331.	31	214.	1.55
Polydax:							
H1F-13J	5½	41	.32	19.5	52	11.5	.42
HD20-B25-H4	8	28	.40	83.0	26	92.7	.42

HOW DO THEY SOUND NOW? and HOW MUCH BETTER COULD THEY SOUND?

Now that the tweeter has been tamed, the speakers sound pretty good, although not perfect. My eventual plan is to replace the fiberglass with BAF wadding, which should stamp out much of the boxiness without overdeadening the bass. I should emphasize that the bass-deadening is quite slight, and still much preferable to the former boxiness—not to mention still sounding much better than the speakers did originally.

Another mechanical improvement high on my list is the installation of braces across all the long panels (1 x 1's should be adequate) and panel damping with bitumenized felt. Researchers have more strongly realized the importance of panel resonances in recent years—in some commercial speaker systems, including some very expensive ones, the panels radiate more at certain frequencies than the drivers! I can feel some vibration in these speakers on bass notes, which I shouldn't be able to do, so some panel damping and bracing is definitely in order.

With the BAF wadding replacing the fiberglass (less toxic, too), and the panels well-damped, the boxiness should be thoroughly banished. BAF wadding and bitumenized felt are both available by mail order from Falcon Electronics, Tabor House, Norwich Road, Mulbarton, Norwich, Norfolk NR48JT, England—their catalogue is an absolute goldmine for the home speaker constructor, and is available for a dollar bill. They even include sample swatches of grille cloths!

The one remaining problem is a slightly sizzly high end, and the insertion of further attenuation cuts the lower frequencies (around 3.5-8kHz) too much. That this is not an inherent problem with the T27 tweeter is shown by its superb performance in the KEF R-104aB system and the Rogers LS3/5a. Both these speakers, it is instructive to note, use highly complex

Continued on page 26

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IMPROVING A SMALLER SPEAKER

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crossovers to deal with precisely this problem; Martin Colloms, in his excellent *High Performance Loudspeakers* (New York, Wiley, 1978), outlines the approach KEF's engineers took to solving the problem, which is an outgrowth of the fact that a speaker coil is far from being a resistive load.

The new R-104aB network, shown in *Fig. 3*, provides a more accurate frequency and phase response for the T27 than the stock network, and I may install it. Another possibility is the LS3/5a crossover. The latter, as well as the treble section of the R-104aB, is also available from Falcon Electronics.

Whatever I do to the crossover, I'll probably replace all the capacitors with mylars, just on general principles. Or I may simply bi-amp the things, using the two Acrosound amps that have been gathering dust in a closet for a while.

Following the lead of Rogers, AR, Electro-Voice and other manufacturers, I added a ring of absorbent material around the tweeter to eliminate cabinet-edge diffraction and woofer-cone reflection and cavity resonance. The difference is dramatic, and not at all subtle: the slight hollowness of the midrange simply vanished, the tizzy quality on the top changed to a *much* cleaner, more effortless sound, and the stereo imaging improved drastically. I would *strongly* urge anyone whose speakers do not have some form of diffraction prevention (meaning nearly everyone) to try the experiment. Make a doughnut-shaped ring out of a wad of ordinary drugstore type cotton by poking a hole in the center and spreading the fibers. Attach it to the front of the speaker, surrounding the tweeter with a space of about 1cm between the doughnut and the tweeter. Make sure the cotton is flush with the front of the speaker cabinet by using some double-stick Scotch tape; there should be no space for the sound to go except forwards. You should notice quite an improvement. If you want to make the modification permanent, cotton doughnuts are somewhat unsightly, so I would recommend instead making a doughnut from soft ½" felt (non-bitumenized) and gluing it to the front of the tweeter. Taper and roughen the inside of the doughnut-hole to avoid cavity resonances. No joke—I know of no greater improvement in audio that costs so little.

GO THOU AND DO LIKEWISE

If you should have a pair of speakers that you feel like upgrading, your design process will resemble mine. To speed up the process a bit, I've provided Table 3—data similar to Hoge's Table I, with additional data on ideal cabinet size (i.e., maximally flat response) and low-frequency cutoff with that ideal cabinet.

To use the table, measure your box and compute its approximate volume (remember that 1 liter = 1000 cubic centimeters). Now look in the table for drivers whose ideal box falls between .7 and 1.4 x the size of your cabinet, with favorable bass cutoff figures. If all is to your liking, measure your box more precisely and charge ahead.

Some of the drivers turn out to require very large cabinets, with a very low bass cutoff (the KEF B200 SP1014, for example). While they make very fine subwoofers, the intended use of these high-Q drivers is in closed-box systems. For this purpose, I have prepared Table 4, listing box volume and cutoff frequency for a maximally-flat closed-box system. Again, find a driver whose ideal box size falls between .7 x and 1.4x your cabinet volume. Within these limits, the bass cutoff should vary no more than 1.5Hz, with no more than .33dB of ripple. Once the driver is chosen, no further calculations are necessary—closed-box systems are inherently simpler to design than vented-box ones.

Incidentally, the eagle-eyed may spot some differences in data between my table and Hoge's. My data were obtained, for the most part, from manufacturers' data sheets, while his are the result of his own tests. At press time, we are in correspondence to try to resolve the discrepancy. Of the drivers listed only one besides the KEF units is made with Bextrene—the Polydax HD-20-B25-H4. I am currently attempting to collect data on other Bextrene drivers, notably Dalesford and Celestion, and will report them as soon as possible.

You have probably noticed a certain partiality on my part towards KEF drivers. I derived this from many sources, including: their fine performance in many high-accuracy commercial systems; the cooperativeness of the company in supplying crossover designs for a particular driver's actual characteristics; their relatively low price; their suitability for the bookshelf-type systems so many of us

TABLE 4
CLOSED-BOX SYSTEMS

Driver	Size (in)	Ideal f_3 (Hz)	Ideal V_B (liters)	Ideal Eff. (%)
KEF:				
B110 SP1003	5	87	5.6	.49
B200 SP1014	8	34	143.	.76
B200 SP1039	8	38	88.5	.63
B200 SP1063	8	40	83.2	.69
B139 SP1044	9x13	48	61.8	2.65
JBL:				
2231A	15	54	71.1	1.47
Altec:				
411-8A	15	38	269.	2.01
CTS:				
8W16R	8	47	54.5	.75
10W18C	10	51	56.2	1.01
10W20C	10	46	116.	1.50
12W32C	12	49	83.0	1.30
Philips:				
AD-12200W	12	51	87.4	1.57
AD-12250W	12	54	92.2	1.87
POLYDAX:				
HD20-B25-H4	8	49	39.1	.63

are blessed/cursed with from earlier times; and a certain rather overt Anglophilia. Be advised that the drivers are *not* worth buying from Falcon: the shipping charges are so high, due to the drivers' high density, that you wind up paying the same price you would here and waiting a lot longer. I bought mine from Victor's Stereo, 5701 W. Dempster, Morton Grove, IL 60053; you can locate other dealers by writing to KEF for their dealer list (KEF, Intratec, Dept. E, PO Box 17414, Dulles Int. Airport, Washington DC 20041) orthrough the classified ads in *SB*, *TAA* or *Audio*. My drivers cost $127, plus $1.85 U.P.S. charges; the wood cost $15, and the fiberglass was about $3.00.

