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Balancing small speakers p 44

SpeakerBuilder

THE LOUDSPEAKER JOURNAL

Cockroft—*The Octaline*

Pierce—*Spreadsheet Speakercad*

Sutheim—*On Richard Heyser*

Koonce—*Wrong Box Fix*

Frane—*Simple Stands*

Meraner—*Compensation: Yes/No?*

Brush—*Port Principles*

Gonzalez—*LMP: Show & Tell*

Galo—*Bass Bonanza*

Sommerwerck—*SCES '87*

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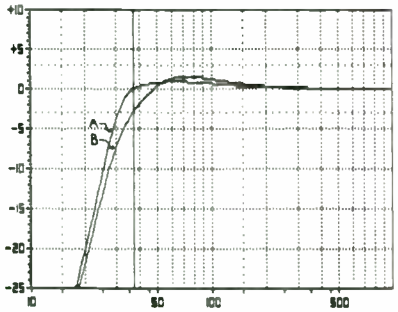
TECHNICAL DATA 20WR8

Power	150 W	F_s	43.8 Hz
Sensitivity	88 dB	Vas	33.1 1
Bandwidth	35-2000 Hz	Q_t	0.56
Xmax	11 mm	Q_e	0.69
R_e	5.1 ohms	Q_m	2.88
Mag. Weight	26 oz.	Voice Coil Dia	38 mm



ENCLOSURE RESPONSE GRAPH DATA

Enclosure Volume	Response Curve	F3	Vent Area	Vent Length
2.00 cu. ft.	A	35 Hz	7 sq. in.	4″
1.50 cu. ft.	B	37 Hz	7 sq. in.	6 5/8″

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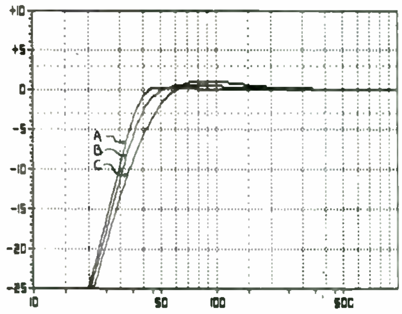
TECHNICAL DATA 20WR4

Power	150 W	F_s	45.3 Hz
Sensitivity	92 dB	Vas	28.8 1
Bandwidth	35-2000 Hz	Q_t	0.48
Xmax	11 mm	Q_e	0.59
R_e	2.8 ohms	Q_m	2.62
Mag. Weight	26 oz.	Voice Coil Dia	38 mm



ENCLOSURE RESPONSE GRAPH DATA

Enclosure Volume	Response Curve	F3	Vent Area	Vent Length
2.00 cu. ft.	A	36 Hz	7 sq. in.	3 3/4″
1.50 cu. ft.	B	39 Hz	7 sq. in.	5″
1.00 cu. ft.	C	46 Hz	7 sq. in.	7 1/4″

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FAST REPLY #GB201

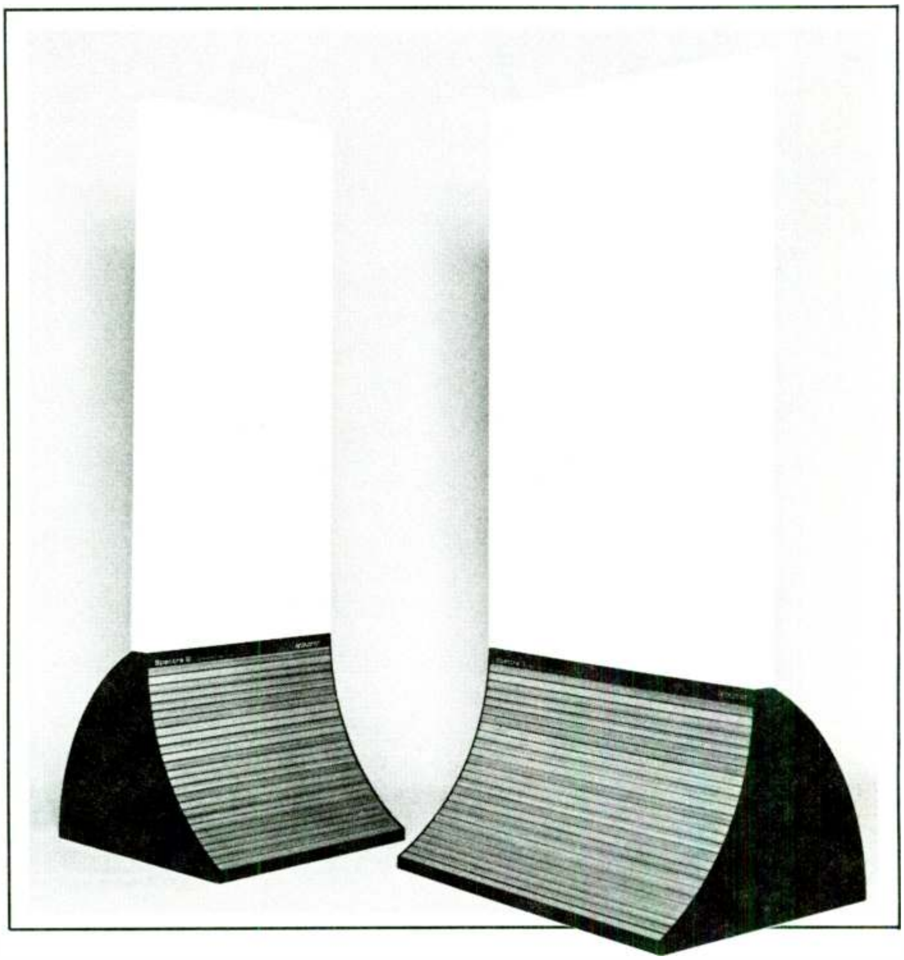
Good News

POLYDAX SPEAKER CORPORATION introduces a new titanium composite dome tweeter. The thin titanium coating increases the dome structure's strength and stiffness while the soft polymer used as a base provides superior damping. Their suggested retail price is $27.95 per unit. For more information contact Polydax, 10 Upton Dr., Wilmington, MA 01887, (617) 658-0700.

Fast Reply #GB668

The Three-Way "Ferrallipse"™ Definitive Image Speaker System by **SIGNET** eliminates high-frequency "beaming" and "combing" effects. The bass and midrange sections of the SL-100 system consist of a 10″, long-throw, low-frequency driver with a vented aluminum voice coil form and polymer impregnated cone, plus a 3″ soft-dome midrange driver with a 3″ voice coil. Contact William Kanner, Signet, 4701 Hudson Dr., Stow, OH 44224, (212) 986-6668.

Fast Reply #GB23



ACOUSTAT announces Spectra 2 and Spectra 3 full-range high SPL electrostatic loudspeakers employing variable width operation. All Spectras use two massive transformers in push-pull, and allow radiation of low frequencies from full array width, transitioning down to a 3.3″ wide line source at highest frequencies. A built-in switchable dynamic woofer extends low-frequency dynamics by approximately 10dB. Both Spectra 2 and 3 are 66″ tall with an array depth of 2⅛″. A ±5° array tilt is provided. Available in black or white grille colors and in a variety of wood tambours, Spectra 2 (22″ wide) is $2,795/pair and Spectra 3 (32″ wide) is $2,995/pair. Contact the Acoustat Division of The David Hafler Co., 3101 Southwest First Terrace, Ft. Lauderdale, FL 33315-3380, (305) 462-6700.

Fast Reply #GB323

DAHLQUIST says the M905 in their new DQ-20 series is the first loudspeaker that keeps pace with recent advances in digital electronics and also applies new principles of driver/enclosure interaction. The M905 enclosure features panels of varying thickness bonded to special damping panels in conjunction with internal braces. Each model is tailored to minimize coloration and to reduce enclosure excitation. Contact Dahlquist, 601 Old Willets Path, Hauppauge, NY 11788, (516 234-5757.

Fast Reply #GB342

SPEAKER BUILDER

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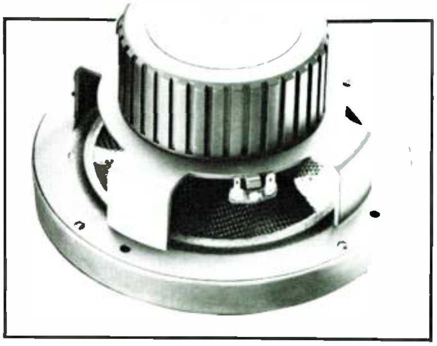
ALTEC LANSING CONSUMER PRODUCTS has added the ALS-8 8″ subwoofer to its line of "Voice of the Highway" car-audio components. The ALS-8 package consists of two 8″ subwoofers featuring carbon-fiber cloth, long-throw high-compliance woofer cones, 15.7oz. strontium magnets, heavy die-cast aluminum frames, double-damper construction, and 30mm voice coils with four layers of flat ribbon wire.



The ALS-8 is responsive from 45Hz–3kHz, ±3dB, and can handle 150W peak and 75W nominal. It has an SPL of 90dB, an Fo of 45Hz, and less than one percent distortion from 60Hz–3kHz. The ALS-8 package has an impedance of 4Ω and a suggested retail price of $200.

Altec Lansing is also introducing the ALC-10, an adjustable crossover that can change frequencies to accomodate any subwoofer. The ALC-10 includes a dynamic-equalizer control that assures low distortion at high power. The equalizer increases bass response at low power levels and reduces it as power increases (preventing cones from exceeding maximum excursion).

Two adjustments control the equalizer: one lets you choose the equalization frequencies (30–200Hz), and the other cuts or boosts the equalization frequencies by 9dB. The available crossover frequencies are 50, 80, 100, and 150Hz. All crossover points have a 24dB/octave slope. The ALC-10 has a high-pass output with a fixed crossover of 100Hz, a subwoofer output and a signal-control light. The suggested retail price is $65.

Contact Altec Lansing Consumer Products, Milford, PA 18337.

Fast Reply #GB328

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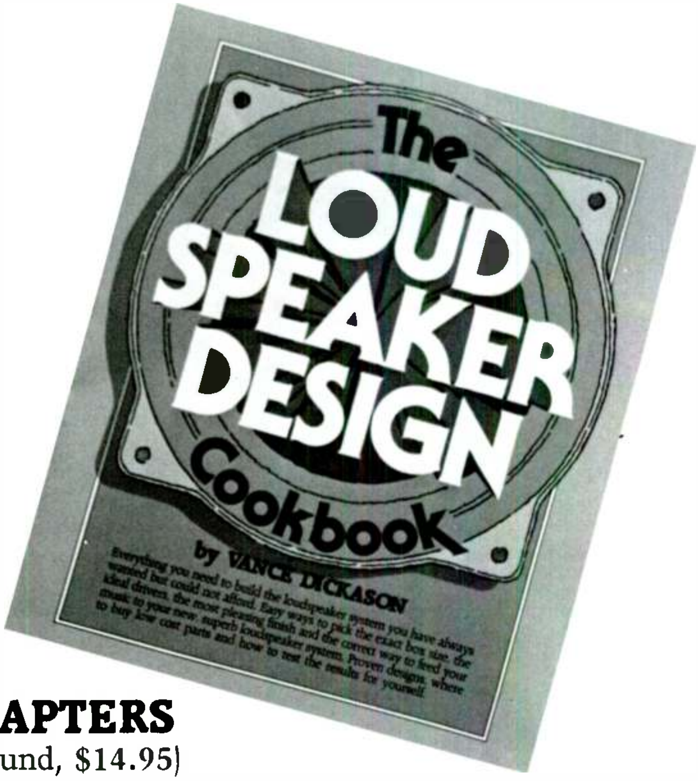
—ROBERT M. BULLOCK, III
Contributing Editor, *Speaker Builder*



EIGHT CHAPTERS

(82 pages, softbound, $14.95)

1. ***Closed-Box Low-Frequency Systems:*** Definitions, History, Driver "Q" and Enclosure Response; Woofer Selection; Box Size Choices and Parameters, Design Equations; Design Tables; Maximum Input; Cut-Off Frequency; Filling the Box; Dual and Compound Woofers.

2. ***Vented-Box Low-Frequency Systems:*** Definition; History; Driver Q & Enclosure Response; Selecting a Woofer; Alignments; Box Size; Design the Vent; Design Tables; Locate the Vent & Tune the Box Q_L Measurement; Subsonic Filters; Damping; Electronically Assisted Vent Types.

3. ***Passive-Radiator Low-Frequency Systems:*** History; Driver Q and Enclosure Response; Woofer Selections; Alignments; Box Size; Finding Delta for PRs; Design Tables; Box Tuning; Q_L Measuring; Augmented PRs; Dual-Woofer Formats.

4. ***Transmission Line Low-Frequency Systems:*** Line Length and Damping; Tuning a TL; Enclosures; Woofer Slection.

5. ***Cabinet Construction: Shape and Damping:*** Rectangular Boxes; Alternate Shapes; Box Dampng.

6. ***Mid- and High-Frequency Drivers: Applications and Enclosures:*** Application; Driver Bandwidth & Crossover Choices; Two-Way and Three-Way Formats; Driver Separation and Horizontal Dispersion; Midranges; Mid- and High-Frequency Enclosure Dimensions.

7. ***Passive and Active Crossovers:*** Passive Networks; Operational Principles; Two-Way Filters; First-Order Networks; First-Order Reverse Polarity; Second-Order; Third-Order; Fourth-Order; Design Formulas; Unsymmetrical Two-Ways; Three-Way Crossovers; Three-Way APCs & Formulas; Driver Load Compensation; Series Notch Filters; Equalizing Impedance; Attenuation; Correcting Phase; Shaping Response; Crossover Inductors and Capacitors; Active Crossovers; Computer-Aided Design for Crossovers.

8. ***Loudspeaker Testing:*** Terms; Break-In; Calculating Resonance; Impedance; Compliance; Voice-Coil Inductance; Amp Source Resistance; Series Resistance; Air Volume & Driver Compliance; Driver Q; Frequency Response; Conversion Factors.

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About This Issue

The fertile mind of **John Cockroft** gives us yet another project, this time involving a stuffed line (p. 9) leading off this third 1987 issue of *Speaker Builder*. The legendary **Richard Pierce** called me some months back with a new idea. His first article on adapting computer spreadsheets to design tasks starts on page 16. I welcome **Peter Sutheim** to our pages with great pleasure. I asked him to do a summary of the late Richard Heyser's work. His first of two articles begins on page 21.

Contributing Editor **G. R. Koonce**, the Liverpool Wizard, tells us how to use the wrong box with the right driver starting on page 24. **Jim Frane's** excellent guidelines about building a stand for your smaller speaker begin on page 28. We are pleased to offer it after delaying publication far too long. **David Meraner** also has waited patiently for publication, tells us all about the pros and cons of driver compensation.

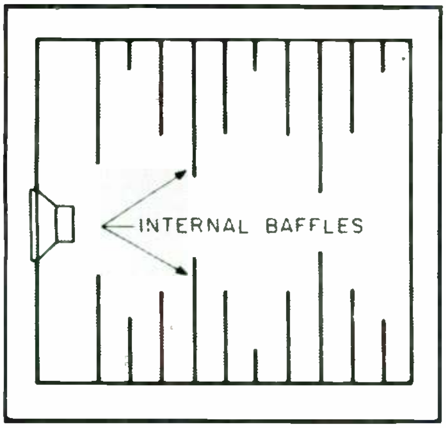
Richard Brush explores what we might call the ins and outs of port design, starting on page 34. When **Ralph Gonzalez** first submitted his LMP articles I suggested he should offer some proof of the pudding. Models look a lot neater, usually, than space/time examples. His fully baked confection begins on page 38. I welcome a New Zealander, **Peter Muxlow**, to our pages to begin a new feature we're calling *Technology Watch*. Peter will look at new loudspeaker patents on a regular basis, and this time, showcases Beveridge's latest electrostatic (p. 42).

Contributing Editor **Gary Galo**, preparing an update on his four-way transmission lines, has been diligently sifting bass drivers in the eight- and ten-inch category. His helpful tips on the newest candidates starts on page 47. **Bill Sommerwerck** combed out the CES bedlam in Chicago last June to report on the latest industry offerings in drivers and systems. His critical review, concentrating on the technologically significant, begins on page 52.

SpeakerBuilder
THE LOUDSPEAKER JOURNAL

VOLUME 8 NUMBER 3 AUGUST 1987

FEATURES



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DEPARTMENTS

Editorial

ISSUES

Our most pressing issue this late summer of 1987 is the threat of CBS copycode legislation now in committee in both houses of the US Congress. In brief, CBS and many of the world's recording companies, frightened into hysterical paranoia by the threat they perceive in the impending sale of digital audio tape recorders, have asked the Congress to require by law the presence of an anti-taping chip in all DAT machines. The chip would turn it off if it detected the absence of some 250Hz of sound from any pre-recorded material, including compact disks

CBS, claiming proprietary interests in the exact process they propose, are saying that all examples produced by critics of the technique do not correspond to what they will do. They have not provided (as of early August) any samples of altered recordings that others may examine independently. They have provided samples to the National Bureau of Standards who will make tests, presumably, of the audibility of the alteration, or whether the rest of the recorded material is affected in any way, and report to Congressional committees.

Rumor has it that the Recording Industries Association of America whose spokespersons have been speaking for the CBS proposal, have had some second thoughts about the matter.

Any number of questions should be examined thoroughly, and publicly, before any such decision is made. At the very least, any action should be postponed until full discussion of the issues is possible.

In my opinion, the government ought not to be involved in such matters for two reasons. First, I believe the founders of the country were right in thinking the least government is the best government. I also think it is absurd to suppose that this government could possibly enforce such a law and, even if it could it would not protect the copyrighted property of composers, performers and recording companies effectively.

You will find excellent summaries of the matter in the July '87 *High Fidelity*, August '87 *Audio*, and in Vol. 10, No. 5 of *Stereophile*. If you agree with me that Congress should take plenty of time in deciding this matter, the people to write to are your Congressional Representatives and Senators. The bills are:

House Bill No. HR-1384
Senate Bill No. SR-506

Also share your opinions with:

The Home Recording Rights Coalition,
P.O. Box 33576
1145 19th St., NW,
Washington, DC 20033,
(800) 282-TAPE

On a far happier note, another matter of issues I'd like to discuss is an increase in the number of issues this magazine will publish in 1988. We are pleased to announce you will be receiving six issues of *Speaker Builder* next year. If you have already renewed for 1988 or 1989 or even 1990, you have a nice bonus. Your subscription will expire at the end of each of those years, just as it was scheduled to.

This third issue of the 1987 series, our second 72-pager in a row, carries a special card offering bargain early renewal prices to all current subscribers. Be sure you take advantage of it. And yes, you may extend your subscription if you like.

Naturally, there's always some bad news with this sort of change. Prices for *Speaker Builder* will be rising to $20 per year, and $35 for two years, on January 1, 1988. Back issues will also increase. All our costs are going up and we believe you wish us to continue the same high level of quality we have maintained in the past.

Another issue of note is the good news that over half the first printing of Vance Dickason's *Loudspeaker Design Cookbook* has been eagerly bought up by *Speaker Builder* and *Audio Amateur* readers in the three months since it was published. Other publications are preparing to publish reviews of what, to us, looks like a runaway best seller.

Mr. Dickason is already at work on a sequel to *LDC*. We expect publication in the late Spring of 1988. Watch for an announcement of the publication date. Mr. Dickason is also welcomed as a Contributing Editor of this publication and Managing Editor of our new monthly newsletter *Moving Coil*, serving the loudspeaker driver industry.

We also take pleasure in announcing the issue of a reprint of the earliest series of articles on loudspeakers, and much else, from the pages of *Audio Engineering*, the direct ancestor of the present *Audio* magazine. *The Audio Anthology* contains the first loudspeaker construction articles which appeared forty years ago. A trip down memory lane.—E.T.D.

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(202) 775-0101

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(202) 728-4964

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THE OCTALINE:
A SMALL TRANSMISSION LINE
BY JOHN COCKROFT

I'm not convinced that acoustic labyrinth or organ pipe theory really explains the action of a transmission line (TL) loudspeaker system. When a vented speaker system's duct or box is filled with acoustic material, it behaves differently than a normal vented system.[1] The most significant difference is, in the stuffed system, the cone moves farther for a given input indicating a duct damping action loss.

I contend a similar situation occurs within a pipe when it is stuffed to the point where impedance and sonic peaks are being controlled. Though I have no scientific study to back it up, I believe the acoustic material—not the pipe's wave flow—is doing most of the work.

THEORY. In my opinion, the most important paper on TLs was written by A. R. Bailey in 1965.[2] Though he made no mention of line length versus resonant frequency (that discussion came later due to a mistake in terms made by those who came after Bailey), Bailey did use the term "acoustic labyrinth." My *Fig. 1*, based on one of Bailey's original drawings, indicates he was referring to the type of enclosure based on an auto muffler principle, where the sound is rarified and compressed alternately to remove its energy. Bailey mentioned the acoustic labyrinth only in relation to the work of others, especially the Hartley "Boffle." It was in no way applicable to the description of his TL design. Because, however, Bailey used the term "acoustic labyrinth," and the term was also associated with the unfortunate Stromberg-Carlson quarter-wave pipe, his fine design has been saddled with quarter-wave theory ever since.

Though Bailey did his testing with an 8′ line, he later developed a 6½′ commercial product. He didn't explain why in his article. The curve for the 6½′ speaker is about 3dB down near 25Hz, and down approximately 10dB at 15Hz. 6½′ is a quarter-wavelength for 50Hz, not 25Hz. Irving Fried used approximately 6½′ lines in most of his systems and also claimed very low frequencies.

I make my lines on the premise that if the line is a little shorter, the acoustic material should be a little denser and the cross section a little greater so the driver can "breathe" more easily. In my opinion, and in the opinion of those who have listened to my lines, this premise has proven successful.

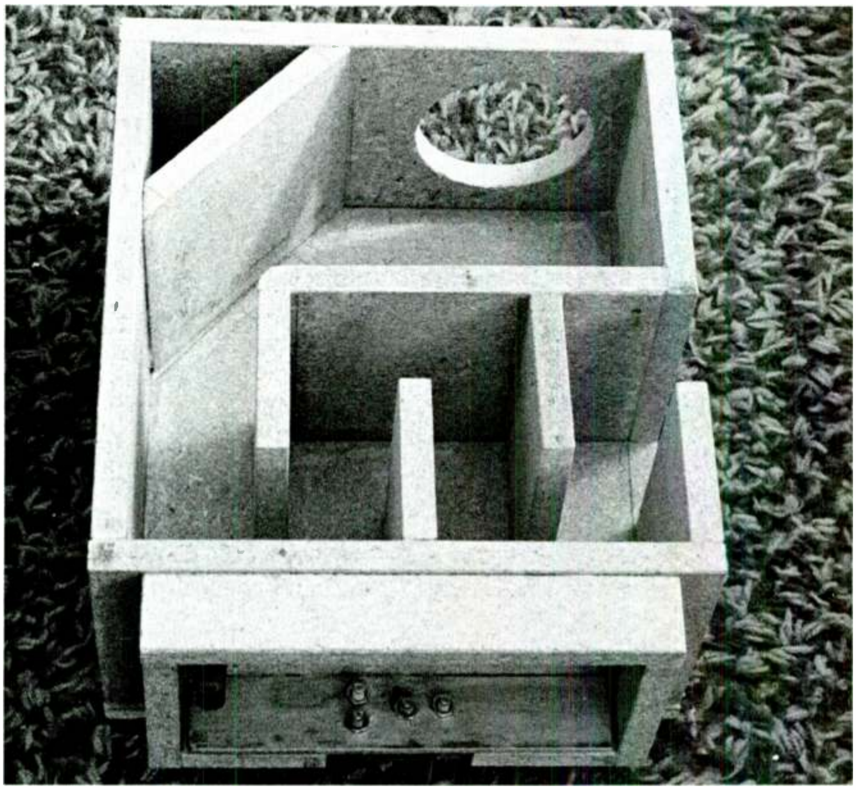

PHOTO 1: The unstuffed Octaline with front removed. The author slightly modified the base from the prototype in the photo so he could make everything from particle board.

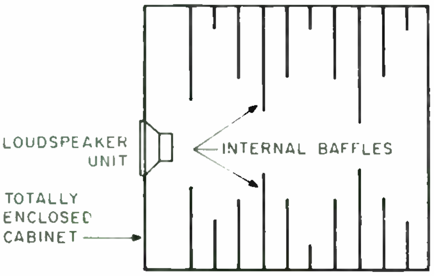

FIGURE 1: Acoustic labryinth, based on one of Bailey's original drawings. It differs entirely from the Stromberg-Carlson's quarter-wave acoustical labyrinth. The Hartley "Boffle" was similar but open-ended.