CONCLUSION

Upgrading a pair of not-so-hot speakers is not a particularly daunting task; I finished the main part of the design and construction work over one long weekend, and I'm not by any means an experienced woodworker. Although the speakers are not perfect, nor are they state-of-the-art, I do feel they are state-of-the-$140-art and a vast improvement over what I had.

To those folks who feel intimidated by the math involved in the design process, I offer my sympathy and the following cautionary tale. Be not discouraged! □

MUSES AND MUSIC

Since the music moves you—the muse is almost surely able to do so as well. The writer's muse, that is. Put pen to paper or better yet, typewriter ribbon to paper with a clear, orderly account of your adventure in speaker construction, or any related field of endeavor leading to good listening. Send it along with a stamped, return envelope. We pay modestly for articles, so if your muse moves you, write us about it and we'll answer promptly with suggestions and saying whether or not we have such an article, whether one is already in preparation, or whether we are interested. Some of our best articles come from people who have never before written for periodicals. And if your muse is as silent as a tomb, don't let that stop you. Write anyway and let's see what develops. We have a nice sheet of suggestions for authors which we will send to nearly anybody who asks for it.

A CAUTIONARY TALE

In the beginning the Lord created the heavens and the earth, and the moon and the stars, and the land and the sea, and the fish that swim and the birds that fly, and he told all of the animals to go forth, and be fruitful, and multiply. After a time the Lord decided it was appropriate to inspect his handiwork, so he went down to Eden to look around.

All seemed to be well; the beavers frolicked in the water, with little beavers playing in the shallow places; the birds fluttered about their nest, while the little birds cheeped merrily away; even the elephants lumbered proudly along with a baby elephant tagging behind. The only discordant note was sounded by two forlorn snakes who sat pathetically alone in a deserted clearing. The Lord was moved and concerned, so he quietly walked into the clearing and asked, "Is anything the matter?"

"Everything!" moaned one of the snakes. "There's nothing we'd like better than to follow your directive, and be fruitful and multiply and all that, but we can't—because you made us adders!"

(Note: those of you who are already groaning had best bear up—there is far, far worse to come.)

Well, the Lord admitted he had made a terrible mistake and he couldn't come up with any obvious way to correct it. "However," he said, "I promise I'll think as hard as I can about it. In the meantime, you might consult with some of the other animals; one of them might have a solution."

So the Lord went back to Heaven, and thought and thought until tears came to his eyes; but try as he might he could not think of a way out. Reluctantly, he journeyed back to Eden to admit defeat.

When he got to Eden, however, things seemed somehow different. The beavers winked and grinned as he went by and when he arrived in the clearing he found a huge fallen tree. From the toothmarks at the base he could tell it was the beavers' work, but this was the least of his interests. For sitting on the side of the tree, smiling and beaming like any proud parents, were the two snakes—with fully a dozen snakelings wriggling happily around them.

"Well!" exclaimed the Lord. "I had come down here to confess that I couldn't solve your problem, but you seem to have done quite well without me. Tell me, how did you do it? Being adders, how could you possibly succeed in multiplying like this?"

"Ah," said the mother snake. "Even adders can multiply—on a log table!"

Diffraction—the True Story

by Robert C. Kral

Diffraction is an acoustic phenomenon that has taken its place beside the Loch Ness monster as a creature suffering from an identity crisis. The major difference between the two is that diffraction has received relatively little attention. In the following article I thoroughly document diffraction's effect on loudspeaker systems, in an attempt to clear once and for all the murky depths of the loch.

WHAT IS DIFFRACTION?

Suppose you are standing on a bridge supported by rectangular concrete pillars sunken into the bed of a small river. It's a quiet afternoon; you're relaxing. You pick up a pebble and drop it into the water below.

Now watch what happens. When the wave crest created by the pebble approaches the rectangular pillar, the pillar's front and sides create noticeable disturbances. This is similar to what happens when a sound wave traveling through air strikes a solid rectangular object. The incident wave will tend to pass around the obstacle, and in the process its direction of propagation will change. This phenomenon is known as diffraction.

In 1938 Muller, Black and Dunn gave diffraction a rigorous mathematical treatment[1]. They investigated the diffraction produced by differently shaped objects in the laboratory, then tried to approximate the experimental results mathematically with the theory they developed. *Fig. 1* shows their results for a cube. The vertical scale shows the difference between the sound pressure on the front face of the cube and the constant sound pressure of the incident wave, expressed in decibels, while the horizontal scale gives the ratio of the length of the front face of the cube to the wavelength of the impinging wave.

Take a look at *Fig. 1's* $\theta=0$, $\theta=30$, and $\theta=60$ degree curves. Notice how the sound pressure increases and then becomes constant as the wavelength becomes small in comparison to the size of the cube. This characteristic has some interesting historic value.

In the 1920s experimenters began to suspect an inaccuracy in their sound pressure measurements. They reasoned that the pressure at their microphone's diaphragm would be double that in the undisturbed sound wave because the wave would be reflected by the diaphragm. To compensate for this effect, they halved all their sound pressure measurements.

Other experimenters were hesitant to follow suit. They reasoned that the measured sound wave would not be reflected by the diaphragm: instead, they suspected the wave would flow around the microphone. This controversy prompted investigation into diffraction which proved that if the wavelength is small compared to the size of the diaphragm, the wave will reflect. If the wavelength is large compared to the size of the diaphragm, the wave will flow around it. Therefore, the effect of diffraction is to vary the sound pressure on the diaphragm from the true pressure in the incident wave, at low frequencies, to double this value at high frequencies. *Fig. 1* nicely documents this effect.

Note two important points. First, diffraction is contingent upon frequency. In other words, the effects of diffraction will vary depending on the relation of the obstacle's size to the wavelength of the incident wave. Secondly, diffraction is contingent upon the angle at which the incident wave strikes the object (we call this the angle of incidence). Diffraction's effect is most pronounced when the incident wave strikes the object squarely (the angle of incidence is zero), and is mitigated as the angle of incidence increases.

THE ODD COUPLE: DIFFRACTION AND THE SPEAKER CABINET

Our discussion so far must seem devoid of any relation to loudspeaker systems and their performance. Enter the acoustic reciprocity theorem!

Muller, Black and Dunn found the diffraction caused by a cube in a sound field. They measured the sound pressure with a microphone placed in the cube's front face, creating the sound field by placing a loudspeaker four feet away. The acoustic reciprocity theorem says, in short, that the same sound pressure will be recorded at the microphone regardless of whether the loudspeaker (the source) and the microphone (the point of measurement) exchange positions. In other words, *Fig. 1* also shows the effect of diffraction on the frequency response of a loudspeaker mounted in a cube, as measured by a microphone four feet away.

We may now tailor the two points I brought out earlier to fit this new situation. First, diffraction varies with frequency—or, alternately, diffraction is contingent upon the wavelength the loudspeaker produces and the size of the speaker enclosure. Secondly, the effects of diffraction vary depending on the position of our microphone relative to the system's axis. The effects of diffraction are most severe right in front of the speaker (on axis), but diminish as one moves to one side or the other (off axis).

Before we get carried away, I have to temper these remarks. A driver will *not* diffract sound waves over its enclosure's outside surface if it is "beaming." In other words, diffraction poses problems only at those frequencies that the driver radiates strongly 90 degrees off axis (parallel to the surface of the front baffle). And all diffraction experiments must be carried out in an anechoic chamber. In a normal reflective environment it would be impossible to isolate the effects of diffraction.

OLSON AND THE GOLDEN RULES

In 1951, Harry F. Olson determined the effect of diffraction on the frequency response of a small, full range driver mounted on the front baffle of each of 12 differently shaped enclosures[2]. His results for cubical, rectangular, and spherical enclosures appear as the solid curves in *Figs. 2, 3, and 4*.

Let's look at the cube first. The sharp discontinuities at each edge of the front surface produce a strongly diffracted wave. The first peak occurs at 460Hz and the other peaks and dips occur at multiples of this frequency. Not coincidentally, 460Hz corresponds to a wavelength of 2.4 feet, which is approximately the cube's width.

Now let's look at the rectangular enclosure. Alas, problems arise. It's difficult to make the same generalizations we made about the cube because the driver is not equidistant from all four edges. In the case of the cube, each edge produced diffracted waves of the same phase and amplitude, compoun-

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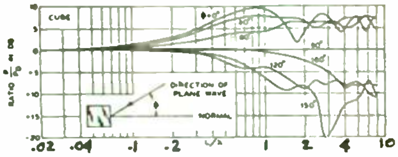

Fig. 1. Ratio of the pressure on a cube to the pressure in the incident wave.

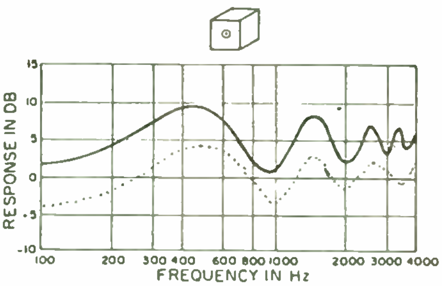

Fig. 2. Diffracted response of cube.

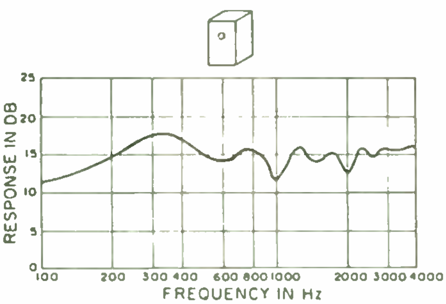

Fig. 3. Diffracted response of rectangular parallelepiped.

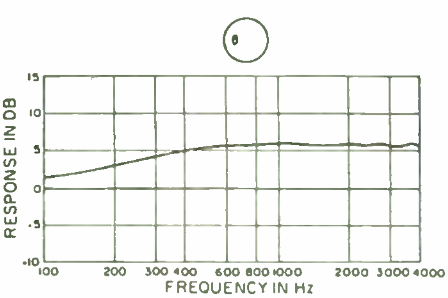

Fig. 4. Diffracted response of sphere.

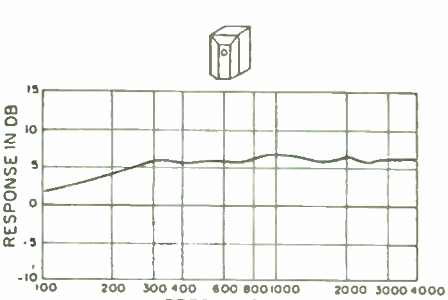

Fig. 5. Diffracted response of rectangular truncated pyramid & parallelepiped.

Continued from page 28

ding the net effect. This brings us to the First Golden Rule of Thumb for loudspeaker engineers concerned about diffraction:

1. Loudspeakers mounted on the front baffle of an enclosure should not be equidistant from any two or more sides. This will help ensure that the effects of diffraction will be staggered.

Fig. 4 is really interesting. Notice the sphere causes no significant peaks or dips whatsoever, because it has no sharp edges; the diffracted waves are therefore of uniformly varied phase and amplitude. Since a spherical enclosure would be difficult to construct Olson proposed a rectangular truncated pyramid and parallelepiped combination. *Fig. 5* shows the enclosure and its frequency response characteristic. This brings us to the Second Golden Rule of Thumb for diffraction-conscious engineers:

2. There should be no sharp boundaries on the front baffle of an enclosure upon which drivers are mounted. In other words, there should be a smooth, gradual transition from the cabinet's front to its sides. (Sorry, rounding the edges with a file won't help.)

THE WORLD RIDDLE

Trouble is, diffraction's a cloudy issue, similar in this respect to Doppler distortion and phase coherence. One must wonder why manufacturers are bent on building rectangular enclosures if these boxes are plagued by diffraction.

Are our views biased? Olson, by mounting one full range driver at or near the center of each enclosure and measuring the effects of diffraction directly on-axis, surely evaluated a worst-case condition. Most high-fidelity speaker systems consist of two or more drivers, each producing its own peculiar pattern of diffracted waves depending on the bandwidth it covers,, where it is mounted, its radiation 90 degrees off-axis, and the crossover network. And people often listen to a stereo set-up way off-axis. So what's happening in the real world?