HALF THE LENGTH. I have named this system the Octaline (*Photo 4*) because I have arbitrarily chosen a length about one-half that of a line based on Bailey's thinking. To compensate for this shortness, I have (also arbitrarily) increased the acoustic lagging density from 0.5 to 0.7 lbs. per cubic foot. Actually, I chose the figure 0.69 because, with that density and the box's volume, the material came to an even 4 oz.

For packing material, I construct all my lines using either polyester Fiberfil® pillow stuffing or long fiber surgical cotton, and I have never sensed the sound was lacking in any respect.

At the time Bailey was testing his devices, polyester or similar fillers were not readily available, so he didn't mention them. For the most part, he was testing reactive materials (such as fiberglass or rock wool) against resistive types (such as wool, cotton, cellulose acetate, polyester, and so on). In the low frequency area, he found the reactive materials were less satisfactory than the resistive materials.

I believe too much attention has been paid to long-haired wool. The care and feeding of wool, so to speak, is just too much work for the possible slight advantage you might gain over polyester or long fiber cotton. I moth-proof my closet, and in about two months, a whole 8 oz. block of moth killer dissolves into thin air. I know of no way to permanently moth-proof wool. Wool must also be supported inside the lines, while the other materials are essentially self-supporting. Simply on the basis of cost, polyester seems to make the most sense, while cotton batting is excellent for lining the line areas directly adjacent to the driver.

SMALL IS BEAUTIFUL. I am interested in small speaker systems because I live in a small space (which is getting smaller as speakers continue to pile up around me). No matter what size system you build, however, the principles remain basically the same. I am particularly fond of the Octaline because, to me, it is a most "delicious" system. I don't like to turn it off, and people who borrow it don't like to return it. I find it to be lovely on voices, "smooth and creamy," and yet can "speak" with a certain authority—a feature which is surprising considering its 3½″ cone. In my opinion, it is a truly musical loudspeaker (so many, I think, are not). This is saying quite a bit for a speaker system you can build for about $25 or $30.

TABLE 1

PARTS LIST

⅝″ particle board (6′ shelf board sold at department stores)

2	11½ x 12¾″ front/back
3	5¾ x 11½″ top/bottom/long side
2	5¾ x 6″ upper short side/reflector (Y)
1	5¾ x 7/8″ horizontal line piece (X)
4	5¾ x 3⅜″ lower short side/short line pieces
1	9½ x 2″ base front
2	4½ x 2″ base sides
1	8¼ x 2″ base back
4	feedthroughs (see text)
1	6.6μF Mylar capacitor, 50V (2 3.3μF in parallel)
1	5Ω resistor, 5 or 10W
1	2Ω resistor, 5 or 10W
2	banana jacks
2	four-prong tie points
1 pkg.	surgical cotton
4 oz.	polyester Fiberfil® pillow stuffing
1	Radio Shack #40-1022 4″ woofer
1	Radio Shack #40-1376 ¾″ tweeter
7	#6 x ¾″ sheet metal screws

Miscelaneous

16 gauge hookup wire
Mortite® or Duxseal® caulking
white glue diffraction ring

The Octaline is easy to construct. A single 6′ x 11½″ x ⅝″ particle board shelf, sold at most discount department stores, supplies more than enough material for one unit. I designed the enclosure so the Octaline's front and rear panel widths are the same width as the shelf board. The length of one of the side pieces is also the same width as the board. The line depth (front to back) is 5¾″ for the Radio Shack #40-1022 4″ speaker. If you were to increase it to, say, 7″ (internal dimensions), the Octaline would probably be excellent with 5½″ speakers such as the Peerless TO-125F. You must, however, also increase the amount of polyester to 5 oz. (0.7 lbs. per cubic foot) and modify the crossover.

When I was ready to construct the Octaline, the only driver I had available was a slightly modified Radio Shack #40-1022. I used it, and I think a stock 1022 would also work well. If you wish to modify it so it matches my prototype, you can do the work with the driver mounted in the box.

CONE DOPING. My modification consisted of doping the cone with two coats of white glue (such as Elmer's) diluted 1:1 with water. I used a #3 camel's hair brush (an inexpensive one will do) and spent about 15 minutes going around each cone and dome, trying to keep the surfaces wet and applying each coat as evenly as possible.

I let the first coat dry overnight before I put on the second. This was a matter of convenience for me, but an hour or so wait between coats should be adequate. Be sure you wipe off any glue you get on the rubber surround before it dries. If you use a driver with a plastic cone, this treatment is not necessary.

In addition, I modified the driver by gluing a ring of ⅛″ diameter solid lead wire (solder works, too) around the dome where it joins the cone. If you cut the ring into four parts, it will lie flat and be easier to install. Paint a ring of full strength white glue around the junction of the dome and cone and lay the ring parts in it. When it sets up, paint some more glue over the junction and around the ends of the pieces so they will not buzz or rattle. Before you go to all that trouble, try using the stock 1022. The cone doping is probably of more value than the added weight.

It will be easier to cut the holes for the drivers after you partially finish the box;

you'll have something to grab onto while cutting. Before assembling, pre-glue all parts by painting a coat of full strength white glue over both sides of all joints. To smear it out, use a paste or acid brush, or just the tip of your finger. Allow the glue to dry, then re-glue when you assemble the parts.

Glue the top piece to the front panel, followed by the full length side piece and the upper section of the opposite side. Next, glue the bottom and lower side piece, followed by the tunnel piece (X) [*Fig. 2*] and the three short tunnel pieces. Finally, glue the reflector (Y) into place. When the glue is dry, go around and add fillets to all joints. (A third time around won't hurt.)

THINKING AHEAD. Now, you can cut the driver holes. Make sure they are the right size, then break the edges with a file so they won't be rough. It is a good idea to paint a 1-inch wide circle of smoothed-out white glue around the holes so the sealing material will work better when you mount the drivers. Also, spray a little flat black paint over and around the area to be occupied by the drivers before you mount them. This will make it easier to achieve a neat paint job later on.

Next, mount the four feedthroughs. These can be as simple as 10-32 brass machine screws with nuts, washers and lugs, or short sections of threaded rod with the same accessories. I used five-way binding posts, but you can use whatever suits your style or budget.

Solder the speaker lead wires (I used 16 gauge zip cord) to the feedthroughs. Make sure you identify the feedthroughs' polarity both inside and outside the box, and be sure you identify the wires for polarity and so you know which driver they go to. Your feedthroughs should be several inches longer than the box's height. Now, bring all four out of the woofer hole and tape them together so they won't get in the way.

Use a roll of surgical cotton from a drugstore to fasten a batt about ⅜" to ½"-thick (I used two plies as it came off the roll) inside the front panel in the area bordered by the top and side panels, and (X) and (Y). Cover over the tweeter hole, and later, make two holes with a pencil point and poke the tweeter wires through the batt. Make a similar batt which you will place under the back panel just before you glue it in place (*Photo 2*). Then, fasten batts to the inside, upper side panel, the top of (X) and along (Y), and over to the top panel's inside. Make sure these batts don't quite reach up to the top edge of the panels where they could interfere with your back panel gluing.

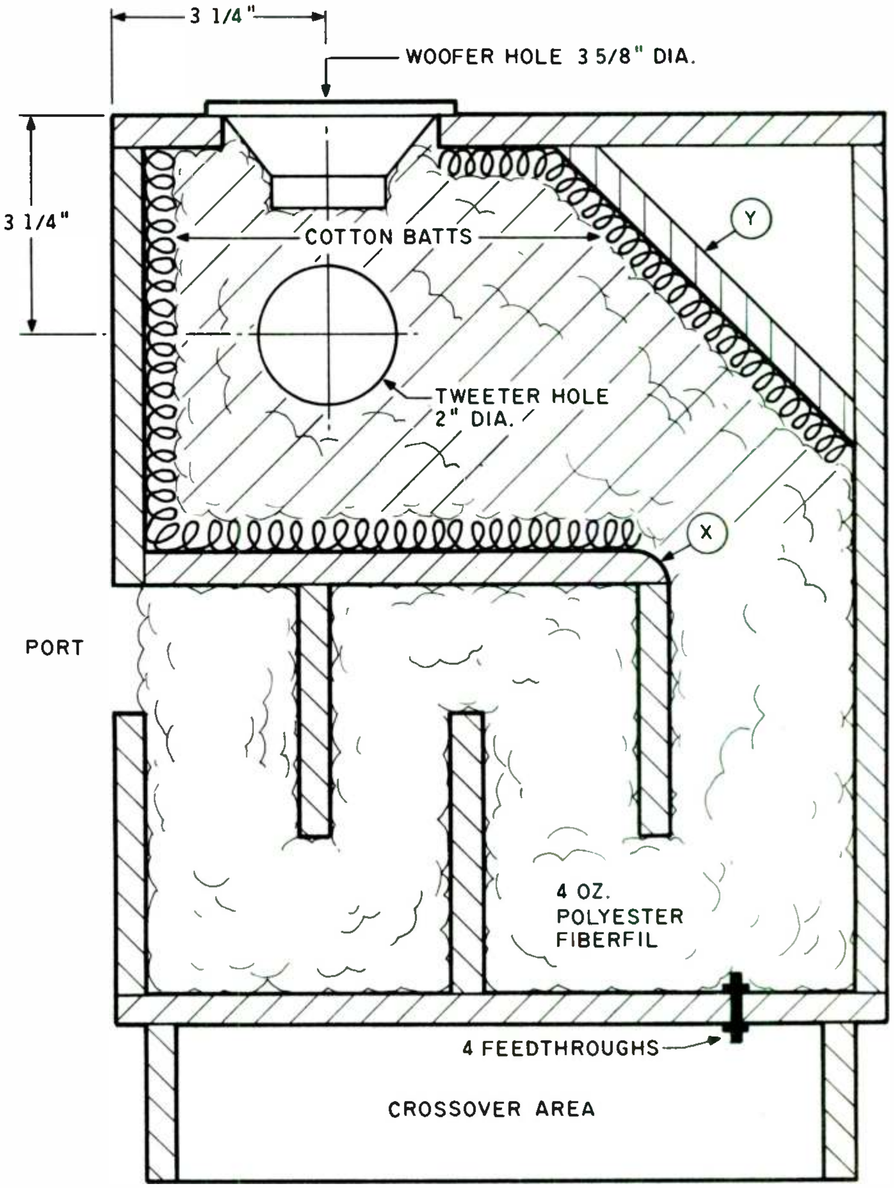

FIGURE 2: The Octaline's general layout. Install additional cotton batts on the inside front and rear walls of shaded area below the woofer.

FLUFFY POLYESTER. Now, measure out 4 oz. of polyester pillow stuffing. Since I have a gram scale, I used 114 grams. If you can't measure it, divide a 12 oz. bag into three equal piles and use one. Sometimes, polyester pillow filling comes in 16 oz. bags, so in that case, make four piles. I recently purchased some that came in the form of a loose batt-like roll. Here, you could measure the area and cut off an appropriate amount. You would then have to pull the material apart, again and again, until it is nice and fluffy. Even when polyester filling doesn't come in a roll, however, you should pull it apart to obtain a light, even texture.

Place the polyester in the line as evenly as possible, but if it is less than even in some spots, it is better to have a little more near the driver than at the line's port. I don't recommend putting any in the triangle behind the reflector (Y), although in *Photo 2*, you can see some at that location. I had that much left over and just stuck it there instead of throwing it in the wastebasket. Place the previously made cotton batt over the polyester in the driver area.

Now, you can glue on the back. Lightly press the stuffing down below all the panel tops so the fuzz won't get into the joints. Squeeze a ¼" bead of white glue on all the box and tunnel edges and on (Y). Carefully lower the back panel in place and line it up. Glue will squish out like crazy, but ignore it until after you square up and apply a weight to the back panel. Then, clean up the mess with a damp rag. Leave the weight on overnight.

As readers of my earlier articles know, I don't nail my enclosures together. I use only glue, relying on weights and fixtures to hold everything in place. You can use nails or screws if you wish, but my neighbors in the apartment complex probably appreciate the fact I'm not annoying them with hammering. [*Strap clamps would also work.—Ed.*]

When the back is dry, poke the four feedthrough wires down into the woofer cavity and set the enclosure on the floor top-first. You can now assemble the base. Then, install the crossover network (such as it is) and the inlet jacks. I used banana jacks and plugs on the inlet lines. Your crossover installation will be easier if you glue a couple of four-prong tie-points to the enclosure's bottom. To these, you can directly solder the resistors, capacitors, and jack wires.

SYSTEM PLACEMENT. Since this is another system in which I have incorporated Roy Allison's principle of critically coupling the speaker to the room (the vertically aimed speaker placed close to the rear wall), make sure the enclosure's rear edge is as close to the rear wall as possible; ¼" is reasonable, but more than ½" would probably be too much for optimum conditions. Also, place the speaker at least a couple of feet from corners. If you have high or wide moldings at the bottom of the rear wall, you may have to redesign the base to make the above-mentioned conditions possible.

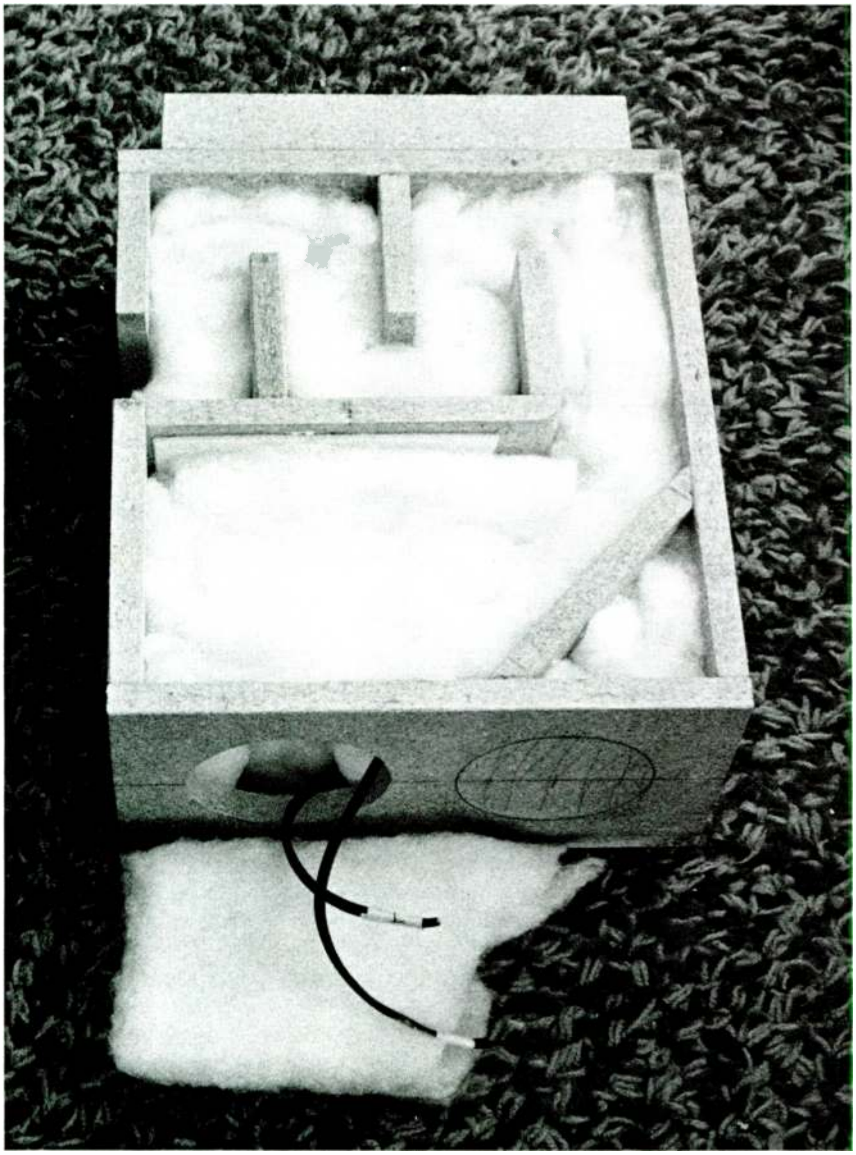

PHOTO 2: The stuffed Octaline with front removed. A half-inch of felt is shown on piece "X". The author found cotton batting to be more effective and easier to obtain. Cotton batt, seen in foreground, was placed on the polyester filling in the upper part of the line (above "X") before the front was glued on.

Connect the drivers to the correct wires, using the correct polarity. To mount them, use Duxseal® or Mortite,® and #6 x ¾" sheet metal screws or wood screws.

Here are several equations should you wish to experiment further. Please realize when you change the resistor, the crossover frequency will also change (I have included the equation for adjusting for that change).

$$A = 20\ \mathrm{Log}_{10}\ (R_p/R_p + R1) \qquad (1)$$

where A is the attenuation in $-$dB, R_p is the parallel resistance of R2 in the crossover diagram and the tweeter DC resistance (or perhaps the moving system's minimum impedance), R1 is the series resistor in the crossover diagram (*Fig. 3*), and Log_{10} is the logarithm indicated by the "Log" key found on hand calculators.

$$R_p = 1/(1/\ R2 + 1/\ \text{tweeter DC resistance}) \qquad (2)$$

$$C = 1/6.28\ (R_p + R1)\ F \qquad (3)$$

where C is the capacitance in farads ($1\mu F = .000001$), and F is the desired crossover frequency which, for the Octaline, is a calculated 3710Hz. So, if you make R2 = 2.5Ω, C will = 6.3μF. For R2 = 3Ω, C will = 6.1μF. The difference appears to be so slight, you might ignore it. To find out just what the crossover frequency would be for R2 = 3Ω:

$$F = 1/6.28\ (R_p + R1)\ C \qquad (4)$$

Here, C = the original 6.6μF, and $R_p = 2$. (The tweeter's DC resistance is 6Ω.) Therefore, F = 1/6.28 (2 + 5) .0000066, so F = 3447Hz. That's about a 7% crossover frequency reduction. It might not make much difference, but if it does, now you know what to do about it.

FINISHING METHODS. I am usually less than enthusiastic when it comes to finishing a speaker. I have neither the equipment nor inclination, and little time to accomplish this task. I am mostly interested in what a speaker sounds like, not what it looks like (not that the sight of a pretty speaker doesn't interest me). Though a coat of flat black Nextel® paint is usually the extent of my finishing, I realize many of you do not live alone and may require more justification for the ex-

Continued on page 14

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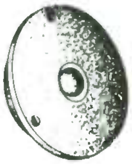
- SPL 90 dB
- Magnet 4 15 oz
- FS 1500 Hz
- 3 KHz-20 KHz
- 60 Watts @ 5 KHz, 12 dB



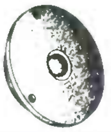
D19TD-00-08

$5⁵⁰

CTN OF 42
4.50 ea.

3/4 INCH SOFT DOME TWEETER
FERROFLUID

- 8 OHMS
- SPL 89 dB
- Magnet 4 15 oz
- FS 1700 Hz
- 2 5 KHz-20 KHz
- 80 Watts @ 5 KHz, 12 dB



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Continued from page 12

istence of your effort in a living room environment.

The simplest method, and probably the one with the greatest sonic improvement, is to merely bevel or round-off all the cabinet's front and side edges. This will make the enclosure appear less boxy and may reduce diffraction effects. Do not bevel the box's rear top edge where the system is coupled to the wall. To provide contrast, you could leave the base corners sharp, or you can bevel or round them.

Beveling will make it more difficult to veneer or laminate the enclosure, so in this case, it might be better to use paint. A nice touch might be a white epoxy, or a polyester boat finish rubbed out to a high gloss. You could do the same to the base, or perhaps use a flat black. With this "high tech" look, it might look better, and it will definitely sound better, if you leave your drivers exposed.

If you don't alter the edges, it should be relatively easy to veneer the enclosure or laminate it with plastic. Of course, do so before you install the drivers.

A more traditional approach is to install narrow molding around the top and bottom front and sides, and then stretch grille cloth around the front and sides and staple in the back (*Fig. 4*). For a smoother job, eliminate the diffraction ring and cover the entire front with a 4″ layer of high density foam, such as Charfoam® —a grey polyester urethane most often seen in custom camera cases and available in foam shops.

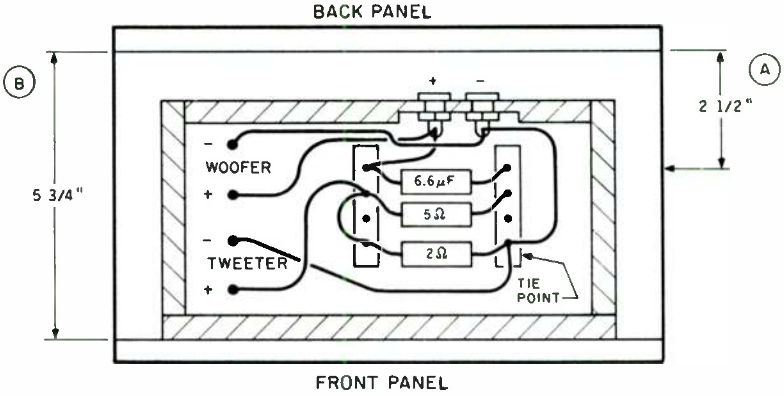

FIGURE 3: Bottom of the enclosure, showing base and crossover details. The undercut base back section, to allow installation of banana jacks (A), is from the rear of the top piece to the woofer centerline. (B) is the line depth dimension mentioned in the text.

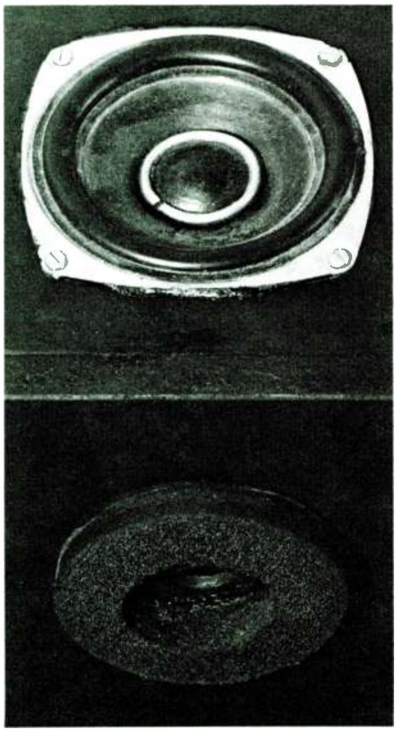

PHOTO 3: Installation details. Note the lead ring around the woofer dome. It is easier to install the ring when you cut it into four sections. Also note diffraction ring on the front of the tweeter.

Cut a round hole in the foam to allow the tweeter to fire out. A simple way to do this is to get a short piece of 2″ diameter pipe. With the foam on a flat piece of wood, position one end of the pipe on the foam and whack the other end a few times with a hammer. This probably won't cut through, but it will leave a nice, round, compressed ring. You could also use the open end of a small can, or a biscuit cutter. For an easy center cut-out, use a pair of manicure scissors.

FINAL STEPS. If the foam is ¼″-thick, your molding can be ⅜″ or ½″ deep, and maybe 1″ high. Put on the upper molding in such a way that it extends ½″ above the box's top. This will also form the top grille frame's front and side rails. To complete the molding, fit a ½″ x ½″ piece to the top's rear. Fasten a piece of the ¼″ foam, with a cut-out for the woofer, onto the enclosure's top, fitting it into the confines of the molding. For the grille, simply cut a section of ½″ open foam such as is used for furnace filters. It is available, in packaged form, in most hardware stores and usually comes in black or dark brown.

Cut a piece of cardboard to fit into the grille frame, and use it as a template when cutting the foam with a single-edge razor blade. If you make it a little tight, it will not require any further fastening, yet you can lift it out for easy cleaning. (You can wash it

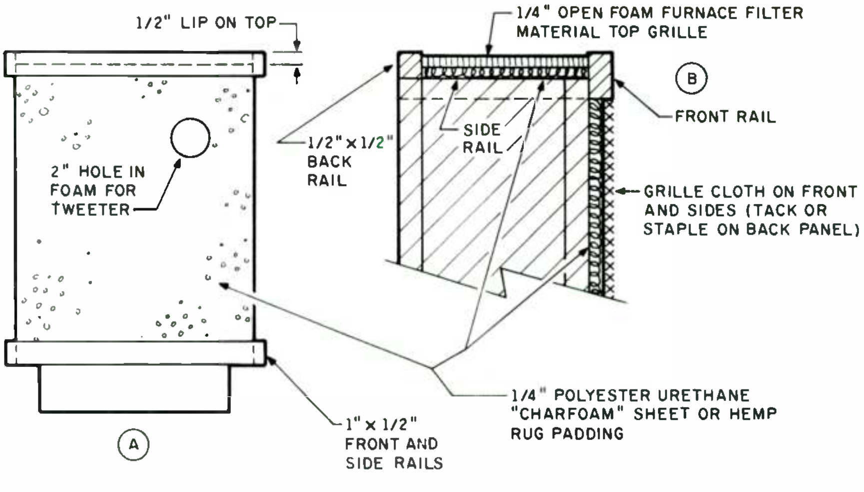

FIGURE 4: One method of finishing the Octaline (A). Details of grille, foam and molding (B). See text. In this instance, the diffraction ring is not necessary. Use open weave plastic grille cloth, such as saran.