THE ANSWER

Several years ago I endeavored to satisfy my curiosity by determining how diffraction affected the frequency response of a best-selling two-way bookshelf system.[3] I began by writing a computer program based on Muller, Black and Dunn, which could predict the diffraction-affected response of a non-directional driver mounted in any given location on a rectangular baffle of any given dimensions. To check the program's utility, I tried to duplicate Olson's findings for a driver mounted in the center of a two foot cube. My results—the dotted curve in *Fig. 2*, displaced 5dB for clarity—compared favorably with Olson's. Then I applied the program to the bookshelf system under investigation.

Fig. 6 shows how diffraction would affect a full range non-directional driver placed in the tweeter's position on the enclosure's front baffle (the curves are displaced 5dB for clarity). Please note the broad 8dB peak centered at 1kHz and the 5dB valley centered at about 2.5kHz in the on-axis response. As the angle off-axis increases, the peak becomes broader, the valley becomes shallower. At 60 degrees off-axis, the net effect is a boost of about 6dB at the higher frequencies. The curves for the woofer's position (*Fig. 7*) are similar, except the peak is centered at about 800Hz and the valley at 1.5kHz.

To apply these computed diffraction curves to the bookshelf system's drivers, I determined their bandwidths and relative strength of radiation 90 degrees off axis in an anechoic chamber. Although the woofer responded beyond 1kHz, it did not do so 90 degrees off-axis. All that diffraction could be responsible for, therefore, would be a broad peak centered at 800Hz. The tweeter, however, contributed measurably above 900Hz, and its 90 degrees off-axis response was strong up to about 4kHz: hence, the tweeter's response should be elevated somewhat between 1 and 6kHz, with a 5dB valley in between.

Now look at the anechoic frequency response curves in *Fig. 8* (displaced 5dB for clarity). In the on-axis plot, diffraction predictably imparts a broad 8dB peak centered at 1kHz. The boost incurred by diffraction is mitigated above 4kHz, where the tweeter begins to beam. Centered at 2.5kHz is a cavernous 13dB pit, attributable largely to diffraction. Surprisingly the off-axis curves follow the computed predictions even more closely. Notice how the curves flatten out at the off-axis positions, and how the 2.5kHz pit shrinks and moves up in frequency.

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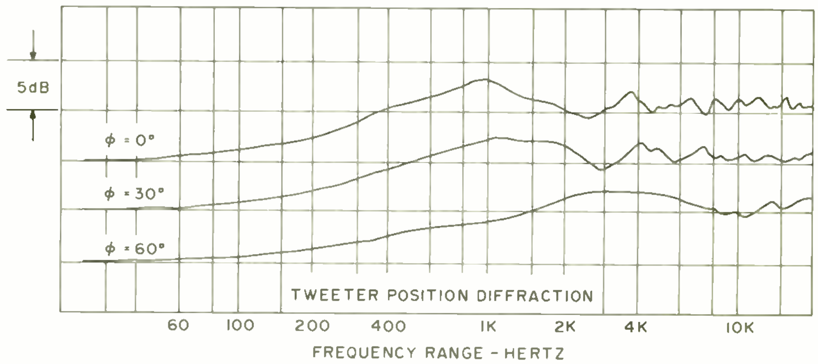

Fig. 6. Tweeter position diffracted.

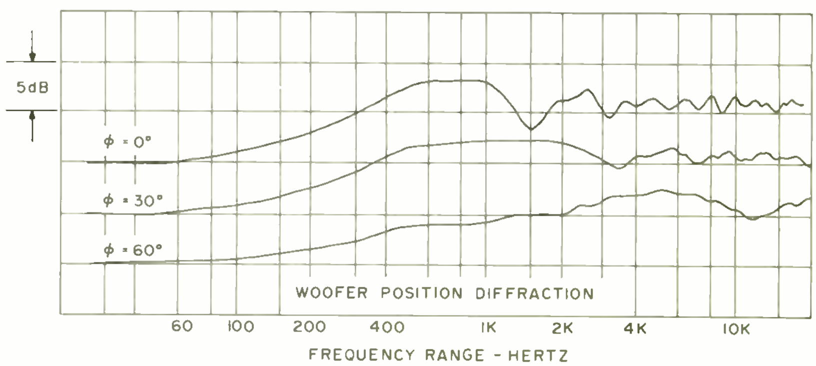

Fig. 7. Woofer position diffracted.

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DIFFRACTION—THE TRUE STORY

Continued from page 30

A MORE DETAILED INQUIRY

We can best understand the unpredictably large valley at 2.5kHz by dissecting the on axis anechoic curve (*Fig. 9*). The solid line shows the woofer's response in the system, the dashed line shows the tweeter's response, and the dotted line shows how the two combine in the crossover region. Notice the tweeter is solely responsible for the dip, which centers at 2kHz rather than 2.5kHz, where the computed curves suggested it should be. The enclosure sides are solely responsible for this. When I mounted the tweeters in a mock-up of the front baffle itself, so no enclosure sides affected diffraction, the dip moved back to 2.5kHz (its amplitude was unaffected).

Part of the problem is a crossover anomaly. The tweeter and woofer responses add at 1kHz to raise the left wall of the dip 5dB. And in *Fig. 10*, note the right wall of the dip is raised 5dB by a 4kHz peak in the tweeter's on-axis response, measured outside the cabinet with the crossover connected. This peak is apparently caused by diffraction around a 4" square piece of ¼" pressboard, upon which the tweeter diaphragm is mounted, and which is mounted by design a quarter inch in front of the front baffle. Because this diffracting surface is a part of the tweeter, and because there is free space between it and the front baffle, the pressboard will color the tweeter's response regardless of whether we evaluate the tweeter in the cabinet or in free air. At any rate, these two problems contribute five decibels to the 13dB aberration.

Finally, diffraction around an inch deep rectangular molding, which serves as a grille frame on the cabinet front, adds 3dB to the 1kHz peak, 3dB to the 4kHz peak, and 1dB to the 2.5kHz dip, for a net effect of four decibels. I evaluated the effects by removing the molding from the front baffle mock-up mentioned earlier (rather than by sawing the molding off the original enclosure) by mounting the tweeter in its proper location, and by measuring its response on-axis. The molding had a similar though somewhat more subtle effect on the off-axis response. Nevertheless, this accounts for four more decibels of the 13dB aberration, leaving an approximate 4dB dip at 2.5kHz, neatly attributable to diffraction around the edges of the enclosure.

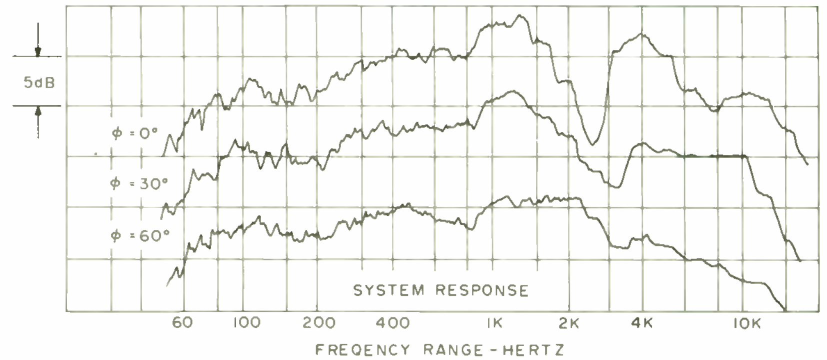


Fig. 8. System response Frequency range—Hertz.

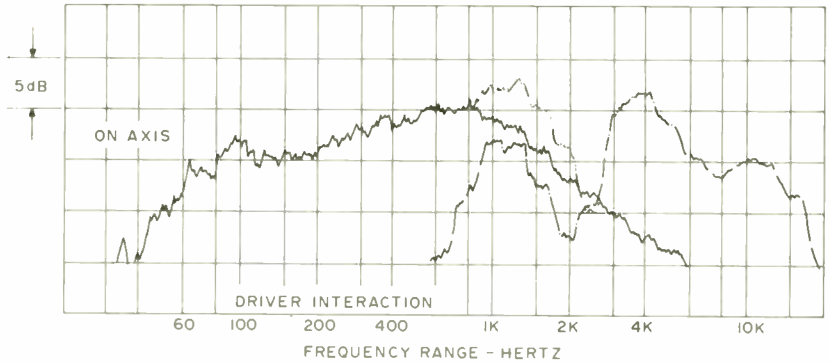


Fig. 9. Driver interaction.

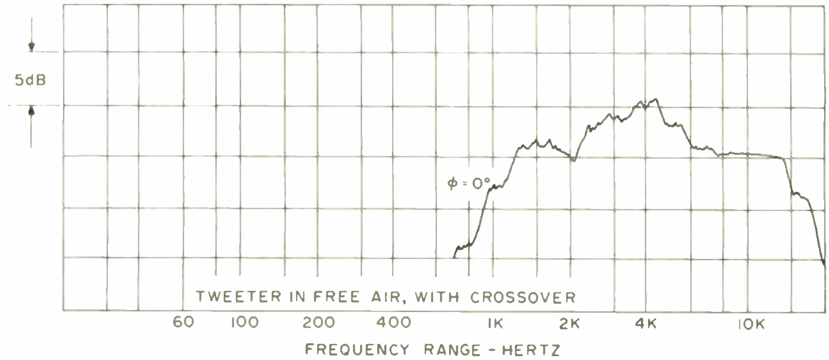


Fig. 10. Tweeter in free air, with crossover.

WHAT DOES IT ALL MEAN?

In home hi-fi speaker systems diffraction works in mysterious ways. Although the front baffle edges are the main diffracting surfaces, other less obvious factors may cause the effects of diffraction to snowball. For instance, the edges may be responsible for 5 or 10dB aberrations. If a driver is not mounted flush with the front baffle, diffraction might add or subtract up to 5dB to or from the system's frequency response. If a molding extends beyond the front baffle surface to serve as a grille frame, another 5dB may be added or subtracted. And if we do not give meticulous care to diffraction's role in the crossover region we might incur still other anomalies, perhaps 5dB or so in magnitude.

The end result could be a giant 25dB response variation; or diffraction might impart only a gentle five decibel boost at certain frequencies. That depends on how many drivers we use in the system, their bandwidths as limited by the crossover network, their radiation 90 degrees off-axis, and the size and shape of the enclosure. If these qualifications seem overwhelming, all we need to quell diffraction is to flush mount each driver on the front baffle so it is not equidistant from any two edges, and to eliminate all protrusions and abrupt discontinuities from the cabinet's front. If we take these two steps we need worry no further.

THE REAL WORLD

Right now you're probably saying, "Big deal. All these measurements have been made in an anechoic chamber. So what's diffraction doing in my living room?"

Aha! Good question. Basically, you can forget about diffraction in your living room. I'll give you a few good reasons.

First of all, measuring a loudspeaker's frequency response on-axis in an anechoic chamber gives no indication of how the speaker will perform in a room. Frequency response measurements taken in a reverberation chamber give a more accurate indication of its performance. Such a room reflects all the sound produced inside it—unlike an anechoic room, which absorbs all the sound. Hence, instead of measuring a system's response at one isolated position relative to it's axis, the reverberation chamber averages out the system's response in all directions.

Now, since diffraction will occur only at those frequencies at which a driver is omnidirectional, and since its effects will be apparent only in a narrow area in front of the speaker, the diffracted waves represent only a small portion of the total sound produced by the speaker, even if they seem substantial in on-axis anechoic measurements. Hence, the effects of diffraction will not be apparent in a reverberation chamber, nor will they be apparent in a normally reflective listening environment—especially when one considers that most serious stereo listening is done well off-axis, where the effects of diffraction have all but disappeared.

Also, sound waves inside a room are reflected and diffracted over and over again. Although the enclosure's front baffle may have been the main diffracting surface in the anechoic chamber, its role in a reflective listening environment could be radically different. In fact, more deleterious diffraction might occur around the bookshelf than around the bookshelf speakers.

SORTING IT OUT

You can see why manufacturers have metaphorically thumbed their corporate noses at diffraction: they feel rectifying the problem would not be "cost effective." Perhaps they are right. A viable solution would necessitate construction of Olson's "rectangular truncated pyramid and parallelepiped combination." This enclosure is more difficult and therefore more expensive to fabricate than a standard rectangular box, yet it can yield no readily audible improvement. Most people don't know what diffraction is anyway, and they don't care. Perhaps this is as it should be. We may regard diffraction as kin to magnet weight and gap flux density: of consequence only insofar as it affects a readily measurable performance parameter. Even then it's the black sheep of the family, since its effects vary with the loudspeaker's environment.