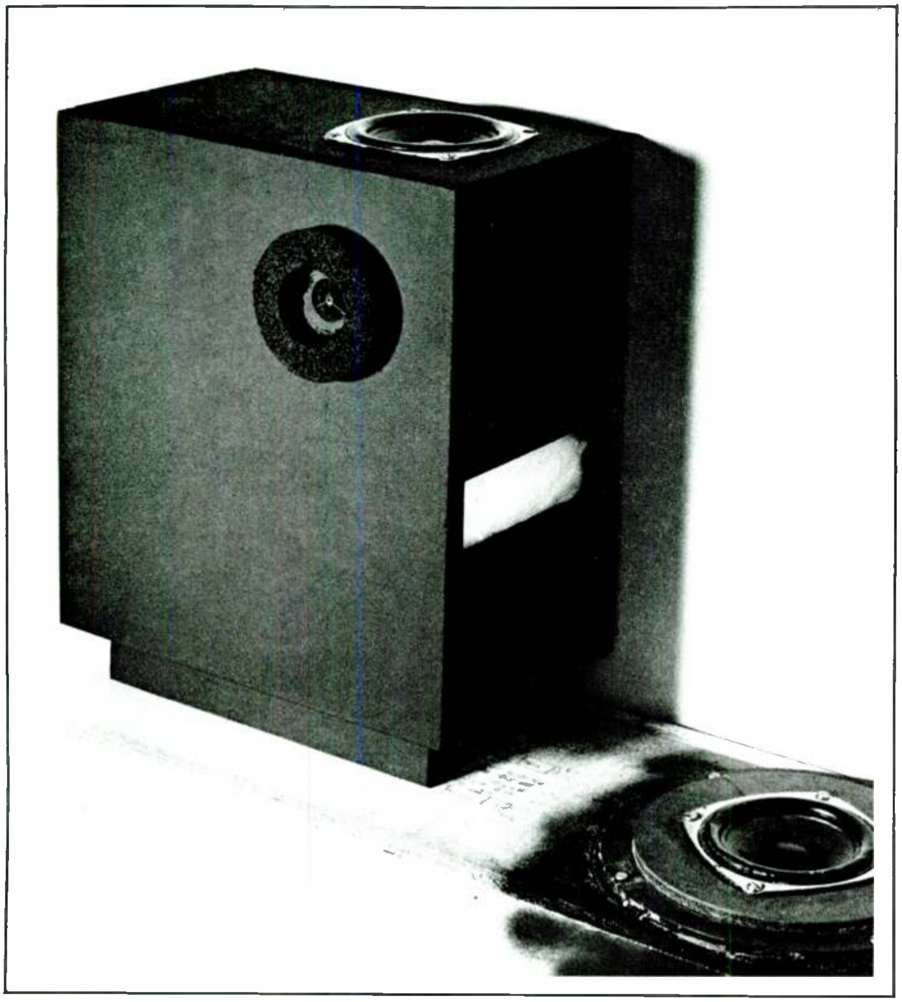

PHOTO 4: The finished Octaline.

right in the sink, but make sure it's dry before replacing.)

As a substitute for the foam, you could use jute, or hemp rug padding used by David Meraner (Craftsman's Corner, *SB* 1/86). The latter would probably be hard to handle, but should be effective.

Though I designed the Octalines so you can use them by themselves, you may wish to consider using them as satellites with a subwoofer. A crossover of about 150Hz–175Hz would be satisfactory. The Octalines might also do well in a van where their sound could be a welcome alternative to the usual mobile audio fare.

REFERENCES

1. Thiele, A. N., "Loudspeakers in Vented Boxes, Part II," *JAES*, June 1971, pp. 473- 474.
2. Bailey, J. R., "A Non-Resonant Loudspeaker Enclosure Design," *Electronics & Wireless World*, October 1965.

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PART I

RAPID LOUDSPEAKER DESIGN USING SPREADSHEETS

BY RICHARD PIERCE

Here is a new approach to designing and simulating closed-and vented-box loudspeaker systems. Unlike other software solutions such as custom-written personal calculator or computer programs, this method uses a paradigm which relieves designer and user from much of the software design and implementation hassles and also presents the data in a much more appropriate form for optimizing many separate parameters. The software tool is available on most personal computers, and I have implemented the technique on over a half dozen different systems.

Because of the work presented by Thiele[1] and Small[2-4] describing the systematic analysis of loudspeakers and enclosures, the correct design of direct-radiator loudspeaker systems has become far more a science than the personal art of a few self-appointed experts. The further efforts of Small and Margolis[5], Bullock and White[6] and others[7], have resulted in specific software methods for solving driver-enclosure designs. These and other articles have all used either general purpose computer systems programmed in languages such as BASIC or FORTRAN, or personal programmable calculators sporting their own peculiar languages. Designing and writing such a program, one quickly discovers, requires that about 20% of the effort goes into solving the actual problem (designing direct-radiator loudspeaker systems) and the rest is taken up with hassling with the details of the programming language, user interface, operating system, and so forth. As a result, many of the published software packages are either limited in scope, difficult to use, or such a rat's nest of poor programming that they are nearly impossible to adapt to different applications or programming environments. We frequently encounter these problems in attempting to port such programs from environments like Apple computers to DEC mini-computers. It seems you can't expect a good loudspeaker engineer to be a great software engineer, and vice versa.

In attempting to come up with an easy-to-use software system for doing driver and enclosure prototyping, we thought of using a software tool originally intended for business, the "spreadsheet calculator." The problems we wanted to solve with such a system were many: designing enclosures given specified drivers, designing drivers given specified enclosures and parts inventory, designing the individual components of drivers (voice coils, magnets, and the like) based on the requirements of the final system, prototyping new design ideas, and so forth. We wanted all this done by a single, integrated, simple-to-use tool.

Most programs we reviewed would, at best, accomplish but one of these objectives, and were not very interactive, in the sense that any major change in parameter setup (such as the driver's Thiele/Small parameters) required us to re-run the program from scratch.

On the other hand, a spreadsheet calculator allows us to have all the needed parameters in view at once, permitting us to change any combination of them, and view the resulting new system.

In this article, we will not investigate, in any great detail, the already well established mathematical models used in loudspeaker design. Instead, we will explore how these algorithms are implemented on a typical spreadsheet calculator, showing the significant advantages over other methods.

THE SPREADSHEET PARADIGM. Spreadsheet calculators were originally designed to explore various business scenarios for business people. They are so named because their layouts look much like an accountant's spreadsheet of rows and columns of figures, all related in an organized fashion to the problem being described. The most well known commercial spreadsheets include "Visicalc" and "Lotus 1-2-3." (A colleague has, half jokingly, referred to my use of the spreadsheet as "Speaker 1-2-3."

A spreadsheet calculator contains an array (usually two dimensional) of "cells" arranged in columns and rows. Each "cell" is addressed by its column and row: usually, columns are lettered and rows are numbered. A cell may contain a constant, a formula whose values can be either constants or references to the values in other cells, labels or simple strings to be printed on the screen, commands, or simply nothing. The contents of a cell are changed by moving a cursor to it and entering the new data. The values in cells containing equations which depend on the new or changed data are then updated. Certain cells can be targeted as "goals," meaning that the spreadsheet will iterate through the cells on which the goal cells depend until the goals are reached (if possible). The goal cells then display the resulting model.

As an example of a simple model, let's look at the formula for the resonant fre-

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ABOUT THE AUTHOR

Richard Pierce is currently the director of research and development for Precision Loudspeakers, Amherst, NH; and the senior graphics software engineer in the production test division of GenRad Inc., in Concord, MA. In addition to design and simulation of audio and electrosonic systems, he is also extensively involved in Baroque keyboard music and instruments and has constructed several harpsichords and organs as well as having restored several old organs in Belgium.

	A	B	C
1	L:	**0.0**	henries
2	C:	**0.0**	farads
3	f:	1/(2*pi*sqrt(B1*B2))	hertz

FIGURE 1.1: A simple spreadsheet based on an equation.

	A	B	C
1	L:	**0.001**	henries
2	C:	**3.60e-3**	farads
3	f:	83.88	hertz

FIGURE 1.2: A spreadsheet with values for calculations.

quency of an inductor-capacitor tank circuit:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

A simple spreadsheet based on this equation, showing the formulas, is illustrated in *Fig. 1.1.*

In cell [B1] we enter the value of the inductor, and in [B2] the value of the capacitor. The spreadsheet will look at the formula in [B3], note the references to [B1] and [B2] and use those values to solve the equation. Cells [A1], [A2], [A3], [C1],[C2], and [C3] contain labels that make the spreadsheet easier to use and read. The actual appearance of the cells on the spreadsheet would only show the resultant values, not the equations. *Figure 1.2* shows the same spreadsheet as it would apear with some reasonable values used for the calculations (in this example, as in all that follow, cells that can be modified by the user are highlighted with bolder type).

Often, the user has the option to specify the exact format of numerical presentation. For example, cell [B3] displays its value in fixed point notation with two decimal places, whereas cell [B2] is in scientific or "e" notation with three significant digits.

In more complex applications, cells containing formulas can refer to other cells that themselves contain formulas, describing potentially complex models. To illustrate with an example, consider a small model intended to calculate the resonant frequency of a loudspeaker, given its effective mass and compliance. In this example the mechanical units are first converted to acoustical units, then those results are used to compute the resonant frequency. The relationships being solved here are:

$$f_S = \frac{1}{2\pi\sqrt{M_{AS}C_{AS}}}$$

where the effective acoustic mass is related to the mechanical mass by:

$$M_{AS} = \frac{M_D}{{S_D}^2}$$

the effective acoustical compliance is related to the mechanical compliance by:

$$C_{AS} = C_{MS}{S_D}^2$$

and C_{MS} is the mechanical compliance, M_D is the mass and S_D is the effective projected area of the diaphragm. The spreadsheet, with the formulas, would look like *Fig. 1.3.*

"Plugging in" values from a real driver for d, M_D and C_{MS} results in *Fig. 1.4.*

The only limitation to a model's complexity is the maximum size of the spreadsheet, which, even in the smallest version examined, is several thousand cells.

A spreadsheet calculator for loudspeaker design should include:

- Calculations performed in floating-point arithmetic;
- Output formats in fixed-point and floating-point scientific notation;
- Availability of standard math operators (including exponentiation) and transcendental functions, such as $\log_{10}(x)$, $\sqrt{x}$, and so forth.

The further availability of graphing functions, customizable menus, database access and so forth, while not necessary, can only enhance the versatility of the final tool.

ENCLOSURE APPLICATIONS. In many ways, the spreadsheet model for closed- and vented-box systems is the most impressive and useful. The model in use at Precision Loudspeakers (Amherst, NH) allows us to quickly design both types of enclosures given the Thiele/Small parameters of a driver. Obviously we quickly discover some very strict limitations to the bandwidth, power handling capacity and cabinet dimensions for direct radiator loudspeakers when we can juggle all these parameters. More than once a customer has been disappointed to learn that building a system consisting of a 6″ woofer in a ten liter enclosure that is 3dB down at 20Hz with 5% efficiency and capable of playing at levels exceeding 110dB is a physical impossibility.

Let's take, as an example, a section from the closed-box system design spreadsheet shown in *Fig. 2.1.*

In this example, we have entered the basic Thiele/Small parameters d, X_{MAX}, f_S, V_{AS} , Q_{MS}, and Q_{ES} in cells [C1] through [C6]. The spreadsheet calculates the remainder of the driver parameters Q_{TS}, η_0, SPL, S_d and V_d automatically, as the needed parameters became available. Next, we enter the target system Q, Q_{TC} and the enclosure damping coefficient (an empirically derived number describing cabinet stuffing) into cells [C13] and [C14]. The spreadsheet can then calculate the optimum box volume, the tuning ratio, the −3dB frequency, and so forth. If, in this example, the driver's Q_{TS} is higher than the target Q_{TC}, the spreadsheet reports "alignment not possible" in the recommended volume cell, and the rest of the enclosure data is left blank. Alternatively, the spreadsheet could be asked to find the lowest Q possible, or driver parameters needed for a given enclosure size and response function.

Spreadsheet models for both closed- and vented-box systems have been combined to allow comparison of two configurations using the same driver. In this version, a table comparing the frequency responses at select frequencies gives an easily visible comparison between the two alignments as in *Fig. 2.2.*

Further, we can derive other information, such as the parameters for higher-order systems equalization, inclusion of

	A	B	C	D
1	Effective diameter	d:	**0.0**	cm
2	Effective area	Sd:	(pi*(C1/200)^2)	sq. m
3	Mechanical mass	Md:	**0.0**	kg
4	Mechanical compliance	Cms:	**0.0**	m/N
5				
6	Acoustical mass	Mas:	(C3/(C2^2))	
7	Acoustical compliance	Cas:	(C4*(C2^2))	
8				
9	Resonant frequency	Fs:	(1/(2*pi*sqrt(C6*C7)))	Hz

FIGURE 1.3: Formulas to calculate the resonant frequency of a loudspeaker.

temperature-limited power handling (all of the above power figures are based on excursion limiting) and so on.

We have not shown much of the underlying intermediate mathematics in the above examples. While obviously vital to the final solutions, displaying these intermediate results would only serve to confuse the user. Items such as enclosure losses, conversion from mechanical to acoustical units, and the like, can be done "off screen," or in "hidden cells." This also allows the user to incrementally build the application, as these intermediate results aid in debugging the model as it grows. There may, however, be a slight performance penalty in using many simple steps rather than a few complex ones.

The value of a spreadsheet implementation becomes apparent when you consider that the update time for the entire spreadsheet is often less than two seconds when a parameter is changed. The update can be deferred until several parameter changes have been made, thus saving time in recalculating for each entry. In addition, judicious setup of the model allows viewing and changing *all* the relevant parameters in a given application.

DRIVER DESIGN APPLICATIONS. At Precision, we are receiving requests to design new drivers for specific applications, so we must be able to specify drivers and driver components quickly and accurately to supply customer needs. For example, one application might require a driver with the same diameter, f_S and V_{AS} as a standard model, but a lower Q_{TS}. One way of accomplishing this is by changing the motor assembly. Changing the magnet structure is difficult because of the limited magnet materials and configurations available as well as the time and expense necessary to re-tool new front plates and pole pieces.

But the voice coil can be changed readily. A portion of the driver and enclosure design spreadsheet allows the user to configure new voice coils, selecting a wide variety of standard wire sizes and cross-sections, winding lengths, and number of layers. All the parameters that might affect the final performance of the system are calculated, including DC resistance, coil mass, X_{MAX}, Bl product, and the like. It is most enlightening to change the wire size from, say 28 to 30 gauge, or from copper to aluminum, leaving everything else constant, and watch what happens to the final system response as a result of the changes in Bl product, mass and DC resistance. Again,

	A	B	C	D
1	Effective diameter	d:	**13.2**	cm
2	Effective area	Sd:	13.68e-3	sq. m
3	Mechanical mass	Md:	**15.3e-3**	kg
4	Mechanical compliance	Cms:	**1.52e-3**	m/N
5				
6	Acoustical mass	Mas:	81.7	kg/m^2
7	Acoustical compliance	Cas:	0.285e-6	m^3/N
8				
9	Resonant freauency	Fs:	33.0	Hz

FIGURE 1.4: A spreadsheet with "plugged-in" values for a real driver.

	A	B	C	D
1	Effective diameter	d:	**13.30**	cm
2	Maximum excursion	Xmax:	**0.70**	cm
3	Resonant frequency	Fs:	**33.0**	Hz
4	Equivalent volume	Vas:	**40.0**	L
5	Mechanical Q	Qms:	**2.04**	
6	Electrical Q	Qes:	**0.39**	
7	Total Q	Qts:	0.33	
8	Reference efficiency	n0:	0.36	%
9	Output level (1 watt)	SPL:	87.5	dB
10	Effective area	Sd:	138.9	sq. cm
11	Maximum displacement	Vd:	97.3	cu. cm
12				
13	Target system Q	Qtc:	**0.707**	
14	Enclosure damping		**2**	(0-5)
15	Recommended volume	Vb:	8.03	L
16	Tuning ratio	a:	4.61	
17	-3dB frequency	F3:	78.2	Hz
18	Peak response ripple	Rh:	0.00	dB
19	Maximum acoustic output	Par:	0.29	W
20	Maximum SPL		103.7	dB SPL
21	Maximum inuut power	Per:	82.9	W

FIGURE 2.1: An example from the closed-box system design spreadsheet.

	A	B	C	D	E
31		PERFORMANCE COMPARISON			
32			CLOSED	VENTED	
33	Enclosure volume	Vb:	8.03	19.86	L
34	-3dB frequency	F3:	78.2	44.9	Hz
35	Response ripple	Rh:	0.00	0.14	dB
36	Maximum output	Per:	0.29	0.12	W
37	Maximum SPL		103.7	100.1	dB SPL
38	Maximum input	Per:	82.9	35.3	W
39		FREQUENCY RESPONSE			
40			CLOSED	VENTED	
41		15.9	-27.70	-31.60	dB
42		20.0	-23.70	-24.46	dB
43		25.2	-19.72	-17.47	dB
44		31.7	-15.77	-10.75	dB
45		40.0	-11.93	-4.90	dB
46		50.4	-8.32	-1.36	dB
47		63.5	-5.18	-0.24	dB
48		80.0	-2.82	-0.05	dB
49		100.8	-1.34	-0.03	dB
50		127.0	-0.58	-0.03	dB
51		160.0	-0.24	-0.03	dB
52		201.6	-0.10	-0.02	dB

FIGURE 2.2: A table comparing frequency responses.


H.


A.


B.


E.


G.


D.


C.


F.

all the answers are available within a few seconds after a parameter change. An extract from the voice-coil spreadsheet is shown in *Fig. 3.1.*

Another spreadsheet model facilitates quick measurement of Thiele/Small and dynamic parameters of drivers using the normal free-air and reference volume tests which will be included in *Part II* of this article.

```
                       A                 B          C          D
 78           Wire type:
 79               Copper                 1
 80             Aluminum                 2
 81      Phosphor/Bronze                 3
 82               Silver                 4
 83    Select wire type:                 1
 84                      WIRE PARAMETERS
 85   Select wire guage:                           31
 86             Material                       Copper
 87     Specific gravity                         8.96
 88          Resistivity                         1.72
 89                     COIL FORM PARAMETERS
 90  Coil former diameter           df:          3.25        cm
 91    Coil former length           Lf:          1.30        cm
 92     Number of layers                            2
 93                      MAGNET PARAMETERS
 94   Top plate thickness          Tfp:          0.79        cm
 95     Flux density in gap          B:        9500.0        gauss
 96                       VOICE COIL DATA
 97       Number of turns            N:           111
 98  Coil outside diameter                       3.34        cm
 99     Total wire length           Lw:         11.28        m
100    Length of wire in gap         l:          6.86        m
101            Bl product           Bl:          7.03        N/A
102             Coil mass          Mvc:          3.24        g
103         DC resistance           Re:          6.05        Ohms
```

FIGURE 3.1: An extract from the voice coil spreadsheet.

FURTHER APPLICATIONS AND ENHANCEMENTS. We have developed standard crossover configurations, allowing near-automatic optimization of crossovers and impedance equalization networks to the specific characteristics of the driver. Part of the driver and enclosure design spreadsheet generates the component values for the completed system's electrical equivalent circuit, along with an accurate model for the voice-coil inductance. It also includes the effective shunting resistance due to eddy currents in the magnet circuit. We can then accurately design and simulate crossovers loaded with realistic terminal impedances.

Currently, we are also building an application that would integrate the spreadsheet models with the engineering data base. This would allow us to specify a given target response (either a set of driver parameters or a complete system specification) and have the spreadsheet either recommend the closest matching standard driver, or a plausible set of off-the-shelf components along with any needed changes.

Finally, we are exploring ways to interface the spreadsheet directly with data acquisition hardware and software, allowing real-time data to be available appropriately scaled to engineering units in selectable cells within the spreadsheet. The models may then be used in conjunction with a sophisticated driver quality control program for production use. A printout of the resulting spreadsheet may be used either as a repair ticket for out-of-spec drivers or as an assurance to the customer of the driver's performance.

CONCLUSIONS. The spreadsheet is a rapid, easy-to-use and versatile tool for modeling driver and system performance in an engineering and manufacturing environment. It is especially valuable in determining the feasability of otherwise marginal configurations. The ability to generate new voice-coil and magnet configurations has been especially useful in designing drivers to fit specific and well defined applications.

In spite of the seeming lack of a spreadsheet language standard, I have successfully implemented these models on a wide variety of programs, including Access Technology's SUPERCOMP20 running on a DEC PDP-11/23, Applix' *ALIS*, an integrated office-automation system on Sun Microsystems workstations running Unix, and a public domain spreadsheet calculator *sc*. Only minor changes were required when porting the models from one system to another.

These models, like all other simulation and prototyping systems, have one weakness. The results are only as dependable as the accuracy of the model. I have invested a lot of time and effort in researching the literature to verify the models, and done further hardware prototyping to determine that the models, no matter how theoretically accurate, do

Continued on page 65

Finding a Spreadsheet

If you have an IBM-PC/XT/AT, one of its clones or a compatible and you haven't gotten around to buying a spreadsheet program as yet, you can purchase a trial copy of *Express Calc*, a *Shareware* product for $10, plus $2 shipping.

Express Calc is not public domain software and is copyright protected. The two 5¼", 360k, DSDD, 9-sector disks contain the *Express Calc* programs, require 256k of RAM, and work with DOS 2.0 or higher with a monochrome or color display. A user's guide may be printed from the disks. You may subsequently register for full support and receive the latest version, a printed manual in a loose-leaf binder, and will be notified of updates when they are available. A registered set is priced at $49 and your initial $10 fee is deducted. Expressware is located at P.O. Box 230, Redmond, WA 98073-0230 (206) 643-3503.

Another product which may interest *SB* readers is *The Twin* from Mosaic Software, Inc., 1972 Massachusetts Ave., Cambridge, MA 02140. The manufacturer claims it is a clone of the more famous *Lotus 1-2-3.* Somewhat more powerful and larger than *Express Calc*, its editor is easier to use and it is bundled with a full graphics package. It requires 320k of RAM, comes on three diskettes, and has a complete manual. It lists for $145 but is widely discounted and is, at this writing, being offered by BCE, 3233 K St. NW, Washington, DC 20007, (800) 545-7447, for $44 (plus $5 shipping).—ETD

Part I

In Memoriam Richard C. Heyser

1931–1987

BY PETER E. SUTHEIM

Four months before his death at the age of 55, speaking to a gathering of hundreds at the Eighty-First Convention of the Audio Engineering Society in Los Angeles by tape recording and telephone hookup from his hospital bed in Pasadena, Richard Heyser expressed some doubts about presenting the paper he was about to read. With characteristic earnestness tempered by characteristic good humor, he wondered publicly whether he should proceed, since not many audio practitioners had read—and probably far fewer had understood—his earlier papers.

Much of Heyser's work, especially that part published within the past decade, has yet to be properly assessed by his colleagues in the wider realms of physics and mathematics. This article does not pretend to be such an assessment. It is, rather, a technical and personal appreciation, in two parts, of Richard Heyser's immense contribution to the field of audio.

Not for everyone would the AES have expended such effort; but then, not everyone would have surmounted a painful and debilitating cancer to present a paper as scheduled. Not for everyone would so many have gathered to hear a paper on so abstruse a topic; not everyone would have earned such respect. Heyser as the president-elect of the AES, chosen as much for his difficult yet enriching contributions over nearly 30 years as for his cheerful energy and his leadership.

A colleague and friend, John Prohs, helped Heyser to tape his paper in the hospital. Heyser's wife, Amy, recalls that he came out of major surgery in the morning, and worked that night till 11:30.

Even a moderately careful reading of Heyser's first AES paper, "A Signal-Biasing Output-Transformerless Transistor Power Amplifier" [hyphens added by this writer], published in the *Journal* of the AES for July 1960, discloses several hallmarks of his writing. He was, later in his career, chided (perhaps mainly by those who read too casually) for obscurity, for the denseness of his prose. But there is the denseness of the bureaucrat, whom one suspects of using language to conceal shallowness of thought, and there is the denseness of the writer who has an immense load of technical thought to convey, and expects interested and careful readers to meet him on common ground. Heyser's writing in this first paper is a model of thoroughness and concision.