On the other hand, such a generalized philosophy may spawn other problems because of its inherent inflexibility. Imagine an engineer who does not recognize diffraction's existence, and who adjusts crossover networks in an anechoic chamber. He will incorrectly attribute the effects of diffraction to the drivers themselves. If he compounds the problem by adjusting the crossovers for maximum smoothness on-axis in the anechoic chamber, the system's frequency response in an average listening room will be anything but smooth.

And what about the poor soul whose speakers are adversely affected by diffraction in his listening room? After all, such a situation is possible. The poor chap would have to listen to his speakers nearly on-axis, either outdoors, where the environment is anechoic or in a room that absorbs most of the smooth off-axis response at the frequencies at which diffraction occurs. I can't think of a better example of this than a recording engineer in his studio. Yet I can't recall seeing a studio monitor that hasn't a rectangular, acoustically impossible cabinet.

And what about the audiophile who's just spent hundreds of dollars on a pair of 12 cubic foot monsters? Cost effectiveness can no longer be used as a valid excuse for designing an enclosure that defies common acoustic sense.

TO THE HOBBYIST

If you like to roll your own, the easiest way to deal with diffraction is to talk softly and follow the two Golden Rules mentioned earlier. Just adjust the dimensions of Olson's enclosure* to yield the interior volume you desire.

*"A rectangular truncated pyramid is mounted upon a rectangular parallelepiped. The lengths of the edges of the rectangular parallelepiped are 1, 2, and 3 feet. The lengths of the edges of the truncated surface are 1 foot and 2½ feet. The height of the truncated pyramid is 6 inches. One surface of the pyramid and one surface of the parallelepiped lie in the same plane."

Of course, if you lack the facilities to make the cabinet, don't worry about it. Diffraction neither promotes tooth decay nor causes cancer in laboratory rats nor imparts a boxy sound to boxy loudspeakers. And if anyone tries to sell you that, just tell him it ain't so.

REFERENCES

1. G. G. Muller, R. Black, and T. E. Dunn, "The Diffraction Produced by Cylindrical and Cubical Obstacles and by Circular and Square Plates," *Journal of the Acoustical Society of America*, Vol. 10, No. 1 (July 1948), pp. 6-13.

2. Harry F. Olson, "Direct Radiator Loudspeaker Enclosures," *Audio Engineering*, November, 1951.

3. Robert C. Kral, "Effects of Diffraction on Loudspeaker System Performance," *IEEE Utah Section Student Proceedings*, Vol. 5, No. 1 (April 1977).

ADDITIONAL READING

L. J. Sivian and H. T. O'Neil, "On Sound Diffraction Caused by Rigid Circular Plate, Square Plate, and Semilnfinite Screen," *J. Acous. Society of America*, Vol. 3 (April 1932), pp. 483-510.

Stuart Ballantine, "Effect of Diffraction Around the Microphone in Sound Measurements," *Physical Review*, Vol. 32 (December 1928)sic, pp. 988-992.

G. W. Stewart, "The Acoustic Shadow of a Rigid Sphere With Certain Applications in Architectural Acoustics and Audition," *Physical Review*, Vol. 33, No. 6 (1911)sic.

Harry F. Olson, *Acoustical Engineering*, D. Van Nostrand Company, 1957, pp. 17-26.

James Y. Pann is a senior professional engineer, an amateur string player and audio hobbyist. His speaker systems are 6×4×2.5—feet that is. The top segments swivel to adjust for best sound response in the listening area. The enclosures are made of double thick ¾" plywood and particle board (plywood outside, particle board inside) front and sides and triple thick back. Sized lumber two inches square provides the internal bracing. Each four-way units weighs about 650 pounds.

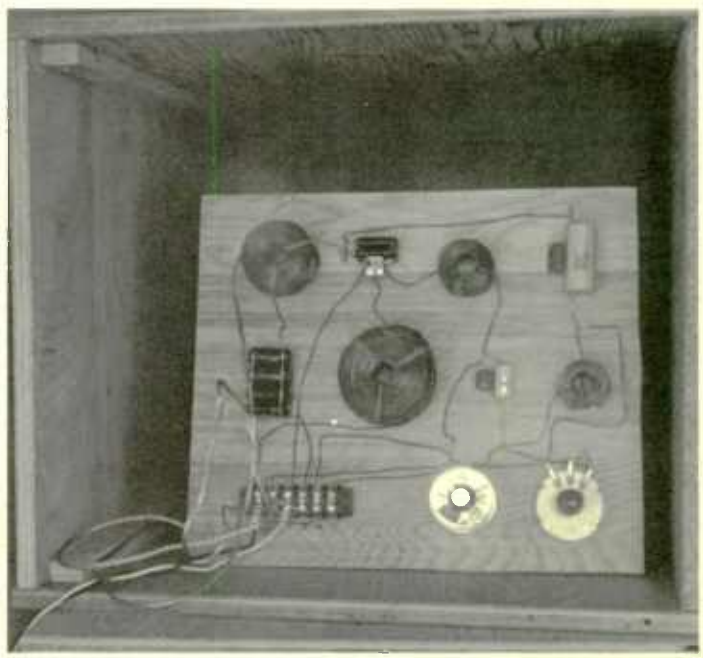
An electronic crossover (12dB/octave) divides the signal at 100Hz and a passive crossover (12dB/octave) further divides the spectrum at 350Hz and 5kHz (see photo). The subwoofers are ElectroVoice 30" drivers; the mid-bass is a 15" cone driver and the midrange and tweeter are horns. The latter three are Speakerlab products.

"Using the CBS pink noise record STR-140 and an SPL meter, the system is adjusted to correspond to a curve derived from the Fletcher-Munson data on hearing.[1] The optimum listening level is at around 70dB when the listener is 15 feet from the speaker system (R & L driven simultaneously). Chamber music at 65dB; symphonic music at 75dB (*fff* at 90dB)." the system builder reports.

The subwoofer is driven by a Dynaco Stereo 120 and the upper three channels by Dynaco Mark IIIs.

Mr. Pann graciously invites listeners to visit him when in the Bay area. He lives in Richmond California 94804.

[1]Now superseded by the S. S. Stevens experiments. See Stevens J. Acoustical Soc. Am. Vol 51, No. 2, pt. 2 (1972) p. 575-601. Also Tomlinson Holman's excellent Preprint No. 1281, (D-4) from the Nov. 4-7, 1977 Audio Engineering Society Convention, titled "Loudness Compensations: Use and Abuse."