He describes an elegant audio amplifier design, entirely DC-coupled, using no transformers, at a time when interstage transformer coupling was still common practice. The amplifier's efficiency approaches that of Class-B designs, but without their drawbacks, by using some of the reactive stored energy of the loudspeaker. (According to Heyser's data, his amplifier's performance is better with a normally reactive loudspeaker load than with the canonical resistive load—a desideratum that amplifier designers seem still to have been struggling with a quarter of a century later.)

He considers the background to his invention, then describes the theory behind it, presents a buildable schematic diagram, and then comprehensively analyzes every aspect of his circuit, touching on almost every single part, explaining the effect of changes in operating conditions, pointing out limitations of the circuit and adaptations for various applications. A brief passage illustrates:

"Input resistors establish the base potentials of T-1 and T-2 such that they are entirely in Class-A operation at all times. Except for the ratio of these base resistors no other resistor is critical and all might be modified by factors of two or greater without degrading performance. Similarly, since all transistors are in the emitter follower configuration, any type transistor may be inserted for those shown provided they meet the circuit qualifications for symmetry, collector dissipation, and maximum Ico as determined by the respective base resistors."

The circuit itself is simple and economical, and is equally notable for its high-frequency extension. Heyser presents an oscilloscope photo of a 10kHz square wave that is quite square indeed—suggesting bandwidth to 200kHz. This he accomplished (presumably because he used the emitter-follower configuration throughout) with 1950's germanium transistors such as the 2N176, whose gain-bandwidth limit scarcely reached that figure.

In a time when hyperbole is so commonplace that "hype" has become everyday slang, it is difficult to make a point by declaring that someone's invention has changed audio forever. Such notions are not unknown, even by the most conservative interpretation; who would counter the assertion that Lister's antiseptic techniques of the early 19th century changed the practice of surgery forever? Yet with the presentation of a paper in 1967, Richard Heyser introduced a measurement technique whose implications are still appreciated only by a relatively small number of audio workers, and which spawned several sophisticated, commercially manufactured instruments to facilitate the technique.

Among other benefits, Heyser made it unnecessary to resort to extremely cumbersome and costly anechoic chambers to make loudspeaker measurements, thus opening the field to serious and competent designers who could not afford access to such facilities. But his discoveries went much deeper than that. It is not an exaggeration to say that the preoccupation of speaker designers over the past 15 years or so with the alignment of drivers, the elimination of cabinet reflections and refractions, the time-and-phase integrity of crossover networks, to name a few examples, is due very largely to the ease with which Heyser's time delay spectrometry permitted engineers to see what they were doing, and to correlate their measurements with audible changes.

For historical accuracy, it is important to make clear that Heyser did not discover time integrity, cabinet reflections and such. Discussion of these matters appears in the literature at least as far back as the early 1950s. But measuring their effects and relating them to how a loudspeaker actually sounded was so time-consuming as to be wholly impractical as a design tool in producing a commercial loudspeaker system. By now, loudspeaker design has changed so thoroughly and permanently that anyone who attempts a commercial design without examining its phase and time performance is simply not competent. That is the true meaning of that irredeemably abused expression, "the state of the art." The state of the art was truly changed by Heyser's work, beginning with the publication of "Acoustical Measurements by Time Delay Spectrometry" (*JAES*, October 1967).

The paper is too long to summarize here; with typical thoroughness Heyser presents his conception in lay language that would feel quite at home in *Scientific American* before moving on to the practical implementation of his invention, and its application to typical measurement situations. It is hard to convey an appreciation of the thoroughness of this work; of the growing confidence (in this reader, at least), that all questions will eventually be answered. Seven pages in we come to this astonishing remark:

"The measurement technique of the previous paragraphs was developed in a highly intuitive manner. Although experimental measurements tend to verify the technique, it is still necessary to analyze two very important considerations: first, the nature of a repetitive glide tone, and second, the validity of identifying the spectrum analyzer display with the acoustic spectrum." There follows more than four pages of mathematical exposition, which has the effect of tying the whole matter up in a neat and rigorous package. We get it all: the review of current practice, the intuitive description of the invention, the experimental validation, and finally the mathematics. It looks good, and it even works, Heyser seems to be saying, but let's do the homework and see if it stands up to mathematical scrutiny.

From the beginning, Heyser's *JAES* papers were by-lined "Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California." Exactly what his work was at JPL seems to have borne an aura of mystery among some of his colleagues, even though it was described in some detail in the biography appended to some of his later papers. It had little to do directly with audio as an entertainment medium or a vehicle of culture. He was in [to quote the official biography] "information systems research. His activities at JPL have involved communication and instrumentation design for all major space programs at JPL, commencing with conceptual design on America's first satellite, Explorer I. More recently he has been involved in the application of coherent spread spectrum techniques to improving underwater sound research and medical ultrasound imaging."

". . .he can explain everything he does in 10 minutes, but. . ."

Heyser was fond of referring to audio as "a hobby that got out of hand." Emanuel Tward, a colleague of Heyser's at JPL and a close friend, wrote in a brief eulogy published in the May 1987 AES *Journal*: "The amazing thing about Dick Heyser was that his interest spanned the range of technology, from the most practical of electronics and acoustics to the most fundamental philosophy of how we make observations of physical phenomena.... He was a boy genius until the day he died. He questioned everything, had to understand everything, and knew so much about everything."

The 1967 paper was only the beginning. Heyser's later work was to reach far into the mathematics of how we conceptualize reality, using audio as a model. From that hindsight, his contributions to audio engineering were almost a kind of by-product.

In 1969, the *JAES* published a Heyser paper in two parts, "Loudspeaker Phase Characteristics and Time Delay Distortion," clearly an outgrowth of his work in time delay spectrometry. If the 1967 "Acoustical Measurements" paper defined a new state of the art in loudspeaker measurements, the 1969 work addressed the loudspeaker itself in a similarly radical way. What ties these seminal works together is Heyser's recognition that "beside the conventionally measured pressure amplitude spectrum there is a pressure phase spectrum, which...has not been as well investigated." The "pressure amplitude spectrum" is, of course, just good old frequency response, as we are accustomed to thinking of it: amplitude, in the form of sound pressure, plotted against frequency.

What was not then apparent to many workers in the field was that, associated intimately with this pressure amplitude spectrum was a pressure *phase* spectrum, and the relationship between the two would tell a great deal about the device under test. Since, in this context, phase is time, Heyser has been credited with introducing the "time domain" into audio considerations. In particular, Heyser observed from his measurements using his time-delay spectrometry that "there was in many cases a frequency-dependent time delay in excess of that caused by the...distance from voice coil to [measuring] microphone diaphragm." (This "delay" was sometimes *negative*—that is, actually an advance: at some frequencies, the sound would arrive at the measuring microphone *earlier* than would be expected from the physical distance between loudspeaker and microphone.)

Heyser found it useful to devise the concept of a "spatial 'spreading out' of the effective acoustic position of a loudspeaker behind its physical position." His other major contribution in this paper was to point out that "the frequency response of a loudspeaker [is] the complex Fourier transform of its response to an impulse of electrical energy." From this would sprout new and illuminating ways of thinking about frequency, amplitude and phase/time.

This work and time delay spectrometry (TDS) bore practical fruit. TDS found application not only in loudspeaker measurement but in ultrasonics for medicine and in underwater acoustic technology—branches of audio usually ignored by *SB* readers. By us, he will be better remembered for setting new standards of technical thoroughness in loudspeaker reviews in *Audio*. Eugene Pitts assumed the post of editor there in 1973. "I knew I needed to improve the quality of our reviews," he recalls, "but I wasn't capable of doing them myself. Bert Whyte told me about Dick Heyser. I called him up out of the blue at Jet Propulsion Labs and explained who I was.

"Dick thought I was a phony, but he was polite enough not to say that. He didn't know that *Audio* had changed editors. He asked if I had read any of his papers and I had to say no. He said, Well, let me send you a couple of reprints and I'll think a little about the testing. He sent me the three 1969 papers. I'm still no good in math, so I skipped over those parts. But I said to myself, if this guy can make these anechoic measurements in an ordinary room—and I could see the principle involved, and I was amazed that nobody else was doing anything with it. I mean, it was just so easy—the filter window delayed in time by the speed of sound over the distance—except for the guy who had to think it up originally. One of Dick's self-deprecating statements [was] that he can explain everything he does in 10 minutes, but it makes him very humble to think that it took him 10 years to think it up. At any rate, he came back with, I think, eleven measurements, and we have stuck with those for these dozen-plus years. He added the complex-impedance Nyquist plot later on."

In those pages of *Audio*, Heyser began to reveal that many of the colorations of speaker systems were not displayed by conventional frequency response (pressure-amplitude versus frequency) measurements, but would show up instead in time-domain measurements. Having the energy from the tweeter arrive at the listener's ears consistently before that from the woofer in a particular system, for example, would likely create a characteristic acoustical "fingerprint" or signature associated with that system, audible perhaps as a "honk," or a softening of percussive sounds. A delay that changed with frequency could be heard as instability or wandering of acoustic images: voices whose position on the stereo stage would change according to the note being sung.

"He was reformulating the mathematics on which all physics. . .is based."

Heyser's reviews typically included energy-time curves, with energy (amplitude) as the vertical axis and time as the horizontal axis, that plainly showed the contributions of the woofer, tweeter and midrange drivers as they "chimed in" (unsimultaneously), and also the spurious contributions of cabinet edges and grille frames. Such a curve is the envelope of the impulse response, generated, in Heyser's technique, not by an impulse as such but as the transform of a glide tone—a sort of elongated "chirp."

In his speaker reviews, Heyser pioneered the use of the crescendo test, which, in his words, "checks the masking influence of loud orchestral passages on a single inner voice." In one particular speaker he examined, "a tone of 440Hz is reduced by approximately 0.7dB when broad-band noise, at 20dB higher level, is superimposed on the tone.... This suggests a slight lateral and depth shift of solo instruments in the stereo illusion when broad-band peaks, such as due to brass, occur predominantly in one channel." Throughout his reviews, he attempted continually to tie together his measurements with his (and others') musical perceptions, by giving musical examples, by referring to frequencies in musical terms of pitch or position on the piano keyboard.

"His first review appeared in November 1973 along with the basic article on what we were doing," Gene Pitts relates. "The first couple of [manufacturers were not too pleased], and [others] sporadically for the next couple of years, because they hadn't kept up with the journals. There were people, sometimes very well known people, who were knocked over. 'You can't review a speaker like that.' Some of them still want no measurements at all, let alone any correlations with listening tests. All too many reviews are requested by marketing folks, who think of me as an adjunct to their public-relations efforts. Dick was anything but that. He would rather not publish than publish something that was adulterated."

Heyser included in each review his opinion of the speaker under test, based on his own listening. "There was unhappiness about that, but more and more through the years there was a recognition that he knew what he was talking about." Pitts acknowledges that some manufacturers withdrew their advertising in response to unflattering reviews, and more threatened to do so, but "we also had the other reaction—of people taking a speaker off the market rather than letting us run the review."

"We had season tickets to the concert series at Ambassador Auditorium," remarked Amy Heyser, "and we occasionally went to the Music Center." (Both are major Los Angeles-area concert halls—the latter the home of the Los Angeles Philharmonic Orchestra.) A harmony textbook sits on a shelf in the Heyser living room.

"I've thought a number of times that adding Dick Heyser to *Audio* made me as an editor," Gene Pitts declared thankfully.

By the mid-1970s, Heyser was publishing papers in the *JAES* with such titles as "A Rosetta Stone for Audio?", "Geometrical Considerations of Subjective Audio", "The Sound of One Clap Handing", and "Fuzzy Alternatives." His friend and former JPL colleague Manny Tward says, "I'm a physicist, not an acoustician, and I think his papers were published in the wrong medium. They're far more significant than something like acoustics. He was reformulating the mathematics on which all of physics and all of observation is based. That's an incredible statement to make, but that's really what he was doing. If judged correct, and disseminated, this will have really fundamental consequences for all of physics."

This is the first part of a two-part article.

ABOUT THE AUTHOR

Peter Sutheim has been a Contributing Editor to Audio Amateur, SB*'s sister publication, and has written for numerous audio and electronics magazines for the past 25 years. He heads the Audio-Visual Department at Occidental College in Los Angeles, produces a weekly audiophile radio show, and consults on audio and acoustical matters.*

HOW TO USE NON-OPTIMUM VENTED BOXES

BY G.R. KOONCE
Contributing Editor

Vented box design is based on the three basic T/S (Thiele/Small) parameters for a driver: f_S, Q_{TS} and V_{AS} (see *Table 1*). You may also find it useful to know the two components which make up Q_{TS}, i.e. Q_{MS} and Q_{ES}.

Numerous equations and alignment charts design "optimum" enclosures, i.e., as flat a response as possible, based on the driver T/S parameters. All such aids assume a Q for the enclosure (Q_B). This is mainly attributed to leakage, and is sometimes called Q_L. Seven is the most commonly used value for Q_B (or Q_L).

The output of these equations or charts is a group of coefficients: h, alpha(α), f_3/f_S, and R_H (sometimes called peak, ripple, hump and so on). These coefficients, along with the driver parameters, result in enclosure design information: V_{Bopt}, f_B and f_3. When you know the values of V_B and f_B, additional equations, tables and charts are available to give you the required length of tuning ducts of various diameters.

At times, it is not practical to use an "optimum" design, such as:

1. The two drivers are not identical and you wish to put them in the same size box.

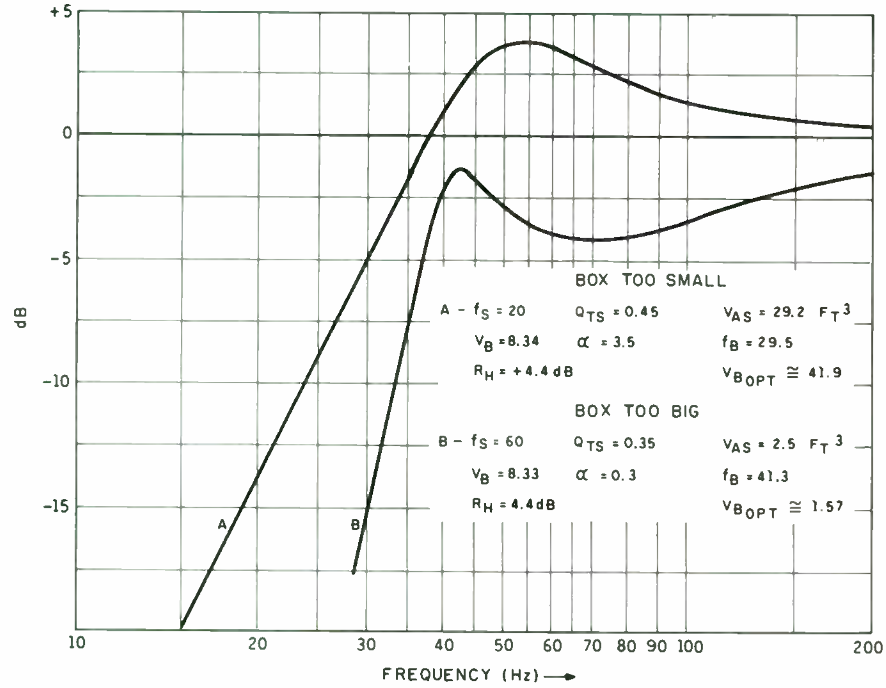


FIGURE 1: Shape of response for $+R_H$ and $-R_H$ errors.

2. The optimum volume is too big and you want to try a smaller box.
3. You are trying to fit an existing driver into an existing box which is not of optimum volume.
4. You may want a non-flat response, such as peaking the bass with a small driver.

Small and Margolis[1] have developed a set of approximation equations which handle non-optimum designs. Over the range Q_{TS} from 0.25 to 0.65, the equations are accurate to about 1dB. They also assume $Q_B = 7$. These equations use f_{SB}, but this is usually not known during design. I have substituted f_S, which is very close to f_{SB}, but error will increase somewhat.

A flood of alignment shapes have been defined, such as BB_4, QB_3, C_4, Be_4, IB_4 and so forth, not all of these being flat alignments. The most common flat alignments used in home audio are the QB_3 for Q_{TS} below about 0.4, and the C_4 for Q_{TS} over 0.4. The Small-Margolis approximation equations follow this most common pair. These equations yield the following, all approximations:

1. With driver parameters, they will yield the normal coefficients (h, α and f_3/f_S) for optimum flat designs.
2. With driver parameters and a given box size (non-optimum), they will yield the above coefficients plus R_H to allow enclosure design and give you an idea of its performance.
3. With driver parameters, box size and tuning, they allow you to plot the frequency response of the enclosure-driver combination.

I have listed all the equations in

Table 2 and provided an alignment chart in *Table 3* for non-optimum designs prepared from these equations.

THE R_H FUNCTION. R_H is the dB value of the anomaly in the response due to non-optimum alignment. If you use too small a box, R_H will be positive and the response will hump above the zero dB line. Conversely, if your box is oversized, R_H will be negative and the response will droop below the zero dB line. *Figure 1* shows curves for the exaggerated case of plus and minus R_H values of 4.4dB. The $-$RH curve is not too attractive, so try to avoid it.

By working with the Small-Margolis equations, you can show to a first order approximation that the R_H value can be made independent of Q_{TS} and expressed as only a function of actual and optimum enclosure volume. The results of relating the V_B/V_{Bopt} ratio and R_H are shown in *Fig. 2*. If you miss the box volume by two to one, it will cause less than 2dB anomaly. But be careful; do not merely take an optimum design and build the wrong size box. The non-optimum enclosure is tuned differently and the -3dB frequency (f_3) will move.

Should you wish to lower an excessive +RH, you can raise V_B (not always easy!) or put a fiberglass mat over the back of the driver. This will lower Q_{MS}, and thus Q_{TS} and move a small box closer to V_{Bopt}. To reduce a $-R_H$, you can reduce V_B by partitioning a portion of the box or filling it with bricks or additional bracing. You can also add some resistance in series with the driver. This raises Q_{ES}, and thus Q_{TS}, giving a better fit to the box volume (*Table 2*). ➤

See pages 26 and 27 for *Fig. 2* and *Table 3*.

REFERENCES

1. Margolis, G., and R. Small, "Personal Calculator Programs for Approximate Vented-Box and Closed-Box Loudspeaker System Design," AES preprint 1650 (B-3). This preprint contains some typographical errors, so study it carefully.

AES preprints are available from: Audio Engineering Society, 60 East 42nd Street, New York, NY 10165

2. R. M. Bullock III covers vented box design and driver parameter measurement in great detail, offers flat and non-flat alignment charts for various values of Q_B and also provides a mathematical approach to tuning non-optimum box volumes. The articles are in *Speaker Builder*, issues 4/80, 1, 2, 3/81, 3/82 and 1/83.

TABLE 1

DEFINITIONS

Driver parameters:

f_S = resonant frequency of moving system of the driver without an enclosure
Q_{TS} = total driver Q at f_S resulting from all driver resistances, electrical and mechanical
Q_{TS} = $(Q_{MS} \times Q_{ES})/(Q_{MS} + Q_{ES})$
V_{AS} = acoustic compliance of driver, expressed as an equivalent volume of air
Q_{MS} = driver Q at f_S resulting from mechanical resistances
Q_{ES} = driver Q at f_S resulting from electrical resistances
R_E = DC resistance of driver voice coil
f_{SB} = resonant frequency of moving system of driver in the vented box ($f_S \cong f_SB$)

Enclosure design coefficients: Alpha (α) = compliance ratio
α = V_{AS}/V_B (V_{AS} and V_B in the same units and box not filled with damping material)
h = system tuning ratio = f_B/f_S
f_3/f_S = ratio of -3dB frequency to f_S
R_H = response anomaly—defined in text

Enclosure-driver parameters:
V_B = net volume of enclosure
V_{Bopt} = net volume of an enclosure which gives an optimum response
f_B = resonant frequency of vented box
f_3 = half power (-3dB) frequency of the driver high-pass system response
Q_B = total enclosure Q at f_B resulting from all box losses; leakage (Q_L), vent loss (Q_P) and absorption (Q_A)
$1/Q_B$ = $1/Q_L + 1/Q_P + 1/Q_A$

TABLE 2

EQUATIONS

Small-Margolis for optimum enclosure (Q_B = 7)
$V_{Bopt} \cong 20\ V_{AS}\ (Q_{TS})^{3.3}$
$f_3 \cong 0.28\ f_{SB}\ (Q_{TS})^{-1.4} \cong 0.28\ f_S\ (Q_{TS})^{-1.4}$
$f_B \cong 0.42\ f_{SB}\ (Q_{TS})^{-0.96} \cong 0.42\ f_S\ (Q_{TS})^{-0.96}$

Small-Margolis for non-optimum enclosure (Q_B = 7) Alpha = V_{AS}/V_B
$f_3 \cong f_{SB}\ (\alpha)^{0.44} \cong f_S\ (\alpha)^{0.44}$
$f_B \cong f_{SB}\ (\alpha)^{0.31} \cong f_S\ (\alpha)^{0.31}$
$R_H \cong 20\text{Log}\,[f_B\ Q_{TS}/(0.4\ f_{SB})] \cong 20\text{Log}\,[f_B\ Q_{TS}/(0.4\ f_S)]$

Small-Margolis for plotting response of V_B (Q_B = 7)
$R \cong 20\text{Log}\{f_N^4/[(f_N^4 - Cf_N^2 + A)^2 + f_N^2(Df_N^2 - B)^2]^{1/2}\}$ in dB
$A = (f_B/f_{SB})^2$
$B = A/Q_{TS} + f_B/(7\ f_{SB})$
$C = 1 + A + V_{AS}/V_B + f_B/(7\ f_{SB}\ Q_{TS})$
$D = 1/Q_{TS} + f_B/(7\ f_{SB})$ $f_N = f/f_{SB}$
where f is the frequency of interest and f_S can be substituted for f_{SB} with slightly increased error.

- My modification of the Small-Margolis equations show that:

$$R_H \cong 20\ \text{Log}\ (V_{Bopt}/V_B)^{0.31} \text{ in dB}$$

- Effect of adding resistance (R_X) in series with a driver on its Q. New electrical Q = Q_{ES}'

$$Q_{ES}' = Q_{ES}(R_E + R_X)/R_E$$

I would limit R_X to about 1Ω for 8Ω drivers.

- Finding f_{SB}: $f_{SB} = f_L \times f_H/f_B$

where f_L is the lower impedance peak frequency and f_H is the higher impedance peak frequency of the vented box system.

The impedance minimum (valley) frequency is f_M, which is difficult to find and does not equal f_B. You can find f_B by nearfield testing since it is the frequency where driver output is minimum. Use the following impedance measurement:

1. For the vented box, find f_L and f_H.
2. Seal the vent and find the now closed box system resonance f_C (peak in impedance curve).
3. Calculate $f_B = (f_H^2 + f_L^2 - f_C^2)^{1/2}$

When measuring f_C, this method is very sensitive to leaks in the box, and I have not had good luck with it.

Table 3 f_3/f_s, h, & R_h for Non-Optimum Alignments
Page 1

Alpha	f_3/f_s	h	R_h for indicated Q_{ts}							
			Q_{ts}= .25	Q_{ts}= .30	Q_{ts}= .35	Q_{ts}= .40	Q_{ts}= .45	Q_{ts}= .50	Q_{ts}= .55	Q_{ts}= .60
.22	0.514	0.625	-8.2	-6.6	-5.2	-4.1	-3.1	-2.1	-1.3	-.56
.24	0.534	0.642	-7.9	-6.3	-5.0	-3.8	-2.8	-1.9	-1.1	-.32
.26	0.553	0.659	-7.7	-6.1	-4.8	-3.6	-2.6	-1.7	-.86	-.11
.28	0.571	0.674	-7.5	-5.9	-4.6	-3.4	-2.4	-1.5	-.66	+.09
.30	0.589	0.689	-7.3	-5.7	-4.4	-3.2	-2.2	-1.3	-.48	+.28
.32	0.606	0.702	-7.2	-5.6	-4.2	-3.1	-2.0	-1.1	-.30	+.45
.34	0.622	0.716	-7.0	-5.4	-4.1	-2.9	-1.9	-.97	-.14	+.62
.36	0.638	0.729	-6.8	-5.2	-3.9	-2.8	-1.7	-.81	+.02	+.77
.38	0.653	0.741	-6.7	-5.1	-3.8	-2.6	-1.6	-.67	+.16	+.92
.40	0.668	0.753	-6.5	-5.0	-3.6	-2.5	-1.4	-.53	+.30	+1.1
.42	0.683	0.764	-6.4	-4.8	-3.5	-2.3	-1.3	-.40	+.43	+1.2
.44	0.697	0.775	-6.3	-4.7	-3.4	-2.2	-1.2	-.27	+.56	+1.3
.46	0.711	0.786	-6.2	-4.6	-3.3	-2.1	-1.1	-.15	+.68	+1.4
.48	0.724	0.796	-6.1	-4.5	-3.1	-2.0	-.95	-.04	+.79	+1.5
.50	0.737	0.807	-5.9	-4.4	-3.0	-1.9	-.84	+.07	+.90	+1.7
.52	0.750	0.817	-5.8	-4.3	-2.9	-1.8	-.74	+.18	+1.0	+1.8
.54	0.763	0.826	-5.7	-4.2	-2.8	-1.7	-.64	+.28	+1.1	+1.9
.56	0.775	0.835	-5.6	-4.1	-2.7	-1.6	-.54	+.38	+1.2	+2.0
.58	0.787	0.845	-5.5	-4.0	-2.6	-1.5	-.44	+.47	+1.3	+2.1
.60	0.799	0.854	-5.5	-3.9	-2.5	-1.4	-.35	+.56	+1.4	+2.1
.62	0.810	0.862	-5.4	-3.8	-2.4	-1.3	-.26	+.65	+1.5	+2.2
.64	0.822	0.871	-5.3	-3.7	-2.4	-1.2	-.18	+.74	+1.6	+2.3
.66	0.833	0.879	-5.2	-3.6	-2.3	-1.1	-.10	+.82	+1.6	+2.4
.68	0.844	0.887	-5.1	-3.5	-2.2	-1.0	-.02	+.90	+1.7	+2.5
.70	0.855	0.895	-5.0	-3.5	-2.1	-.96	+.06	+.98	+1.8	+2.6
.72	0.865	0.903	-5.0	-3.4	-2.0	-.88	+.14	+1.1	+1.9	+2.6
.74	0.876	0.911	-4.9	-3.3	-2.0	-.81	+.21	+1.1	+2.0	+2.7
.76	0.886	0.918	-4.8	-3.2	-1.9	-.74	+.28	+1.2	+2.0	+2.8
.78	0.896	0.926	-4.8	-3.2	-1.8	-.67	+.35	+1.3	+2.1	+2.9
.80	0.906	0.933	-4.7	-3.1	-1.8	-.60	+.42	+1.3	+2.2	+2.9
.82	0.916	0.940	-4.6	-3.0	-1.7	-.53	+.49	+1.4	+2.2	+3.0
.84	0.926	0.947	-4.6	-3.0	-1.6	-.47	+.55	+1.5	+2.3	+3.1
.86	0.936	0.954	-4.5	-2.9	-1.6	-.41	+.62	+1.5	+2.4	+3.1
.88	0.945	0.961	-4.4	-2.8	-1.5	-.34	+.68	+1.6	+2.4	+3.2
.90	0.955	0.968	-4.4	-2.8	-1.4	-.28	+.74	+1.7	+2.5	+3.2
.92	0.964	0.974	-4.3	-2.7	-1.4	-.22	+.80	+1.7	+2.5	+3.3
.94	0.973	0.981	-4.2	-2.7	-1.3	-.17	+.86	+1.8	+2.6	+3.4
.96	0.982	0.987	-4.2	-2.6	-1.3	-.11	+.91	+1.8	+2.7	+3.4
.98	0.991	0.994	-4.1	-2.6	-1.2	-.05	+.97	+1.9	+2.7	+3.5

Before using this alignment chart for non-optimum enclosure volume:

1. You must know the following driver parameters corrected for any added DC resistance, fiberglass damping pads, and so on: f_S, Q_{TS} *and* V_{AS}.
2. You must know the net volume of the enclosure you are going to use: V_B (same units as V_{AS})
3. Find $\alpha = V_{AS}/V_B$ and find the line in the chart corresponding most closely to alpha.

Table 3 f_3/f_s, h, & R_h for Non-Optimum Alignments
Page 2

Alpha	f_3/f_s	h	R_h for indicated Q_{ts}							
			Q_{ts}= .25	Q_{ts}= .30	Q_{ts}= .35	Q_{ts}= .40	Q_{ts}= .45	Q_{ts}= .50	Q_{ts}= .55	Q_{ts}= .60
1.0	1.000	1.000	-4.1	-2.5	-1.2	+.00	+1.0	+1.9	+2.8	+3.5
1.1	1.043	1.030	-3.8	-2.2	-.90	+.26	+1.3	+2.2	+3.0	+3.8
1.2	1.084	1.058	-3.6	-2.0	-.67	+.49	+1.5	+2.4	+3.3	+4.0
1.3	1.122	1.085	-3.4	-1.8	-.45	+.71	+1.7	+2.6	+3.5	+4.2
1.4	1.160	1.110	-3.2	-1.6	-.25	+.91	+1.9	+2.8	+3.7	+4.4
1.5	1.195	1.134	-3.0	-1.4	-.07	+1.1	+2.1	+3.0	+3.9	+4.6
1.6	1.230	1.157	-2.8	-1.2	+.11	+1.3	+2.3	+3.2	+4.0	+4.8
1.7	1.263	1.179	-2.7	-1.1	+.27	+1.4	+2.5	+3.4	+4.2	+5.0
1.8	1.295	1.200	-2.5	-.92	+.42	+1.6	+2.6	+3.5	+4.3	+5.1
1.9	1.326	1.220	-2.4	-.77	+.57	+1.7	+2.8	+3.7	+4.5	+5.3
2.0	1.357	1.240	-2.2	-.63	+.71	+1.9	+2.9	+3.8	+4.6	+5.4
2.1	1.386	1.259	-2.1	-.50	+.84	+2.0	+3.0	+3.9	+4.8	+5.5
2.2	1.415	1.277	-2.0	-.38	+.96	+2.1	+3.1	+4.1	+4.9	+5.6
2.3	1.443	1.295	-1.8	-.26	+1.1	+2.2	+3.3	+4.2	+5.0	+5.8
2.4	1.470	1.312	-1.7	-.14	+1.2	+2.4	+3.4	+4.3	+5.1	+5.9
2.5	1.497	1.328	-1.6	-.03	+1.3	+2.5	+3.5	+4.4	+5.2	+6.0
2.6	1.523	1.345	-1.5	+.07	+1.4	+2.6	+3.6	+4.5	+5.3	+6.1
2.7	1.548	1.361	-1.4	+.18	+1.5	+2.7	+3.7	+4.6	+5.4	+6.2
2.8	1.573	1.376	-1.3	+.27	+1.6	+2.8	+3.8	+4.7	+5.5	+6.3
2.9	1.598	1.391	-1.2	+.37	+1.7	+2.9	+3.9	+4.8	+5.6	+6.4
3.0	1.622	1.406	-1.1	+.46	+1.8	+3.0	+4.0	+4.9	+5.7	+6.5
3.1	1.645	1.420	-1.0	+.55	+1.9	+3.0	+4.1	+5.0	+5.8	+6.6
3.2	1.668	1.434	-.95	+.63	+2.0	+3.1	+4.2	+5.1	+5.9	+6.7
3.3	1.691	1.448	-.87	+.72	+2.1	+3.2	+4.2	+5.2	+6.0	+6.7
3.4	1.713	1.461	-.79	+.80	+2.1	+3.3	+4.3	+5.2	+6.1	+6.8
3.5	1.735	1.475	-.71	+.87	+2.2	+3.4	+4.4	+5.3	+6.1	+6.9
3.6	1.757	1.487	-.63	+.95	+2.3	+3.4	+4.5	+5.4	+6.2	+7.0
3.7	1.778	1.500	-.56	+1.0	+2.4	+3.5	+4.5	+5.5	+6.3	+7.0
3.8	1.799	1.513	-.49	+1.1	+2.4	+3.6	+4.6	+5.5	+6.4	+7.1
3.9	1.820	1.525	-.42	+1.2	+2.5	+3.7	+4.7	+5.6	+6.4	+7.2
4.0	1.840	1.537	-.35	+1.2	+2.6	+3.7	+4.8	+5.7	+6.5	+7.3
4.1	1.860	1.549	-.28	+1.3	+2.6	+3.8	+4.8	+5.7	+6.6	+7.3
4.2	1.880	1.560	-.22	+1.4	+2.7	+3.9	+4.9	+5.8	+6.6	+7.4
4.3	1.900	1.572	-.15	+1.4	+2.8	+3.9	+5.0	+5.9	+6.7	+7.4
4.4	1.919	1.583	-.09	+1.5	+2.8	+4.0	+5.0	+5.9	+6.8	+7.5
4.5	1.938	1.594	-.03	+1.6	+2.9	+4.0	+5.1	+6.0	+6.8	+7.6
4.6	1.957	1.605	+.03	+1.6	+2.9	+4.1	+5.1	+6.0	+6.9	+7.6

4. Find values for f_3/f_S and for h.
   Your box should be tuned to $f_B = h\ f_S$
   The −3dB frequency will be $f_3 \cong f_3/f_S \times f_S$
5. Move out to the column with Q_{TS} closest to your Q_{TS} value. This shows a value of response anomaly R_H, the sign indicating direction. ($+R_H$ is a peak, $-R_H$ is a dip)
6. Conversely, you can search the column representing your driver Q_{TS} until you observe an acceptable R_H value. Then alpha (α), h and f_3/f_B define the enclosure, its tuning and expected −3dB frequency by the equations given above.

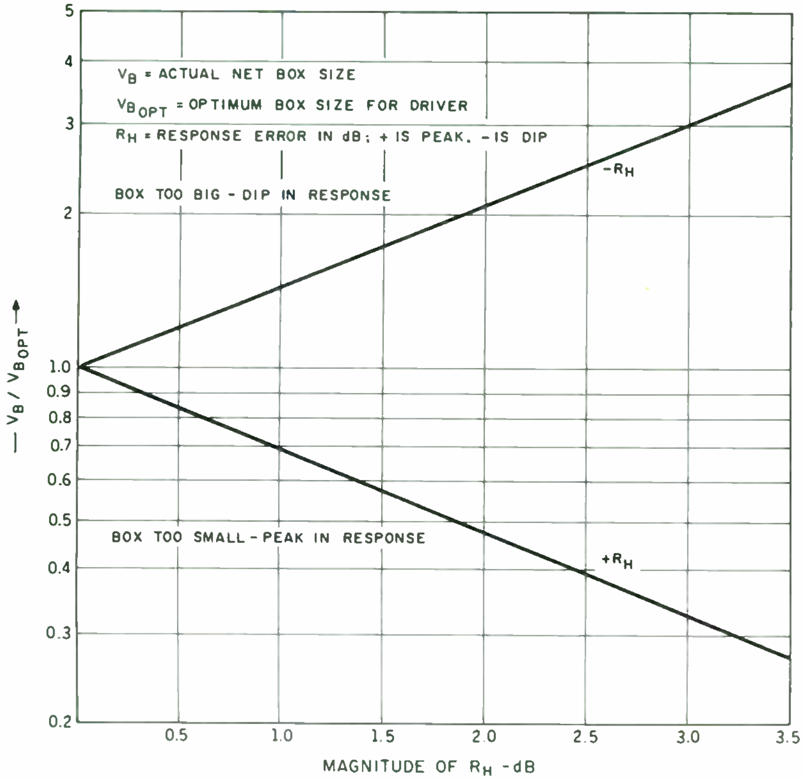


FIGURE 2: Relationship between R_H and improper box size for a properly retuned box.

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 audio 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 write us about it and we'll answer promptly with suggestions and tell you whether or not 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.

BASIC SPEAKER STANDS

BY JAMES FRANE

Unless your speakers are designed to be floor-standing units, they will probably sound better raised off the floor. Early reflections from the floor will couple out-of-phase with direct sound from the drivers at certain frequencies, creating cancellation effects. Reflections at other frequencies will couple in-phase with the direct sound, causing reinforcement at those frequencies. The end result may be varying degrees of uneveness in your loudspeakers' frequency response.

By raising your speakers (particularly bookshelf types) off the floor, the effects of early reflections from the floor will be diminished. You can mount them on a shelf or on stands. Shelf mounting, however, has several disadvantages:

- Many bookshelf-type speakers are too large and heavy.
- Shelf mounting limits speaker orientation, thereby hindering best-possible listening arrangements.
- Many shelves are not sufficiently sturdy and tightly coupled to the room structure, and thus can affect sound clarity.

Speaker stands, however, let you locate your speakers wherever you wish. You can design them so the tweeters are aimed at ear level, and design them to couple the speakers firmly to the floor for improved clarity. Furthermore, you can build them to accommodate virtually any shape or size speaker.

In the following paragraphs, I will describe the stands I designed and built. My design is readily adaptable to any enclosure size, so you can custom-fit them to your speakers. You need only a minimum of tools. The materials are up to you, so the cost can be far less than any stands you can buy.

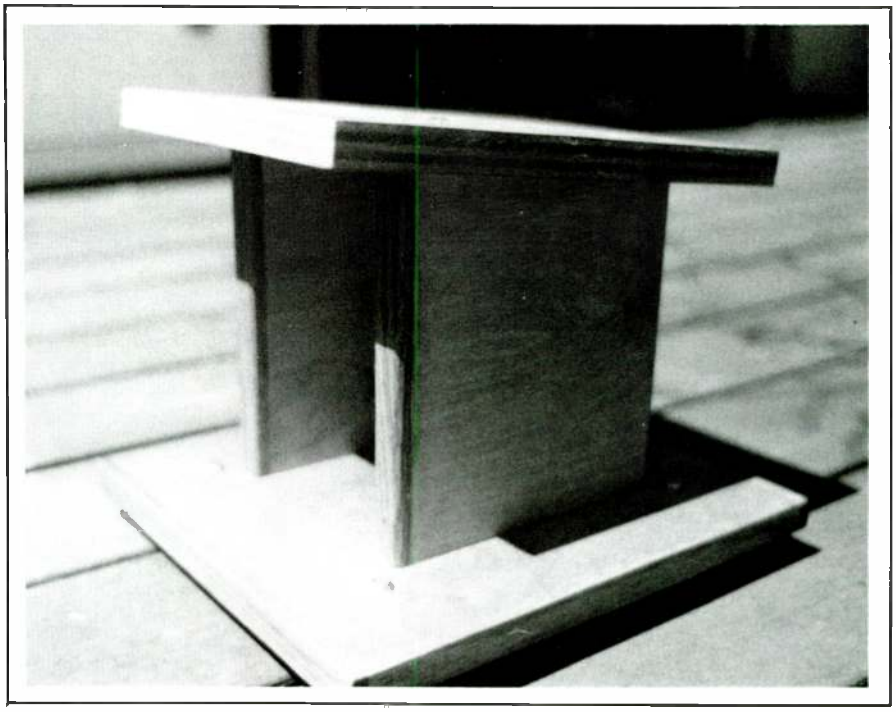


PHOTO 1: The author used scrap pieces of ¾″ birch plywood to build his stands, covering exposed edges with scrap strips of oak.

DETERMINING HEIGHT. Experimentation is the best way to determine your stands' optimum height. I used a test record with pink noise bands over the audible frequency range. Such a test record is available from Soundscraftsmen, 2200 So. Ritchey, Santa Anna, CA 92705 (check with Soundcraftsmen for current price and availability). You can use a signal generator, if you have access to one, instead of the test record.

If your ear is really well-trained, you can use the record to identify variations in your speakers' frequency response. As an alternative to relying on your subjective evaluation, you can use a signal generator, or a sound pressure level (SPL) meter such as is offered by Radio Shack.

Position the sound level meter at your listening position, about the ear height of a seated listener. With the speakers on the floor at the location you intend to use them, make a frequency sweep, recording the SPLs at each frequency on the test record. You will probably find a variation in the frequency response between the speakers' lowest bass and about 900Hz.

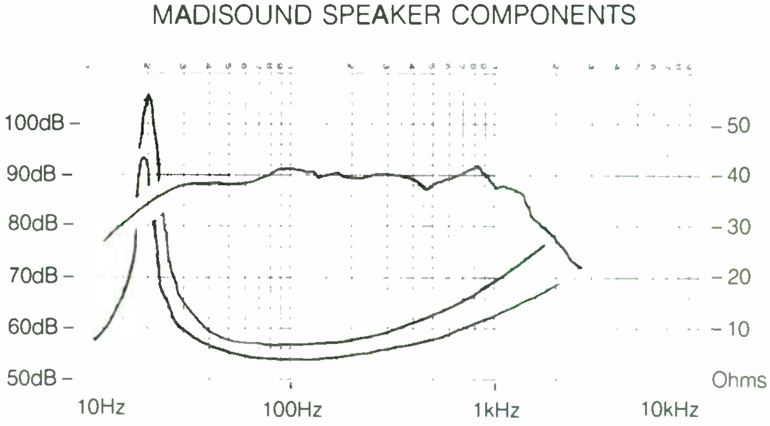
Use bricks, catalogs, or anything sturdy to raise the speakers off the floor at an arbitrary height, and repeat the test. If available, follow your owner's guide recommendations for stand height, otherwise, move the speakers to higher and lower positions and test again. The height that yields the

SLEDGEHAMMER

The SLEDGEHAMMER 15258DVC & 15254DVC are 15" polypropylene woofers, black cone, 2.5" Kapton dual voice coils, 60oz. ceramic magnet.

Model	15258DVC	15254DVC
Fs	20Hz	19Hz
Mmd	170 Grams	160 Grams
Cms	.41 x 10-6cm/dy	.48cm/dy
Vas	360lt. ±2%	360lt. ±2%
Rscc	5.7Ω	3.5Ω
Z min	6.3Ω	3.8Ω
Z max	58.0Ω	43.0Ω
vcL	1.2mH	.72mH
Qms	4.69	4.79
Qes	.53	.41
Qts	.47	.38
Xmax	5.5mm Pk	5.5mm

Surround: Foam
Power Handling: 200W 100/100
Frequency Response: 30–1500Hz
Efficiency: 90.4dB/1W/1M
Uses: Home or Autosound subwoofer
Price: $58.00



SLEDGEHAMMER 15258DVC SUGGESTED ALIGNMENTS (ALL SEALED)

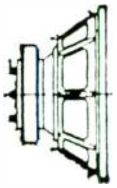
Bass Volume: VB	35 liters	56 liters	70 liters	70 liters	100 liters
Bass ½ Power: F3	47Hz	44Hz	42Hz	40Hz	38Hz
Fill in box	Yes	Yes	Yes	No	No
QTC	.86	.80	.74	.86	.75
Peak at Res: R dB	+1.0	+.3	+.1	+.5	0

SLEDGEHAMMER 15254DVC SUGGESTED ALIGNMENTS (ALL SEALED)

Bass Volume:	56 liters	70 liters	100 liters	100 liters	150 liters
Bass ½ Power: F3	40Hz	38Hz	37Hz	35Hz	34Hz
Fill in box	Yes	Yes	Yes	No	Yes
QTC	.95	.88	.79	.91	.70
Peak at Res: R dB	+1.0	+.5	+.1	+.3	0

SledgeHammer 15DVCs can be connected in series or parallel to achieve net impedance from 2–16Ω.

ORDER INFORMATION: All orders will be shipped promptly, if possible by UPS. COD requires a 25% prepayment, and personal checks must clear before shipment. Adding 10% for shipping facilitates shipping procedure; residents of Hawaii and those who require Blue Label Air Service, please add 20%. There is no fee for packaging or handling. We will accept MasterCard or VISA on mail or phone orders.



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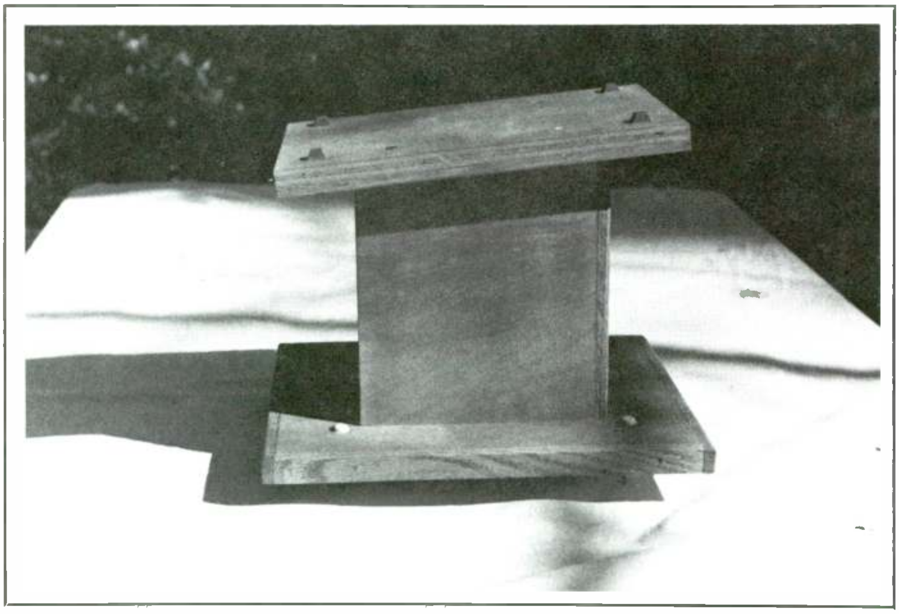


PHOTO 2: You can modify the stand design so the tweeters will be aimed at ear level.

smoothest frequency response is the height you should choose for your stands.

It's important that you conduct these tests with the speakers located where you intend to use them, because early reflections from back and side walls can affect the frequency response as much as floor reflections.

CONSTRUCTION. I built my stands from scrap pieces of ¾″-thick birch plywood (*Photo 1*). I covered the exposed edges by gluing on scrap strips of oak. You can easily modify this particular design so the speakers' tweeters will be aimed at a seated listener's ear level (*Photo 2*).

To size the top pieces, measure the width and depth of your speakers and cut the top pieces to approximately these dimensions. Cut the bases for the stands about 2″ larger than the speakers' width and depth. The bases should be slightly larger to provide stability. Cut the two upright pieces for each stand to the height you determined earlier, minus the thickness of the top and base. Cut the tops of the upright pieces at the angle that will give the desired tilt.

I installed spikes from Shadow Audio (PO Box 55081, Omaha, NE 68155—eight spikes and threaded inserts for $6) in the stands' bases (*Photo 3*) to provide a firm coupling to the floor (I have carpet with padding). The spikes also add clarity to the bass reproduction.

Measure in about 1″ from each base edge to locate the spikes. Thread the spikes into inserts that are, in turn, threaded into holes drilled into the bases. As an alternative, you can install T-nuts in the bottoms of the bases and thread machine screws into them. To improve the machine screws' effectiveness, grind the ends to points.

The stand tops, uprights and bases are held together with the type of hardened steel screws used to install gypsum wallboard. I used 1⅝″-long screws. For added strength and stability, glue the joints with yellow or white wood glue.

The stands shown in the photos are about 10″ high. If your stands will be higher, you may wish to make the uprights from thicker pieces of wood to increase their strength and stability. To increase rigidity, you can also build the upright section in the form of a hollow box. Then, if you wish, fill the boxed upright section with clean, dry sand to add mass and damping. I finished these stands with an oil-based stain and linseed oil, but you can use any finish you wish.

Besides saving money and customizing your stands to your speakers and listening environment, you will have the satisfaction of having built these stands yourself. ▶

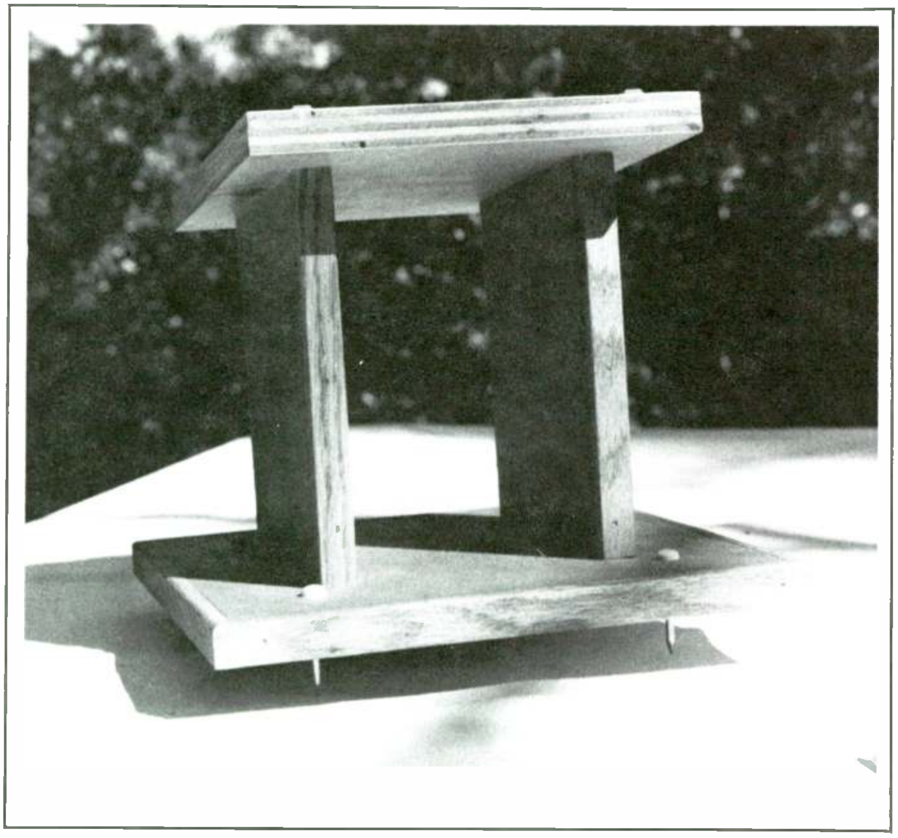


PHOTO 3: The author installed spikes in the base of his stands to provide a firm coupling to his carpeted floor. He believes this adds clarity to bass reproduction.