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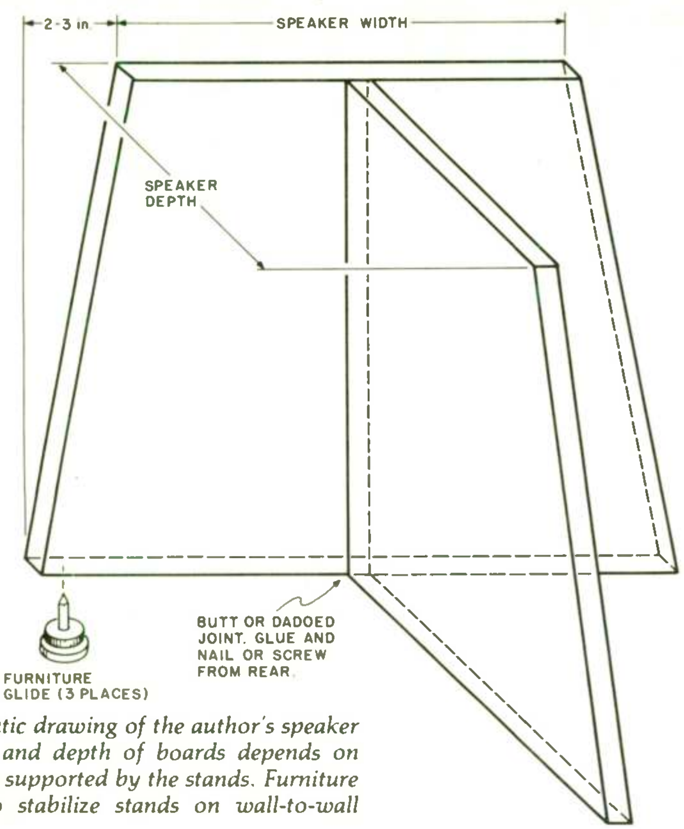

Fig. 1. Schematic drawing of the author's speaker stand. Width and depth of boards depends on speakers being supported by the stands. Furniture glides help to stabilize stands on wall-to-wall carpeting.

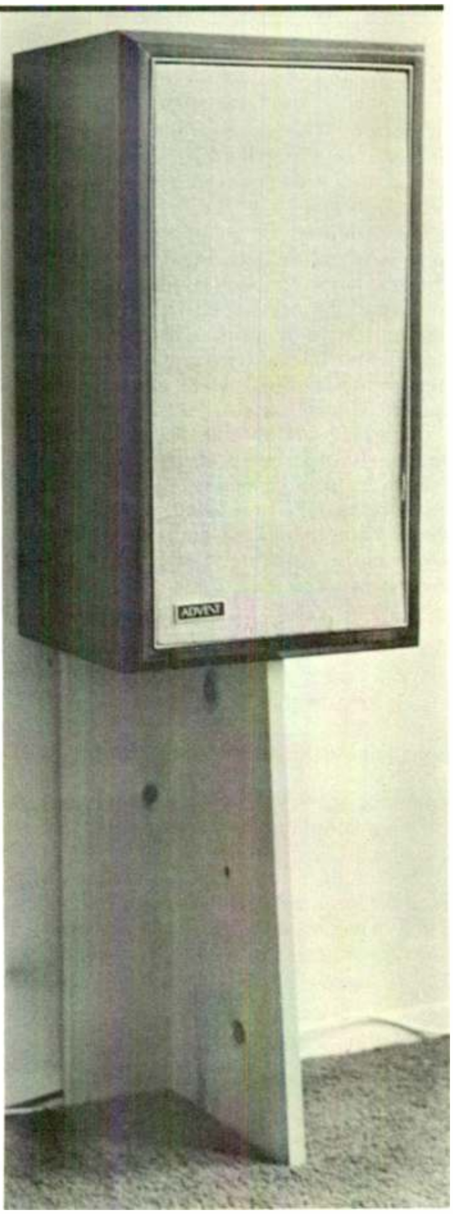

Photo A. Author says rear board should be wider than his prototype—and have tapered shape so the base is two to four inches wider than the top.

SIMPLE SPEAKER STANDS

I DESIGNED THE STANDS shown in *Fig. 1* to support loudspeakers along a wall. They are easy to construct from two pieces of lumber and are reasonably unobtrusive.

I give no dimensions because they vary with speaker size and height above the floor. Make the bottom of each side two or three inches wider than the top to provide stability.

After sanding, I applied a clear penetrating resin finish such as Deep Finish Firzite. It provides an oil-finish appearance without too much work.

Wall-to-wall carpet presents some problems. The carpet and pad may cause the stands to rock if pushed. Install small feet or furniture glides at the extremities of the base to compress the carpet and make firm contact with the floor. Carpet often is secured with a tack-strip which raises the edge a bit. The feet may have to be tall enough to clear the tack-strip or of different heights to adjust for the varying carpet depths.

These probably aren't the stands to have if small children are about. The triangular base is inherently less stable than a rectangle with the same dimensions. Note that my prototype's rear board is too narrow; I should have glued two pieces of stock together for a firmer foundation. Another case of "do as I say, not as I do"!

FREDERICK M. GLOECKLER, JR.
LORTON VA 22079

SB Mailbox

Some editors I have known sit down before the first issue of a new publication is published and write a lot of very interesting letters to "prime the pump" as it were. We've had several letters, some of them with comments, some complementary and the two we are including below. We are asking Mr. Saffran to prepare an article on using the Thiele ideas for a future issue.

I am sure we'll be hearing from many of you about the materials in this issue. We hope you will share your ideas, your questions, and any corrections we need to make. —*The Editor*

THEILE MAGIC IN A WEBB

THE RECENT "DISCOVERY" of Dr. Theile's work on bass reflex enclosures is a great boon to the home speaker builder. So useful is his work that many people now speak of "Theile alignments" instead of the plain old "bass reflex." Whatever you call it, a properly aligned vented enclosure gives the best compromise among box size, cutoff, and transient response of any enclosure design (with the possible exception of slot loading).

I have a dramatic example of this in my living room: a Webb "TLS" which has none of the internal baffles or stuffing that make up a transmission line. (see *TAA* 75/1, p. 3.) Instead it is "just" a box, with a vent at

Continued overleaf

Mailbox

Continued from page 35

the bottom. The result is that instead of the 40 Hertz cutoff of the original design, the system now goes down to 20 Hertz—a very clean and tight bass.

The usual source for information on the various possible alignments is Table 1 of Theile's first paper[1]. His alignments, however, are only specific, arbitrary examples of a continuous spectrum of alignments. To make interpolation between these values easier, I have derived several equations, which are accurate to 2%.