ABOUT THE AUTHOR

James Frane is a licensed marine engineer and a registered professional mechanical engineer. A member of the Boston Audio Society for many years, he has built a number of electronics kits, designed and built four speaker systems, and has modified several others. He continually experiments with room acoustics and speaker placement combinations in search of a close approximation of live music.

IS DRIVER IMPEDANCE COMPENSATION WORTHWHILE?

BY DAVID J. MERANER

Wilfred Harms (*SB* 2/82, pp. 18-19) has examined crossover performance disturbances produced by the reactive nature of speaker impedance, and he (*SB* 4/82, p. 14) and Max Knittel (*SB* 1/83, pp. 11-14) have shown how the undesirable rise of speaker impedance with frequency can be tamed by connecting an appropriate compensating network directly across a speaker's terminals.

The authors imply that if driver impedance *is* compensated for, crossovers will behave as they should. Neither author, however, showed how impedance compensation improved the performance of crossovers, and so one question remains unanswered: is driver impedance compensation worthwhile? I hope to answer that question in this article.

TEST PROCEDURE. If you don't own them already, you can probably borrow the instruments I used (see box, "Test Instruments") for the following tests:

- electrical measurements of the performance of a crossover feeding a driver, with and without compensation;
- acoustic measurements of the test unit, with and without compensation, when fed by the test crossover.

My test driver was a 4½" wide-range unit from Radio Shack (#40-1284). For my crossover, I used the high-pass section of a parallel, constant-resistance, symmetrical 12dB/octave network, shown with part and design values in *Fig. 1.* (The crossover design impedance does not exactly match the compensated impedance of the driver because my crossover did not quite match the test unit's impedance.)

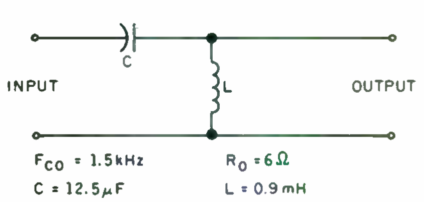


FIGURE 1: For his crossover, the author used a high-pass section of a parallel, constant-resistance, symmetrical 12dB/octave network.

After measuring the driver's impedance versus frequency characteristic, I developed (by trial and error) a compensation network that showed the smallest variance on the average impedance over the selected frequency range (300Hz to 10kHz). Inherent and compensated impedance functions, along with resistor and capacitor values, are shown in *Fig. 2.* I was now ready to evaluate the system.

ELECTRICAL TESTS. I connected the uncompensated driver to the crossover, to which I supplied a variable frequency generator. At each selected frequency, I measured the voltage into the network and across the speaker

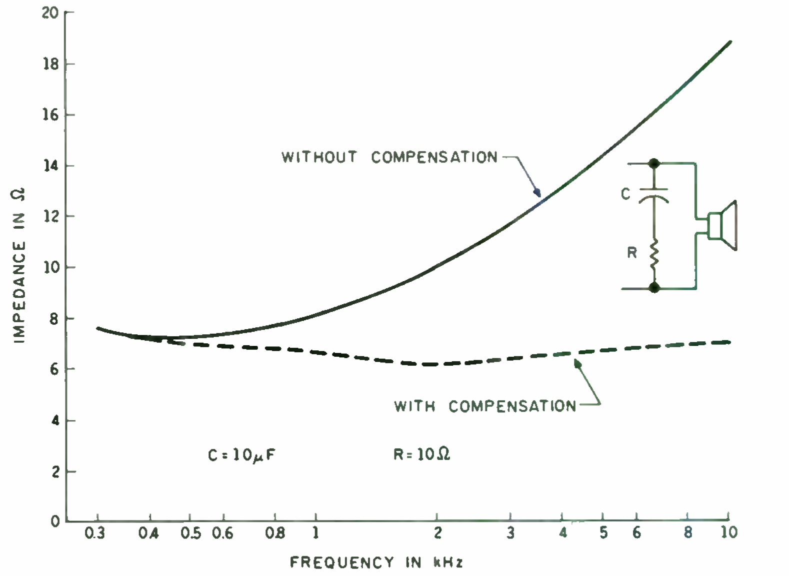


FIGURE 2: Inherent and compensated impedance functions, plus resistor and capacitor values.

ABOUT THE AUTHOR

A graduate of Rutgers University College of Engineering, David Meraner has worked for 35 years as a designer of hydroelectric generators and nuclear reactor coolant pump motors for General Electric Co. A life member of the Institute of Electrical and Electronics Engineers, he has been a long-time audio enthusiast, with his interest rekindled by the work of Theile and Small. The Scotia, NY resident also designs and builds speaker systems for family and friends.

terminals, converting both to decibel values (calculating the logarithm of the ratio of voltage across the driver to the supplied voltage, then multiplying that number by 20). I added compensation and repeated the test. The results, shown in *Fig. 3*, clearly indicate improved performance for the compensated unit. The uncompensated one, on the other hand, shows a substantial overshoot and a gradual tail-off in the pass band region.

ACOUSTIC TESTS. I performed the acoustic test in my living room, mounting the driver on a 10 x 18″ panel supported three feet above the floor. I placed the sound level meter about four feet in front of, and at the same height as, the speaker.

Next, after connecting the test speaker to my receiver's left channel, I conducted the following tests using the CBS Lab STR140 record (band 4, "Left Spots"):

- the driver without crossover or compensation;
- the driver with crossover but without compensation;
- the driver with crossover and compensation.

Results of the test, shown in *Fig. 4*, reveal three interesting effects:

1. The output of the filtered but uncompensated unit exceeds the output of the driver alone, between 1.6 and 5kHz.

Test Instruments

The author used the following instruments to test impedance compensation:

- Digital VOM (volt-ohmmeter) (BK Precision, Model 2815).
- Signal generator (Heathkit, Model SG1271).
- Frequency counter (Heathkit, Model SM2410).
- Sound level meter (Radio Shack, #33-1028).
- "500Ω" resistor (precise value measured at 499Ω) for the following impedance measurements:
  1. Connect the resistor in series with the unknown impedance, and apply the test voltage across the circuit.
  2. Adjust the input voltage until the voltage across the 499Ω resistor measures .499V, signifying the passage of .001A through the circuit.
  3. Connect the voltmeter across the unknown impedance. Change the voltmeter scale to millivolts, observe the reading, and record as ohms of impedance.

2. The filtered cases show output levels, in the lower frequency range, lower than the driver alone. Departure begins at about 1.6Hz for the uncompensated speaker, and at about 2.4Hz for the compensated speaker.

3. The filtered cases show acoustic roll-off at a frequency about an 1/3 octave *below* the design value of 1.5kHz.

While studying these somewhat inexplicable results, it occurred to me that the purpose of the test, after all, was to compare filtered to unfiltered responses. In this case, it wasn't easy because the comparison base (the unfiltered response) also changed.

To solve this problem, I linearized the unfiltered response as a straight line at 0dB, and replotted the filtered responses by the decibel level by which they differed from the unfil-

Continued on page 67

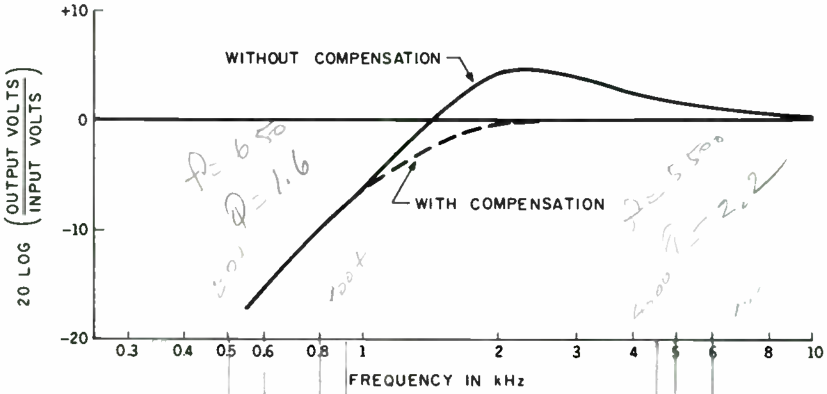


FIGURE 3: Results from repeated measurements of voltage into the network and across the driver terminals, both converted to decibel values.

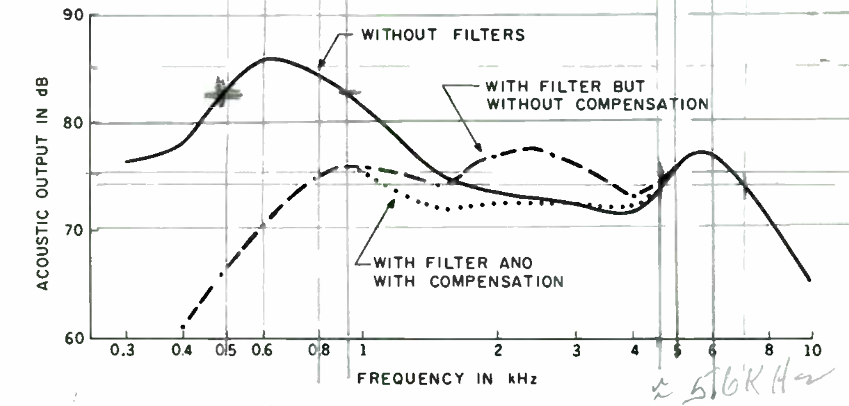


FIGURE 4: The author used the CBS Lab STR140 record to test the driver through the left channel of his receiver.

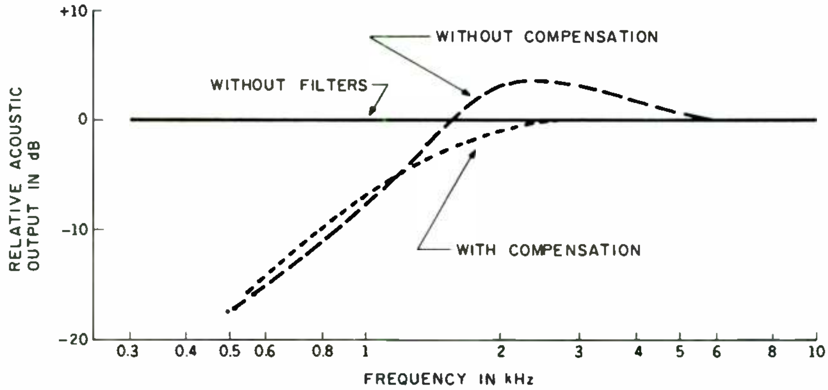


FIGURE 5: After the author linearized the unfiltered response, tests show the filtered response closely follows the electrical performance.

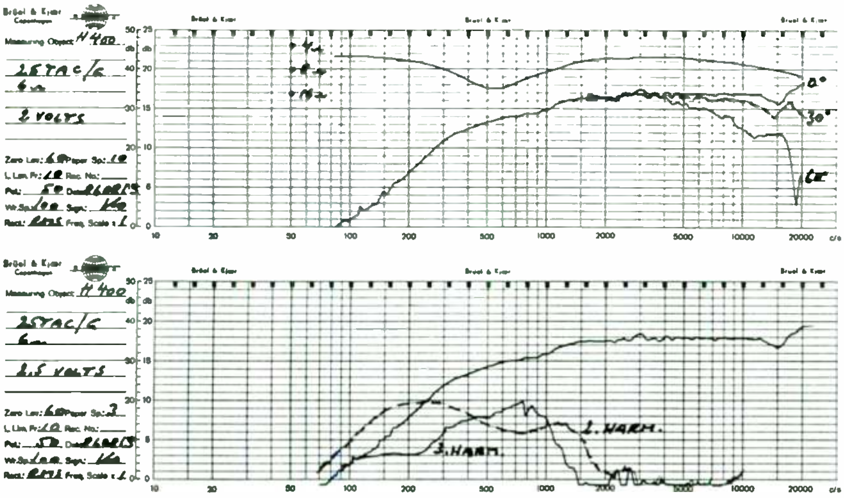
SUPERIOR LOUDSPEAKERS from NORWAY

seas

You will find SEAS drivers in speaker systems by some of the most prestigious names in audio. With innovation tempered by years of experience, our conservative application of the newest materials has produced a series of new domes, new heavy magnet (40+ ounces) woofers, and new dual voice coil woofers.

Some of these are so new that data sheets are not yet available, but an example is the H-400 tweeter. Its 1″ aluminum dome is mounted in a soft polyamide surround, and is protected by a fine mesh screen. A damped vented pole piece and posterior tuned chamber enable a low free air resonance of 660Hz.

H-400 Impedance: Response on and off axis; and Distortion (up 20dB).



SPECIFICATIONS

Recommended freq. range	2000-25000Hz
Nominal power (DIN 45573)	50W*
Operating power (DIN 45500)	3.2W
Nominal impedance	6Ω
Characteristic sensitivity (1M, 1W)	91dB SPL
Voice coil resistance	4.8Ω
Voice coil diameter	26mm
Voice coil height	1.5mm
Air gap height	2.0mm
Magnet weight	0.25kg
Flux density	1.8T
Force factor	3.5Wb/m
Effective diaphragm area	7cm²
Moving mass	0.33g
Free air resonance	660Hz
Weight	0.54kg

*Crossover at 2500Hz, 12dB/octave

Other new SEAS drivers for which samples and/or detailed specifications are, or soon will be available from the authorized distributers listed below:

H-377	1″ polyamide dome tweeter
H-392	1″ polymide dome tweeter with ferro fluid
H-382	1″ aluminum dome tweeter
H-398	1″ aluminum dome tweeter with ferro fluid
H-395	5″ polypropylene woofer with cast frame
H-393	5″ polypropylene woofer with large magnet
H-359	8″ large magnet woofer
H-373	8″ dual voice coil woofer
H-361	10″ large magnet woofer
H-372	10″ dual voice coil woofer
H-339	13″ dual voice coil woofer

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SUPERIOR
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TUNING BASS REFLEX SPEAKER SYSTEMS

BY RICHARD BRUSH

This article will show you how to design, build and tune a port or vent for a bass reflex speaker system. (The terms port and vent will be used synonymously and interchangeably.) I am assuming you already have a bass reflex design or alignment that is theoretically sound in accordance with Thiele-Small theory, and that you are familiar with at least the basics of this theory.

Perhaps you obtained your alignment from a table of alignments in a magazine article, from a speaker manufacturer, or elsewhere. The alignment generally specifies a box volume (V_b) and box resonant frequency (f_b) which may differ from the speaker free air resonance (f_{as}). Port construction details are not usually given because there may be several ways to realize desired box resonant frequency. Your problem is making sure the cabinet is built and tuned to match the alignment parameters.

You can construct the cabinet in any size or shape, or with any material you wish (within reason), so long as it has the correct internal volume. I assume you already know your cabinet must be rigid and airtight (except for the port), so I will not dwell on that matter. Building your port or vent, however, probably looks like tricky work, so the focus of this article will be getting you through that task.

GETTING STARTED. What will you need for the job? Although you will be making a few calculations, I have boiled down the math to a few cookbook formulas, so you won't have to wade through extraneous theory. A calculator with arithmetic and square root functions will be helpful. You will also need some woodworking tools to build the cabinet and port. A few specific tools, which are not absolutely necessary but which greatly facilitate port construction, will be mentioned later. Finally, you will need a sine wave or function generator and a VOM (volt-ohmmeter) or AC voltmeter to measure the impedance curve during the tuning and testing process. Throughout this article, you will find many suggestions and tips to enable you to do the job quickly and confidently without "goofing up."

The port has three common configurations or options: an unducted port (i.e., a hole in the cabinet); a ducted circular port using a cardboard or plastic tube; or, a square or rectangular port made of wood or similar material.

Usually, you must study the design calculations (discussed later) to see whether a particular configuration will work in your alignment or not. If it doesn't, you must try a different configuration. Often, you can make more than one configuration work, so decide which one you want to use, basing your decision on personal preference, aesthetics, or tools and materials available. Before I show you the calculations, I will briefly discuss each configuration from the standpoint of practical construction.

The unducted port is the simplest because it is just a hole in the cabinet wall. In principle, you can make it any area or shape you wish. Its limitation is that, frequently, you cannot get f_b low enough when using an unducted port with your box size. This is typically the situation with smaller cabinets, but it occurs less frequently in larger ones. If you select this configuration, use a rotary rasp in a ¼″ drill to enlarge the hole and round the edges during the tuning and testing process.

The ducted port, featuring either a cardboard mailing tube or PVC plastic pipe, is probably the most popular, flexible, and easily tuned port. It is workable in all but the very largest cabinets, which require a relatively large port. Even here, however, you may be able to use multiple ports to achieve the required port area. You can get cardboard mailing tubes from blueprint and photographic reproduc-

ABOUT THE AUTHOR

Richard Brush is a senior engineer at Ampex Corporation in Redwood City, CA currently designing signal processing circuitry for digital video tape recorders. He received his BSEE from the University of Utah in 1978, and his MSEE from Stanford University in 1982. As a student, he studied electro-acoustics, and wrote several computer programs for modeling and optimizing speaker enclosures using Thiele-Small theory. He has designed, built and tuned several bass-reflex speaker systems which use an auxiliary second-order electrical filter, as well as sealed box and horn and loaded systems. The author is a member of IEEE and the society of Motion Picture and Television Engineers (SMPTE).

tion businesses. I suggest you look in the yellow pages and call several firms in your area since most companies often carry only one size (diameter) tube. That way, you should have several sizes to choose from. If you cannot find a suitable cardboard tube, PVC plastic pipe is an alternative and is available in various sizes at most hardware stores.

For a good fit, be accurate when you cut the hole in the cabinet. The ideal method, which makes the job a snap, is to use a continuously-adjustable hole cutter in a ½" variable speed drill or drill press. This is definitely a slow-speed, high-torque cutting operation. Be sure to wear safety glasses or goggles to protect your eyes against flying wood chips, and avoid using a ¼" or ³/₈" drill. You can also make the hole with a jigsaw or sabre saw, or with a half-round file or rasp, but this involves more work and must be done very carefully for a good fit. (*Jigsaws may be fitted with a radius guide which has a pin in one end. The pin, pushed into the stock at the hole's center, guides the saw in a fine, even cutout.—Ed.*) Try making your hole in a piece of scrap wood before you try it on your cabinet.

The square or rectangular port is probably the most difficult to build and tune. If, however, you have a large cabinet and require a large port, it may be your best choice. Sometimes, you can make the port in the form of a shelf or slot near the bottom of the cabinet.

DESIGN THEORY. In the past, design theory information has typically been presented in the form of nomographs or charts, but for some reason (Murphy?), there never seems to be curves for the exact combination you need. By using a calculator, however, you can evaluate the formulas about as quickly and much more accurately.

The resonant frequency of the box-port combination is given by[1]:

$$f_b = \frac{c}{2\pi}\sqrt{\frac{n \times S_v}{L_{v'} \times V_b}} \qquad (1)$$

where c = speed of sound, n = number of ports (usually one), S_v = vent area (per vent, if more than one), $L_{v'}$ = effective vent length (discussed below), and V_b = internal box volume.

Equation 1 is handy because you can use any set of units as long as they are consistent. For inches, use c = 13,500"/sec; for feet, use c = 1130'/sec; for centimeters, use c = 34,300cm/sec.

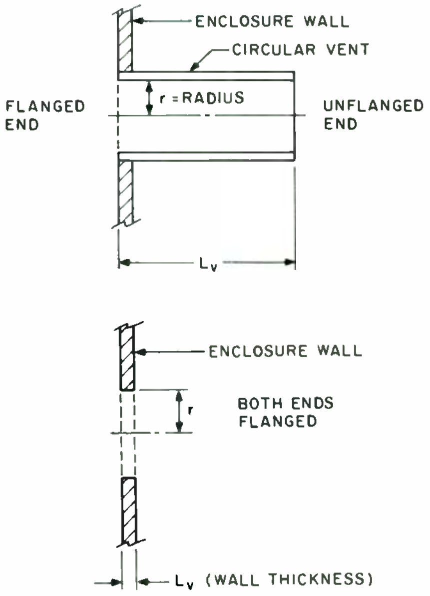

FIGURE 1: The ducted vent (a) and unducted vent (b).

The effective length ($L_{v'}$), is greater than the actual length (L_v) because the moving air mass extends somewhat beyond the ends or faces of the vent. You can take this factor into account by adding an end correction to the actual length, resulting in the effective length. You must add a correction for each end of the duct or port, but the amount of correction depends on whether an end is flanged or unflanged (*Fig. 1*). The corresponding corrections for each end are given by[2]:

$$L_{end} = .85r \text{ for flanged end} \qquad (2a)$$
$$L_{end} = .61r \text{ for unflanged end} \qquad (2b)$$

where r is the radius of the vent. If the vent is not circular, then calculate r for a circle having the same vent area, using the formula:

$$r = \sqrt{\frac{S_v}{\pi}} \qquad (3)$$

Make corrections for both ends of the vent so the total correction is:

$$L_{add} = 1.46r \text{ for ducted vent} \qquad (4a)$$
$$L_{add} = 1.70r \text{ for unducted vent} \qquad (4b)$$

Finally, the effective vent length is given by:

$$L_{v'} = L_v + L_{add} \qquad (5)$$

Now you have all the formulas to do the vent design, but you must select a type of vent. I suggest you begin with an unducted vent (*Fig. 1b*), since it is the simplest, and see if it will work.

Usually, f_b turns out to be higher than you want, because $L_{v'}$ is very small (refer to Equation 1). Making the hole smaller won't necessarily work, because as S_v decreases, so does L_{add} (which is the major part of $L_{v'}$). You end up with a very small hole (perhaps the size of the wall thickness, or less) to get the right f_b. This produces a high air velocity in the vent, giving rise to turbulence and friction losses.

If you cannot do the job with a reasonable sized hole (say 2" or larger), try a ducted port (*Fig. 1a*). If you go this route, I suggest you use the largest available diameter that will still leave you at least several inches of clearance at the rear of the tube. This will help minimize air velocity and losses in the port. The design flow chart (*Fig. 4*) illustrates the step-by-step calculations and decisions involved. If none of the configurations work out, you may have made an error in your calculations, or you may have an impractical combination of box volume and tuning (which is one reason why a passive radiator is sometimes used).

Let's say you have designed the port that will give you the desired tuning. When you build it, give yourself a little margin of error so you can test the box tuning and trim it to the exact f_b you want. Here is a recommended trimming procedure:

If you use an unducted port, cut it smaller than calculated (say, 50% smaller) and measure f_b with the speaker installed, using the procedure described in the next section. The measured value of f_b should be too low, or else you have made an error. The hole should be increased by the amount:

$$\Delta d = \frac{2 \times d \times \Delta f_b}{f_b} \qquad (6)$$

where Δd is the amount to increase the diameter of the hole, d is the present diameter of the hole, f_b is the measured box resonant frequency, and Δf_b is the amount to raise f_b to reach the desired box resonant frequency.

It is a good idea not to enlarge the hole by more than 10–20% at a time, even if you must work on it several times, to make sure you don't overshoot. If you are within this range of error, the correction given by (6) should put you right on target.

If you use a ducted vent, cut it about 20% longer than calculated and measure f_b with the duct installed. (The cut-out should be accurate enough so the duct is held in place by friction.) f_b will be slightly low, or else you have made a mistake. The amount to remove from the duct is given by:

$$\Delta L_v = \frac{-2(L_v + 1.46r) \times \Delta f_b}{f_b} \qquad (7)$$

where ΔL_v indicates the amount to change L_v (it is shortened, as indicated by the minus sign), L_v and f_b are present measured values, and Δf_b is the amount to increase f_b to reach the desired value. You should be fairly close to the desired f_b to begin with, and one correction will put you right on the money.

After tuning to satisfaction, round off any rough edges or corners to reduce possible turbulence.

TESTING. How do you make electrical measurements to test the tuning of your cabinet? Measure the speaker impedance curve, using the setup shown in *Fig. 2*. The resistor R value is not critical. Higher values give a more accurate measurement, but require a higher driving signal from the amplifier. I also recommend a 1W (or more) resistor. Your amplifier must produce enough signal drive for good readings (few function or sine wave generators are designed to drive speakers).

If you have a receiver rather than an amplifier, use either the auxiliary or monitor input, and set the tone controls flat or switched out. The VOM or AC voltmeter need not be highly accurate; you are mainly interested in relative readings. Frequency, however, should be accurate. If you are in doubt about the frequency accuracy of your generator, check it with a frequency counter or by Lassajous patterns against 60Hz on your scope. (For safety's sake, use a low voltage transformer winding as your source.) [*If the driver is new or unused, you will get more representative measurements if you drive it at a low frequency and low power for an hour or two prior to measuring it.—Ed.*]

You can make a useful measurement with the speaker installed, but do so before you cut out or install the port, that is, as a sealed box system. Measure the frequency f_{max} where you get the highest impedance reading. Then, calculate the following quantities[3]:

$$\alpha = \left(\frac{f_{max}}{f_{as}}\right)^2 - 1 \qquad (8)$$

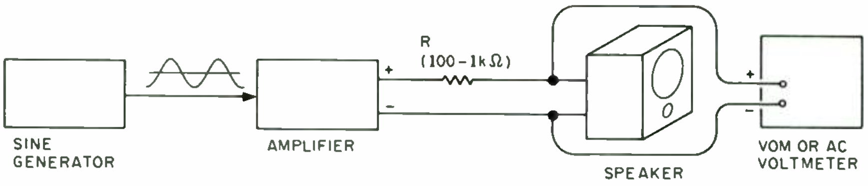

FIGURE 2: Impedance measurement setup.

$$V_{as} = \alpha \times V_b \qquad (9)$$

V_{as} is the speaker equivalent compliance volume, and α is the system compliance ratio, an important parameter for the alignment. Don't be surprised if these measured values differ by 20% or so from their nominal or theoretical values. This is due to normal variations in the mechanical compliance of the speaker surround. Fortunately, this sort of variation will have little effect on the acoustic output response[4] Making this measurement, however, will give you a better check of your impedance measurements to follow.

Now that you have the port installed and have measured the impedance curve, you get something that looks like *Fig. 3*. f_l and f_h are simply the frequencies of the impedance peaks. In general, the amplitude of the two peaks will be different. The minimum occurs at f_b, which generally is different than f_{as}. If is often difficult to accurately determine f_b from the impedance curve since the curve is fairly flat in this region.

Here is a better way: very lightly touch your fingers on the diaphragm. You should feel it vibrating. Slowly adjust the generator frequency around the minimum. At f_b, the cone motion will pass through a null and almost disappear. The null is quite sharp, and you should have no trouble measuring f_b within 1Hz. It is best to use a smaller value of resistor R (say, 100Ω) and turn up the amplifier gain for more sensitivity.

You need not measure f_l and f_h, but I recommend doing so anyway (you are already set up for it) so you can compare the measured values of f_l and f_h with their calculated values[5]:

(10a)

$$f_l = \frac{f_{as}}{\sqrt{2}} \times \sqrt{A - \sqrt{A^2 - 4\left(\frac{f_b}{f_{as}}\right)^2}}$$

(10b)

$$f_h = \frac{f_{as}}{\sqrt{2}} \times \sqrt{A + \sqrt{A^2 - 4\left(\frac{f_b}{f_{as}}\right)^2}}$$

where $$A = \alpha + 1 + \left(\frac{f_b}{f_{as}}\right)^2 \qquad (11)$$

Use the value of α from your measurement of f_{max}, if you have it, before installing the port. Otherwise, use the value from the alignment you designed for.

The calculated values of f_l and f_h ignore the effect of box and port losses (which are negligible), as well as the mutual coupling between the port and speaker diaphragm. The mutual coupling has virtually no effect on the acoustic response, but will cause the

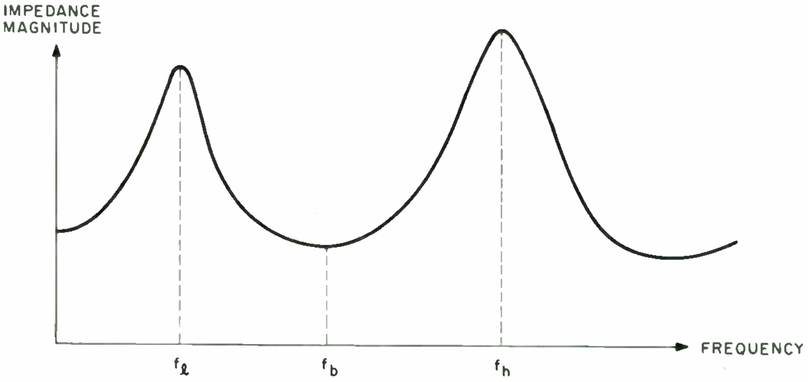

FIGURE 3: Typical bass reflex impedance curve.

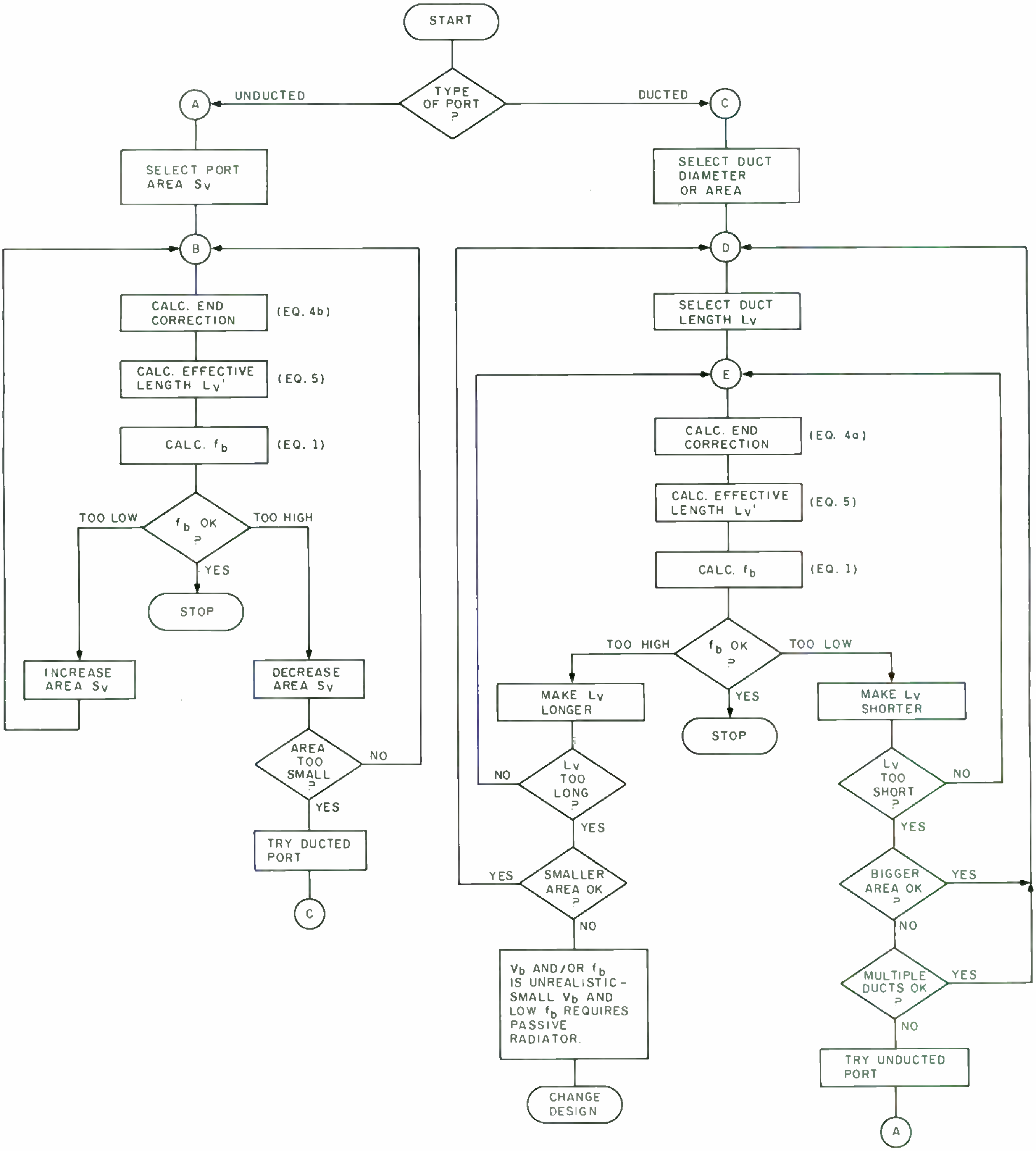

FIGURE 4: Port design flow chart for bass-reflex enclosures.

measured values of f_l and f_h to be slightly closer together than calculated[6] This shift is more noticeable for larger ports, but in any case, should not exceed a few hertz.

When you make these measurements, I suggest you leave the enclosure unlined since this produces the sharpest null at f_b. Afterwards, add fiberglass lining to the enclosure to damp standing waves. (This will not upset the tuning). Do not stuff the enclosure, and make sure the lining does not obstruct the air flow around the rear of the vent.

REFERENCES

1. Beranek, L. L., *Acoustics*, McGraw-Hill, 1954, p. 129, 133.
2. Beranek, op.cit., p. 132, 133.
3. Small, R. H., "Closed-box Loudspeaker Systems, Part 1: Analysis," *JAES*, Vol. 20, December 1972, p. 798.
4. Keele, D. B. Jr., "Sensitivity of Thiele's Vented Loudspeaker Enclosure Alignments to Parameter Variations," *JAES*, Vol. 21, May 1973, p. 246.
5. Small, R. H., "Vented-Box Loudspeaker Systems, Part 4: Appendices," *JAES*, Vol. 21, October 1973, p. 635.
6. Locanthi, B. N., "Application of Electric Circuit Analogies to Loudspeaker Design Problems," *JAES*, Vol. 19, October 1971, p. 778.

LMP: A CONSTRUCTION EXAMPLE

BY RALPH GONZALEZ

I used LMP to design the crossover for a small two-way system featuring a Dynaudio 17W75 woofer and a D28af tweeter. (As mentioned at the end of my main article, I left space on the baffle so I could later add a midrange driver.) I wanted to obtain a smooth, uncolored response with enough bass and treble extension to be musically satisfying, but that wouldn't intrude on my listening room's aesthetics.

The enclosure has a narrow 8½″ x 18″ face. To bring it to listening height, I placed it on an 18–20″ stand (*Photo 1*). Even if it occupies the same amount of floor space as a floor-standing speaker, I think a small stand-mounted speaker looks less imposing.

The Dyanudio tweeter is known for its smooth, wide-band response and high power-handling. The 17W75 woofer, however, requires special attention. This driver offers high power-handling and low midrange distortion. Because of its exceptional rigidity, however, it also exhibits a sudden and steep rolloff at 3kHz. By using LMP2 (see "Modelling the Crossover"), I was able to produce a model that agreed with the manufacturer's curve and with my own phase and magnitude measurements. The LMP in *Fig. 8* uses an approximation to my model, good up to about 3kHz. For a system with a crossover below 1.5kHz (below 800Hz for a first-order crossover), the LMP model will give results similar to the more complicated LMP2.

I had intended to use a first-order crossover, since I believed it would ideally result in a system with a minimum-phase response (see "Frequency Response" in Part I, *SB* 1/87). Because of the driver's natural rolloffs,

```
Figure 8
1.  NUMBER OF DRIVERS? 2

    DRIVER # 1 DRIVER INFORMATION

2.  CORNER FREQUENCY (HZ) OF DRIVER LOW-FREQUENCY ROLLOFF (OR 0)? 60
3.  LOW-FREQUENCY ROLLOFF DAMPING RATIO? .6
4.  CORNER FREQUENCY (HZ) OF DRIVER HIGH-FREQUENCY ROLLOFF (OR 0)? 3000
5.  HIGH-FREQUENCY ROLLOFF DAMPING RATIO? .45
6.  ORDER OF HIGH-FREQUENCY ROLLOFF (2 OR 4 ONLY)? 4
7.  POLARITY INVERSION (Y OR N)? N
8.  SENSITIVITY (DB)? 85
9.  DEPTH DISPLACEMENT (INCHES)? 0
10. FREQUENCY OF RESPONSE STEP (OR 0)? 1500
11. HEIGHT OF RESPONSE STEP (1 TO 6DB)? 3

    DRIVER # 1 CROSSOVER INFORMATION

12. IDENTIFICATION NUMBER OF CROSSOVER (OR 0)? 5

13. VALUE OF COMPONENT K 0 (ENTER -1 WHEN DONE)? 7
14. VALUE OF COMPONENT K 1 (ENTER -1 WHEN DONE)? 9E-6
15. VALUE OF COMPONENT K 2 (ENTER -1 WHEN DONE)? 2E-3
16. VALUE OF COMPONENT K 3 (ENTER -1 WHEN DONE)? -1

    DRIVER # 2 DRIVER INFORMATION

17. CORNER FREQUENCY (HZ) OF DRIVER LOW-FREQUENCY ROLLOFF (OR 0)? 800
18. LOW-FREQUENCY ROLLOFF DAMPING RATIO? 1
19. CORNER FREQUENCY (HZ) OF DRIVER HIGH-FREQUENCY ROLLOFF (OR 0)? 20000
20. HIGH-FREQUENCY ROLLOFF DAMPING RATIO? .6
21. ORDER OF HIGH-FREQUENCY ROLLOFF (2 OR 4 ONLY)? 2
22. POLARITY INVERSION (Y OR N)? N
23. SENSITIVITY (DB)? 80
24. DEPTH DISPLACEMENT (INCHES)? 0
25. FREQUENCY OF RESPONSE STEP (OR 0)? 2500
26. HEIGHT OF RESPONSE STEP (1 TO 6DB)? 6

    DRIVER # 2 CROSSOVER INFORMATION

27. IDENTIFICATION NUMBER OF CROSSOVER (OR 0)? 6

28. VALUE OF COMPONENT K 0 (ENTER -1 WHEN DONE)? 7.5
29. VALUE OF COMPONENT K 1 (ENTER -1 WHEN DONE)? 1.25E-3
30. VALUE OF COMPONENT K 2 (ENTER -1 WHEN DONE)? 8E-6
31. VALUE OF COMPONENT K 3 (ENTER -1 WHEN DONE)? -1
```

FIGURE 8: LMP model the author used for his construction project.

however, empirical results and LMP modelling showed me that a first-order crossover produced a severe dip in response at the crossover frequency. I could eliminate the dip by placing the tweeter a few inches farther away from the listener than the woofer (e.g., by tilting the cabinet back), but I knew this large interdriver time delay would violate the minimum-phase condition, and it was aesthetically unacceptable.

I settled for a second-order crossover which, when combined with the driver responses, resulted in an approximate third-order acoustical crossover (*Fig. 9*). The given values reduce the tweeter's sensitivity an extra decibel to compensate for the inductor's DC resistance in the woofer circuit. I had originally mounted the crossover inside the enclosure, but it is much easier to fine-tune it, upgrade to higher quality capacitors, and so on, when you mount it on the back.

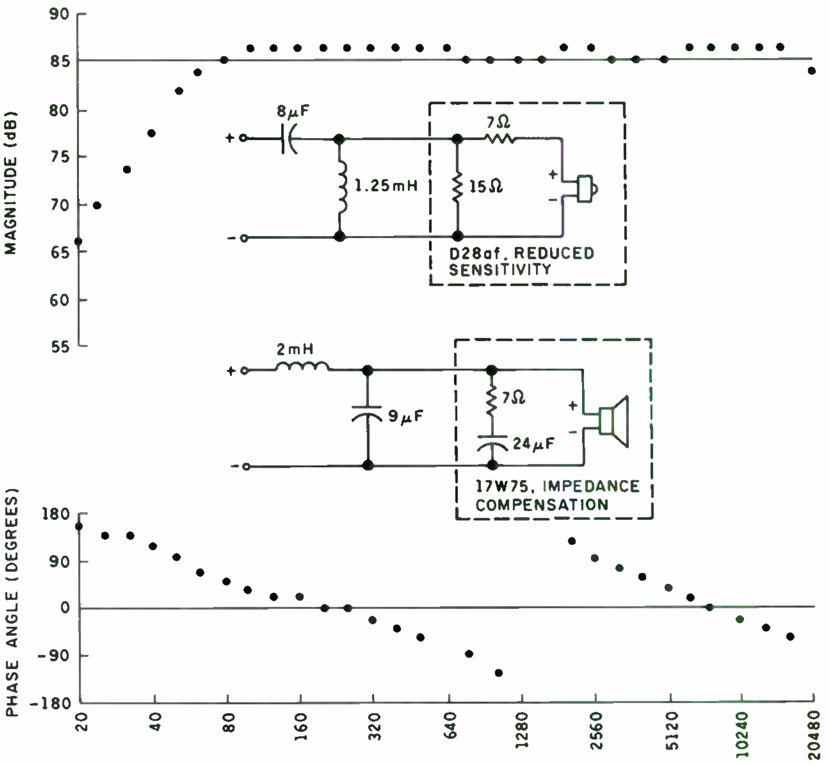

FIGURE 9: Output of the LMP model from Fig. 8, and crossover design.

The enclosure's top and sides are ¾″ veneered particle board. I used a miter joint, but for easier construction, cut these pieces shorter and use ¾″ hardwood inserts. The front, back, and bottom are ¾″ particle board, and an additional "step" of ¾″ particle board aligns the woofer's and tweeter's diaphragm. I used ¹¹⁄₁₆″ battens on the inside edges and used strong wood glue on all joints. Dimensions are shown in *Fig. 10.*

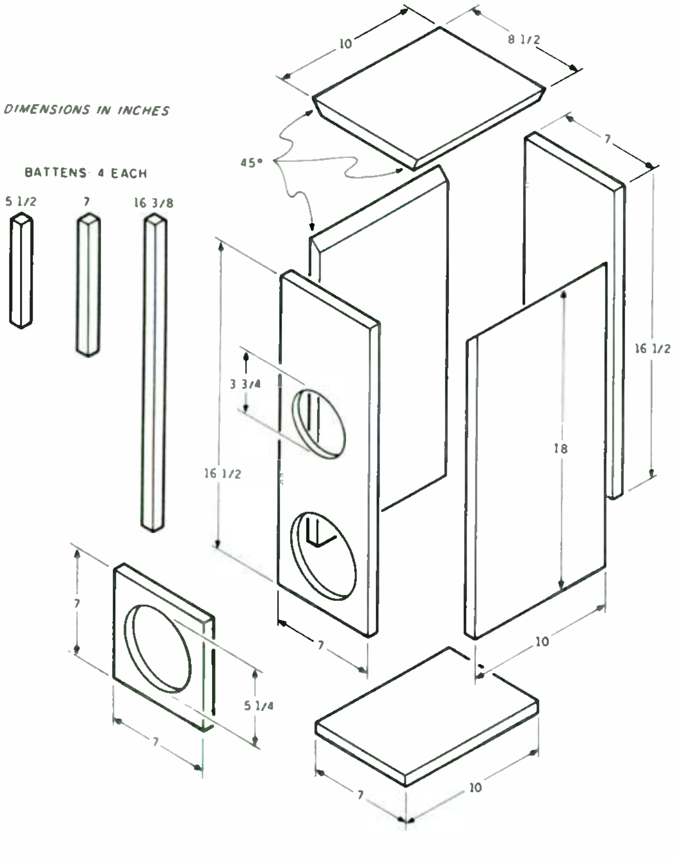

FIGURE 10: Dimensions for the author's enclosure.

While assembling the cabinet, I added a few details that you may consider necessary:

1. I lined the two side walls with lead sheeting (about ¹⁄₁₆″ thick) to reduce the amount of the woofer's transmitted rear radiation. I suspended the lead on a ¼″-thick wood frame so it couldn't buzz against the wall. The lead "inner wall" should resonate at a different fundamental frequency than the wood "outer wall," each wall filtering out the frequencies transmitted by the other. After installing one of the lead frames, I rapped on the lead from inside my partially-constructed cabinet. The lead made a "bonnnngg" sound, despite its strong self-damping qualities. When I rapped on the outside wall, however, I heard the desired higher frequency "knock." To be sure, I unscrewed the lead from its frame and inserted a piece of ⅜″ felt carpet underpadding, sandwiching it with the lead to dampen the ringing. For easier construction, dispense with the wood frames altogether and screw the lead/felt sandwich directly to the walls,

perhaps sealing the edges with silicone. The felt will damp the lead and prevent it from buzzing against the walls, and the combination may also help damp outside wall vibration induced by the woofer chassis' mechanical coupling to the enclosure.

2. Behind the woofer is a slanted surface to stagger front-to-back and top-to-bottom standing waves (*Fig. 11*). The surface does not extend all the way to the side walls, so the volume behind it is not cut off from the enclosure. I used leftover lead sheeting and attached it with a layer of putty. You may find thin wood or masonite easier to work with.

3. Above my woofer is a piece of masonite extending to the side walls and halfway to the rear wall. I added this to avoid asymmetrical rear driver loading, but I'm not sure you need this.

4. I experimented with the damped-vent technique (as discussed in the report on Audio Concepts' Model G, *SB* 1/86), but the results were inconclusive. In an attempt to improve the 17W75's low-frequency damping, I stuffed the volume behind the woofer with wool. Instead, you may wish to experiment by placing thin fabric or felt directly against the woofer's rear openings.

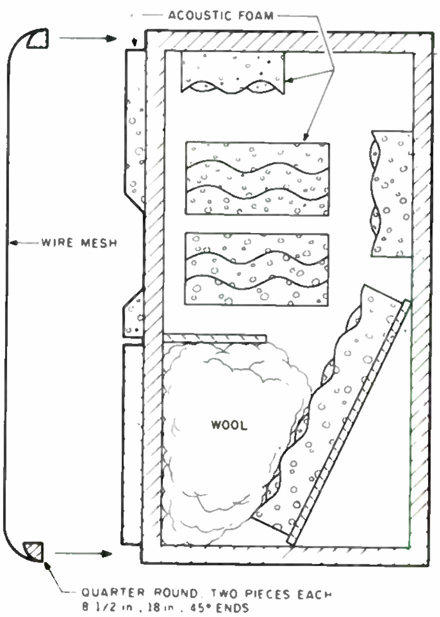

FIGURE 11: A look inside the enclosure.

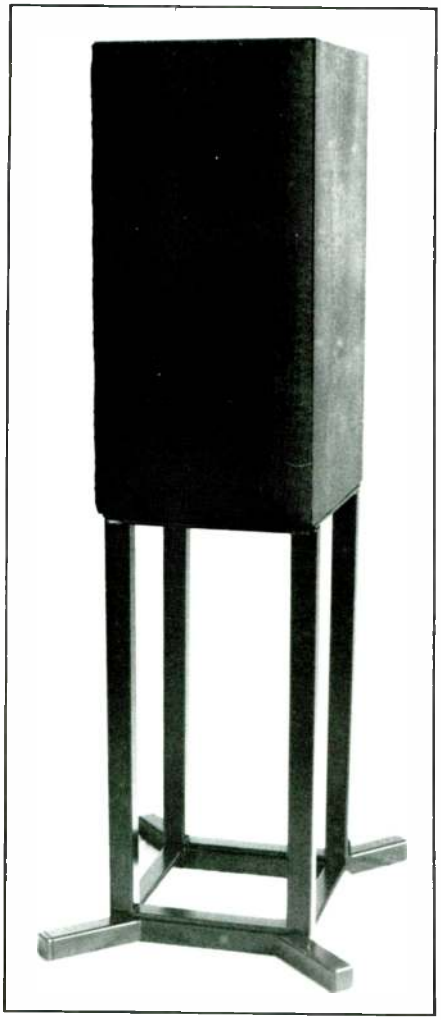

PHOTO 1: The author's completed system rests on an 18-20 stand.

5. I staggered several pieces of acoustic foam throughout the cabinet. I wanted to control top-to-bottom, side-to-side, and front-to-back standing waves while occupying as little volume as possible (*Fig. 11*).

After assembling the enclosure, I stained the top and sides with Minwax® Red Mahogany, applied several coats of polyurethane, and polished with the finest steel wool. I painted the other surfaces black.

To prevent reflections from the woofer step and the grille frame, I glued a 7" x 9½" piece of ¾" foam to the baffle around the tweeter. I used a 4" round hole for the tweeter, but in theory, an asymmetrical hole may be better.

I made my grille frame from 1 1/16" quarter-round molding, held together with Skotch® #0 woodjoiners, and drilled to accept push-on fasteners. I shaped ½" wire mesh to protrude beyond the woofer, spray-painted the mesh black and stapled it to the frame (*Fig. 11*), and covered it with grille cloth stapled to the back of the frame.