The starting point is the Q_t of the driver, which should be adjusted to include resistances from crossover, fuse, or connecting wires. Given this, calculate the ratio of driver compliance equivalent volume to box volume, alpha $= V_{as}/V_b$. If Q_t is less than or equal to 0.42,

$$\log_{10}(\text{alpha}) = \frac{.4185 - Q_t}{.236}$$

If Q_t is greater than 0.42:

$$\log_{10}(\text{alpha}) = 0.225 - \sqrt{1.76 \cdot Q_t - 0.69}$$

From this, $V_b = V_{as}/\text{alpha}$. Do not forget to allow for room taken up by driver(s), vent, and bracing.

The tuning ratio, h, is the ratio of box resonant frequency f_b to resonant frequency of the driver when mounted in the box f_{sb}.

$$h = \frac{Q_t}{0.38}$$

Finally, the expected −3dB point, f_3, should be:

$$f_3 = 0.841\, f_{sb}\sqrt{\text{alpha}}$$

These calculations are good only for alignments 1-9, those in the range $QB_3 - B_4 - C_4$; that is, those without auxilary circuits. They also assume zero box losses; in practice there may be some loss at the lowest frequencies. Those interested in alignments with non-zero losses should see Small's paper[2].

Richard Saffran
Toledo, OH 43606

(1) Theile, A.N. "Loudspeakers in Vented Boxes" *JAES*, May, June 1971.
(2) Small, Richard H. "Vented-Box Loudspeaker Systems" *JAES*, June, July, August, September, October 1973.

POLK PUZZLEMENT

I AM PRESENTLY trying to design a system similar to the Polk 12, i.e., a passive radiator system with two small cones driving the passive. I am having difficulty designing the crossover. Can anyone assist me?

John E. Rector
Rt. 2, Box 445
Keokuk, IA 52632

On Passive Radiators see Audio Amateur *1/77 pp. 18-20; 3/77, p. 57; 1/79 pp. 28-30.—Ed.*

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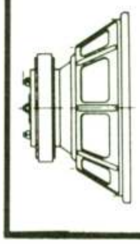

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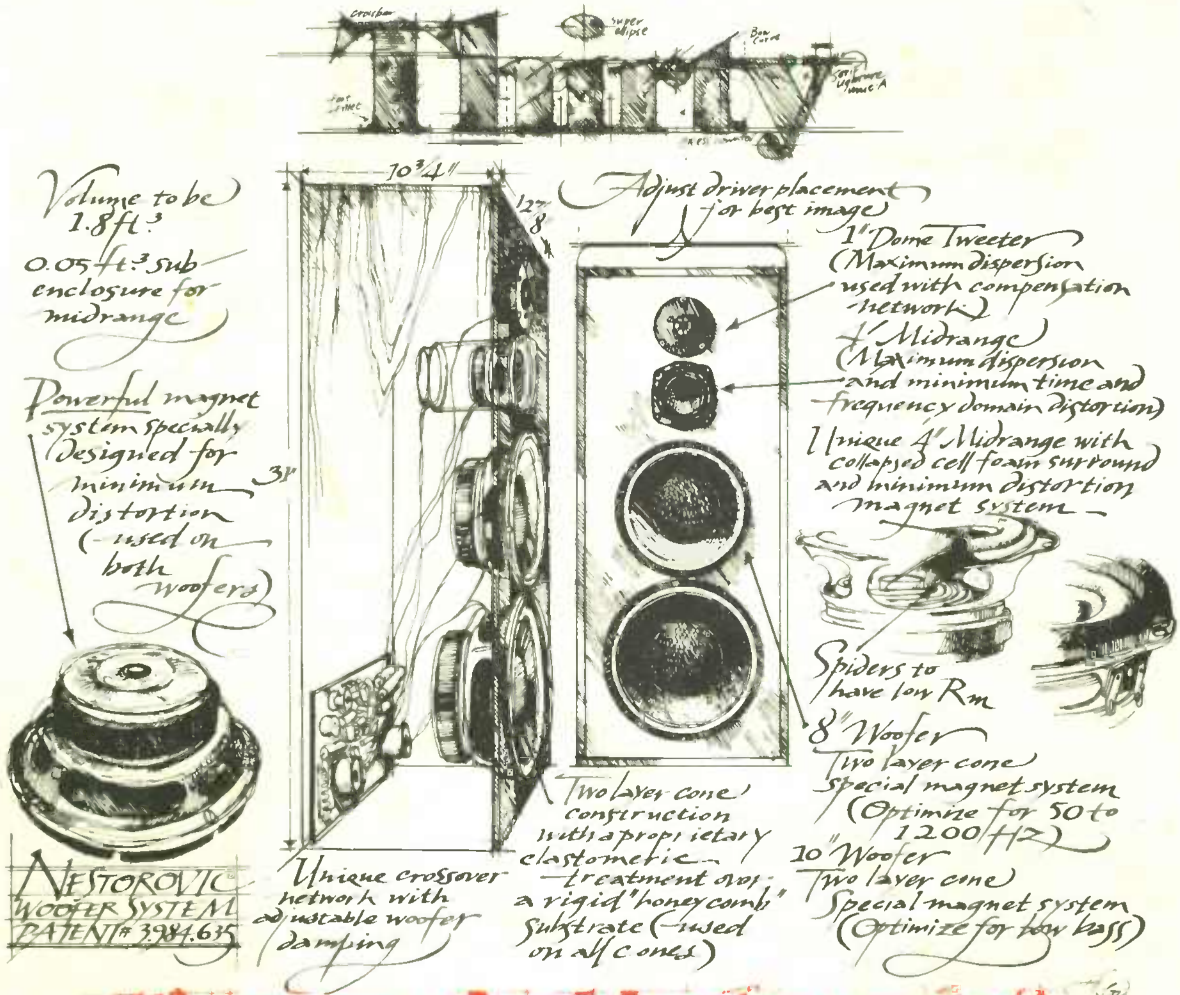

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Because they use the patented Nestorovic Woofer System™, Thirties achieve almost a full octave of extra low bass. Through a unique phase-control network and incredibly high flux density 8" and 10" woofers, you get amazingly tight bass transient response. The result is tremendous bass from a relatively small enclosure. Handling up to 350 watts/channel, Thirties are simply unlike any speaker system you have previously heard.

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And Thirties are just one of ten different speaker designs from Speakerlab. We also have a wide range of speaker parts available. Send for our free catalog — it'll tell you more about us, our kits and our famous patented Nestorovic Woofer System™, Wave Aperture Drivers™, Polylam™ Cones and Subwoofer Drive Systems.

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