The LMP model shows a smooth response (*Fig. 9*) for the completed system, and this was verified by my own, somewhat crude, measurements. The speakers are relatively insensitive, but are neutral in the midrange, delicate in the treble, and "disappear" nicely. ►

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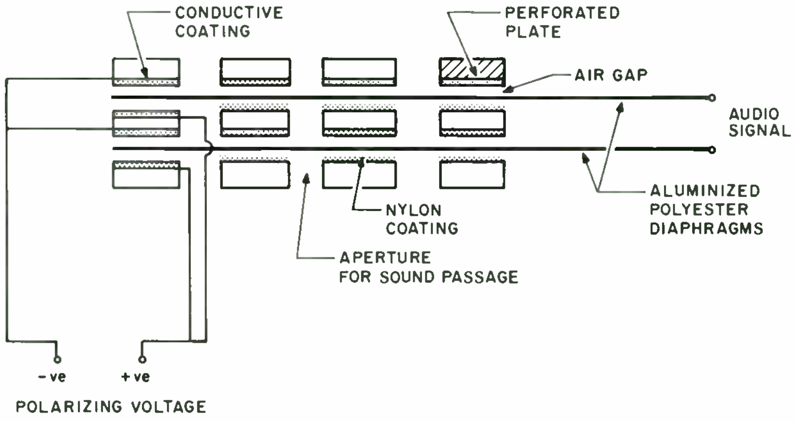
Technology Watch

Beveridge's Double Diaphragm

Electrostatic loudspeaker enthusiasts will be interested in Beveridge's latest thoughts as detailed in his patent AM 4533,794. He describes the construction of a double diaphragm ELS that will give an increased sound output at low frequencies with only a small increase in space occupied by the LS. This overcomes some of the ELS trade-off problems of size versus low-frequency capability. To obtain reasonable, linear movements of the diaphragm, the ELS is usually operated under constant charge conditions. This is done by coating the diaphragm with a high resistivity layer. The signal voltage is applied between the two conductive perforated plates.

Beveridge reverses this process by applying the audio signal between the two diaphragms which have a highly conductive aluminum coating on them. The plates are printed circuit board, etched, perforated and covered with a high resistivity coating and 10″ of nylon film. When it comes on the market, it will be interesting to see its final size as his current model is over six feet tall.

BEVERIDGE ELECTROSTATIC LOUDSPEAKER



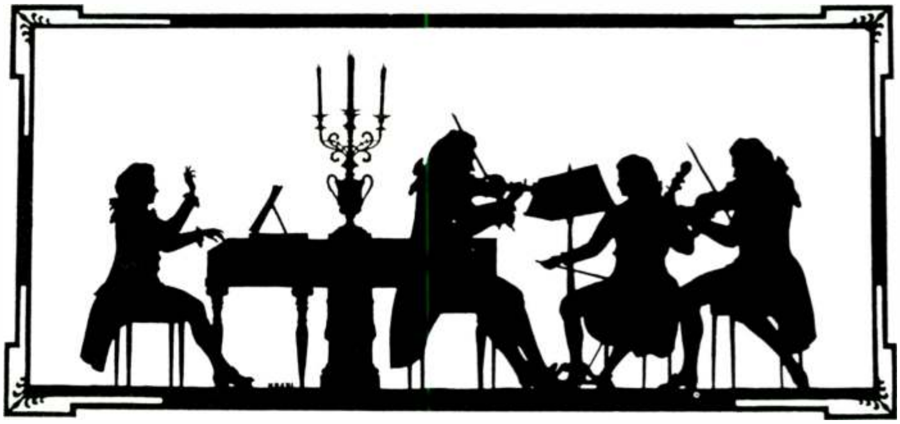
Subjective listening tests for LSs always guarantee a provocative discussion. An interesting preprint from the 81st AES Convention (November, 1986) by Wolcott is titled, "New Subjective Test Allows A/B Comparison with Original Sound." The test uses the speaker's input as the absolute reference and compares aurally the loudspeaker's input with output to judge the quality. To make the comparison, the test loudspeaker's output is converted into an electrical signal via a microphone and fed into a control box for A/B comparison. You simply select between the input and output of the LS under test and listen to the results.

If you use high quality headphones for listening, you will remove the room effects on the monitoring setup. A further extension not mentioned in the preprint is to run the test LS under anechoic conditions.

A preprint from the 66th AES convention (May, 1980) by Gander #1648 details a method of obtaining anechoic conditions by testing outside. The testing takes place on a large, flat, smooth, and rigid-reflective ground surface with no obstruction within five times the lowest wavelength of the test frequency. e.g., at 30Hz the wavelength is 11.4 meters *x* 5 = 57m. An asphalt or concrete parking lot or a playfield would do nicely. The LS is placed on the ground and tilted so it is aimed directly at the microphone. The microphone is placed flush with the ground.

Incidentally, there is no reason why these LS subjective tests could not be recorded on tape for future evaluation (an interesting experiment well within our capabilities). Finally, Philips has patented a unique method of shifting the woofer's high frequency roll-off to a lower frequency (AM 4582,163). The diaphragm of the LS is made permeable to air. This controlled air flow *through* the diaphragm represents an additional acoustic resistance to acoustic waves and results in a lower cut-off frequency for the LS.

Peter Muxlow
Wellington, New Zealand



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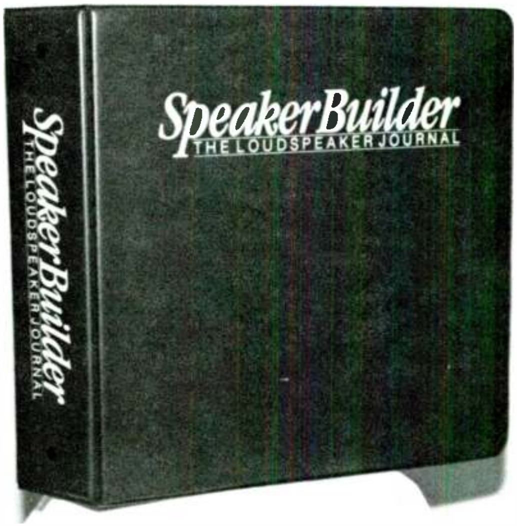

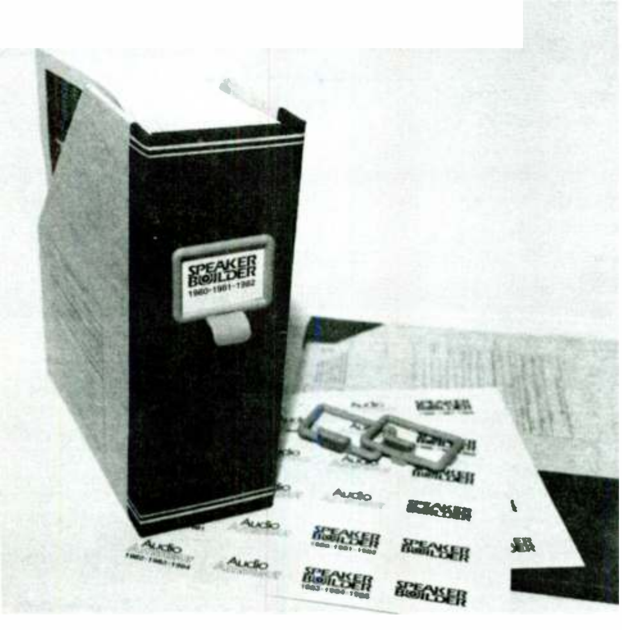

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Tools, Tips & Techniques

BALANCING SMALL SPEAKERS

An intriguing *acoustic* alternative to the passive line-level step circuit I described in *SB,* 3/86, p. 58, exists for eliminating the "response step." The "response step" is the rising trend in the on-axis response of an ideal driver in a free-standing enclosure. This rise may be responsible for the *forward* sound of many small speakers. The response step may reach 6dB as the frequency approaches point F in Hz where the wavelength, W in inches, is equal to the enclosure width: F = 13,500/W (*Fig. 1*). However, a practical driver may have its high-frequency limit near this point, and thus complicate the shape of the ideal step and reduce the effectiveness of corrective measures. Your particular listening room and tastes will also influence the results.

The driver should be mounted so its distance from the various baffle edges varies as much as possible. This helps to ensure a smooth response step and reduces diffraction-induced colorations in much the same way as does beveling or rounding the enclosure edges. Diffraction effects do not arise from the enclosure edges per se, but rather they are the combined reflections from the infinitesimal units of the entire baffle face.

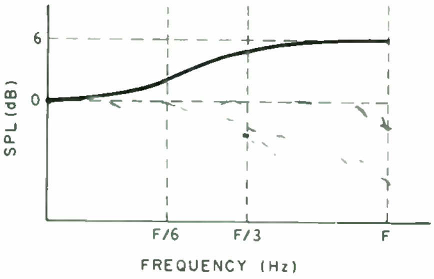

FIGURE 1: The frequency approaches the point where the wavelength is equal to the enclosure width.

Let's consider a system using multiple woofers. You may recall that using several small woofers in place of a larger one extends high-frequency response without compromising bass response and power handling. Mount half of the woofers on the rear or side of the enclosure. Since the rear woofers are out of sight, you may choose to mount them backwards as in *Fig. 2.* Make sure to wire them out-of-phase to maintain polarity. This reduces bass distortion by acoustic cancellation of even-order components. Each woofer in *Fig. 2* may represent several woofers in series or parallel.

At low frequencies all the woofers contribute equally to the axial response. As the frequency approaches that of the response step, the forward contribution of the rear-mounted drivers correspondingly decreases so the net on-axis response remains flat. The net sensitivity at frequencies above the response step, the one usually quoted in driver specs, is reduced by 6dB over the case where all the drivers are front-mounted, so the tweeter level must be reduced accordingly.

The resulting system is nearly omnidirectional up to the woofer's high-frequency limit, and the reverberant response is better balanced. Also, since fewer woofers are on the front baffle, vertical dispersion in the midrange is improved. (If you use more woofers, see my suggestion in *SB,* 2/86, p. 40.)

An inexpensive and unobtrusive sample of the arrangement in *Fig. 2* , using shielded drivers, is shown in *Fig. 3.* If you have a small integrated amplifier (an audio-out jacks on your TV or VCR), adding this speaker to your video system provides much more powerful, extended, and better balanced sound without the boxy, colorations prevalent in built-in TV speakers. If you prefer, you may omit the tweeter and use the Audax AM78GSM full range. (You may have to special order them from Audio Lab, 5269-2 Buford Highway, Doraville, GA 30340, (404) 455-0572.) Otherwise, for use away from a TV screen, you may substitute the non-shielded HIF78BiSM. However, this driver will require impedance compensation when used with a crossover. A 200 cubic inch acoustic suspension enclosure gives a "full" sujective bass, but a vented enclosure or electronic equalization may provide more true bass.

Another method of eliminating the response step in the multiple driver case is to mount all the drivers on the front of the enclosure as usual, and insert a series inductor as in *Fig. 4.* This ensures that only one driver operates above the step frequency (F in Hz) and the extra step is eliminated. Again, an added benefit is improved vertical dispersion since the two drivers don't conflict at higher frequencies. Here, L = R / (1.05 × F), where RΩ is the nominal impedance of each driver in *Fig. 4* and L is in henries. Calculate the crossover assuming use of only one of these drivers and also match the tweeter sensitivity to a single driver. Again, each of the "drivers" in *Fig. 4* may represent a combination of drivers.

or use 8/6

+ L =

Some woofers may require impedance

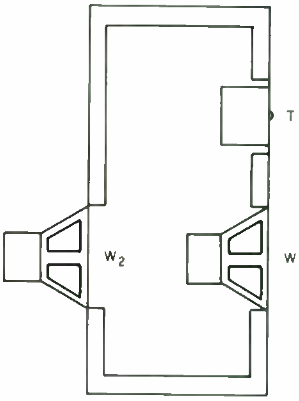

FIGURE 2: The rear woofers are mounted backwards and wired out of phase to maintain polarity.

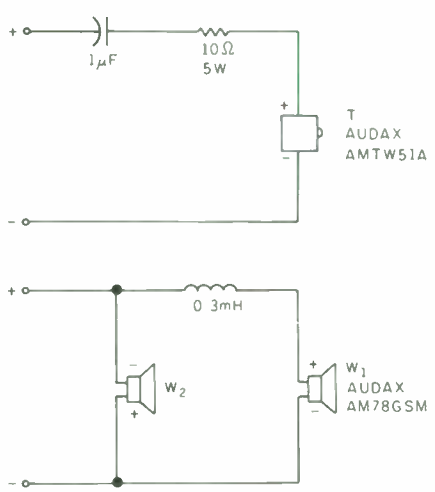

FIGURE 3: An inexpensive Fig. 2 arrangement using shielded drivers.

compensation circuits with this last corrective measure. More importantly, the crossover should remain unaffected by the extra inductor as long as the response step frequency is less than 1.5 times the crossover frequency. If the step is higher than this, the corrective measure may be omitted entirely, since the response step may be partially or completely eliminated simply by reducing the tweeter level. This last comment also applies to systems using only a single woofer.

The final correction alternative may also be used with systems having only a single woofer, where F in Hz should again be less than about 1.5 times the crossover frequency to avoid loading problems. *Figure 5* shows an inductor-resistor combination, where the resistor (R Ω) is equal to the woofer impedance, and the inductor (L in henries) is calcuated from: L = R/(2.1 × F). The crossover should be obtained assuming the woofer's impedance is doubled, and the tweeter level should be reduced 6dB.

To test the effect of this last corrective measure with LMP, *SB,* 1, 2/87, use the notch filter crossover number one with C = O.

Ralph Gonzalez
Philadelphia, PA

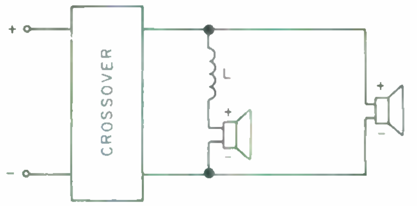

FIGURE 4: A series inductor inserted with drivers mounted on the front.

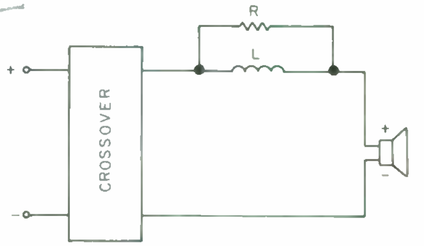

FIGURE 5: An inductor-resistor combination with the resistor (RΩ) equal to the woofer impedance.

REFERENCES

1. Muller, G., R. Black, and T. Davis, "The Diffraction Producd by Cylindrical and Cubical Obstacles and by Circular and Square Plates," *Journal Acoustical Society of America,* Vol. 10, No. 1 (1938), pp. 6-13.

2. Olson, Harry, "Accoustical Engineering" D. Van Nostrand Co., 1957, pp. 17-26.

3. D'Appolito, Joseph, "A High Power Satellite Speaker," *SB* 4/84, pp. 7-14.

4. Kral, Robert, "Diffraction—The True Story," *SB* 1/80, p. 28-33.

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Many factory-built speakers are internally wired using 16, 18, or even 20-gauge wire. The lugs on most speakers easily accommodate these sizes. However, if you wish to wire or rewire a speaker with heavier gauge wire such as Monster Cable, the connection to smaller lugs can be a problem. Most driver lugs are tab-shaped with a round hole in them. To obtain a good mechanical and electrical connection between this type of lug and a heavy gauge wire, cut the lug lengthwise with a wire cutter. The cut should extend from the lug's end to the hole. Spread the two lug halves with needle-nose pliers to provide an opening large enough to receive the heavy gauge wire. Then crimp the two halves of the lug around the wire and solder it to the lug. The crimping makes a strong mechanical connection which will hold the wire while you solder it.

Jim Frane
Orinda, CA 94583

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WEIGHING WOOFER PERFORMANCE

BY GARY A. GALO
Contributing Editor

This report continues my survey of drivers available to speaker builders (*SB*, 2/85 and 2/86) and concentrates on 8″ woofers which I have used in my TL-8 loudspeaker (*SB*, 2/82). Five popular 8″ drivers are covered here, including two Audax Bextrene units from **Polydax**, two polypropylene drivers from **Madisound Speaker Components** and **Meniscus Systems**, and a recent addition to the Audax family using their TPX Advanced Formulation Plastic cone material. I will also discuss a 10″ polypropylene driver from Meniscus, and give a few preliminary comments on some bass, mid-bass, midrange, and tweeter components I have been using since my last article on the subject.

Manufacturers' data for the six woofers is listed in *Table 1*, and more detailed data on the individual units can be obtained from Madisound or Meniscus. The two companies have recently agreed to sell each other's drivers, so all drivers discussed here are now available from both firms. Such cordial relations among "competitors" is a welcome relief these days, and *SB* readers are the end beneficiaries.

OVERVIEW. The Audax HD20B25H-4C12 might be considered their "classic" 8″ woofer. Many system designers, including myself, relied on this Bextrene cone driver back when most available 8″ woofers still employed paper cones. The manufacturer specifies the free-air resonance as 24.7Hz, ±3Hz. The driver employs a four-layer voice coil. Power handling is listed as 40W and the cost is about $27. The HD21B37R-2C12 is essentially the same driver as the HD20B25H-4C12 except that it employs a rigid die-cast frame and a two-layer voice coil. Free air-resonance is specified as 23.7Hz, ±3Hz and the power handling is 50W. The price is around $44.

The TX2025RSN-2CN12 utilizes Audax's latest development in cone materials, TPX Advanced Formulation Plastic which they claim is superior to others, including polypropylene. The increased rigidity, they believe reduces distortion and improves transient response. The new suspension, made of Norsorex is designed to insure that vibrations at the cone's edge will be properly terminated rather than reflected. Norsorex is, they claim, more resistive than either butyl rubber or PVC, the latter is the suspension material Audax previously favored. They specify free-air resonance as 38Hz and power handling as 30W. The unit normally sells for $50.

Madisound and Meniscus continue to expand their woofer lines. Both firms engage other vendors to manufacture drivers to their specifications. Gefco produces the Madisound drivers, and Carbonneau Industries of Grand Rapids, Michigan manufactures the Meniscus Eclipse drivers. Carbonneau is best known as the woofer supplier to Fried Products. The Meniscus units are virtually identical to those Fried uses in his transmission lines, but cost only a fraction of the Fried price.

Madisound has the M8154 manufactured with a clear polypropylene cone and a foam surround. They claim a free-air resonance of 29Hz, ±2Hz, and power handling capacity of 75W. The price is $23. The Meniscus Eclipse W0838R-LE also utilizes a dark gray polypropylene cone rather than clear, and has a rubber surround, a solid concave polypropylene dustcap, as well as a rear-vented pole piece. They claim a free-air resonance of

TABLE 1

MANUFACTURER'S SPECIFICATIONS

	AUDAX HD20B25H-4C12	AUDAX HD21B37R-2C12	AUDAX TX2025RSN-2CN12	MADISOUND MB154	MENISCUS W0838R-LE	MENISCUS W1038R
Price	$27	$44	$50	$23	$35	$42
Impedance	8Ω	8Ω	8Ω	8Ω	8Ω	8Ω
DC Resistance (Re)	6.9Ω	6.8Ω	6.5Ω	4.8Ω	7.1Ω	5.2Ω
Free-Air Resoance (Fs)	24.7Hz	23.7Hz	38.0Hz	29.0Hz	27.0Hz	24.0Hz
Mechanical "Q" (Qms)	4.09	3.43	1.7	9.8	1.42	2.45
Electrical "Q" (Qes)	0.25	0.39	0.63	Not listed	0.33	0.336
Total "Q" (Qts)	0.24	0.36	0.46	0.27	0.27	0.29
Efficiency 1W, 1M	86.4dB	86.4dB	89.0dB	89.0dB	90.0dB	90.0dB
Power Handling	40W	50W	30W	75W	75W	100W
Cone Material	Bextrene	Bextrene	TPX	Polypropylene	Polypropylene	Polypropylene
Surround	PVC	PVC	Norsorex	Foam	Rubber	Rubber
Pole Piece	Closed	Closed	Closed	Closed	Vented	Vented

27Hz, ±15% (4Hz) and a power handling capability of 75W. The price is $35.

The Eclipse W1038R is the latest Meniscus 10″ driver. It has a number of improvements over the previous one I reviewed in *SB*, 2/85. Free-air resonance now meets the previously claimed 23Hz spec. and a rear-vented pole piece and solid concave polypropylene dustcap complete the improvements. Power handling is listed as 100W and the price is $42.

PERFORMANCE. My frequency response and impedance curve measurements for the six tested drivers are shown in *Figures 1* through *6*. I made the frequency response measurements with an ElectroVoice C0-15E omnidirectional condenser microphone placed in the near field. The 8″ drivers were mounted in a modified TL-8 enclosure and the 10″ units in a TL-10. I corrected for the EV microphone response variations when I drew the graphs. The only exception was the Meniscus Eclipse W1038R 10″ woofer. Later I will elaborate on the procedure I used with it. Since all of the 8″ drivers were measured with the same microphone the comparisons should be valid. I measured all impedances in free air.

I oiginally used the Audax woofer, HD20B25H-4C12, in my TL-8 transmission line. I tested several pairs and found these virtues. They have a smooth response up to 2kHz with a gentle roll-off above that point and also meet the factory free-air resonance spec. Every sample I have measured had an F_S of 24Hz, right out of the box without any break-in. However, this driver has two serious shortcomings when compared to other 8″ units. First, its power handling capacity is limited. In a transmission line enclosure it easily reaches its limit when playing digital recordings with low bass at even moderate volume levels. Second, the midrange has a noticeable harshness, a common characteristic of most Bextrene woofers. However this problem is not serious unless the driver is used in two-way systems.

The Audax HD21B37R-2C12 is the die-cast frame version of the above driver. Not surprisingly, its frequency response curve looks very similar to its stamped frame counterpart. Again, smooth midrange response is a virtue. This driver suffers from an even greater limitation in power handling, probably due to the fact that it employs a two-layer, rather than a four-layer, voice coil. I hear the same harshness in the midrange using this driver. I do not wish to give a negative impression of the Audax drivers. When I wrote the 1982 *SB* articles, they were the best 8″ drivers available at anything close to the price. By 1987 standards, however, better drivers can be bought for the same money.

Polydax, the U.S. Audax importer, sent me evaluation samples of the

FIGURE 1: Impedance and frequency response curves for the Audax HD20B25H-4C12 Bextrene woofer.

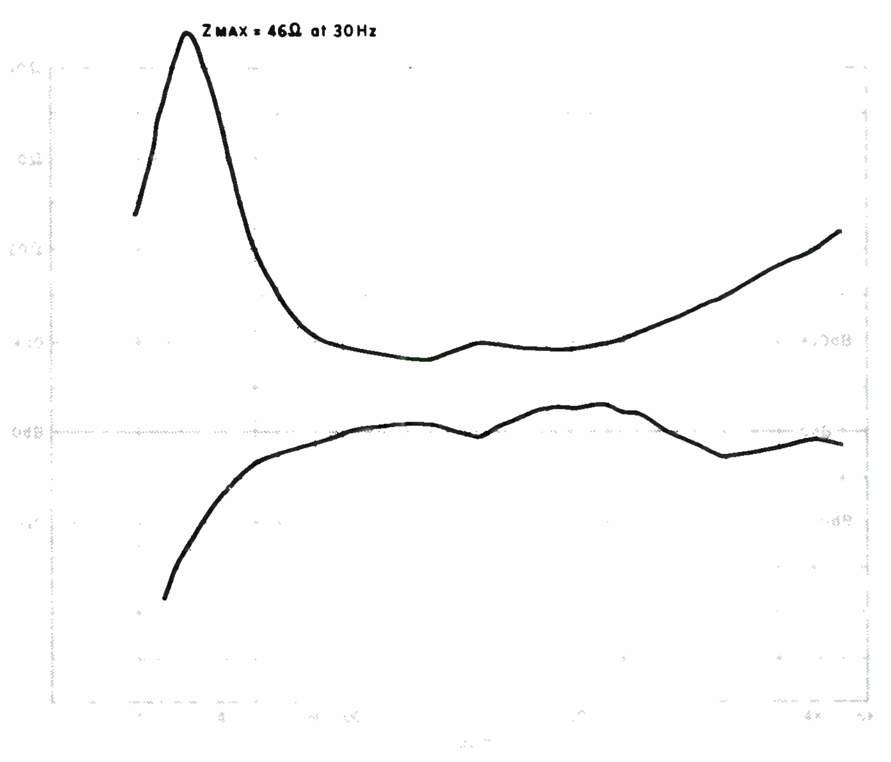

FIGURE 2: Impedance and frequency response curves for the Audax HD21B37R-2C12 die-cast frame Bextrene woofer.

TX2025RSN-2CN12. I was disappointed in this driver because although the manufacturer claims a free-air resonance of 38Hz, neither of my samples even came close. After a 24-hour break-in with a 40Hz sine wave, both samples had an F_S of 63Hz, and the frequency response curve shows an excessive low-frequency rolloff to confirm the deficiency. But this was not the most serious problem. These TPX drivers are uniquely constructed; the cone has no center dustcap. Instead, the pole piece extends forward through the cone's center an protrudes about 2″. The front of the pole piece is covered with a decorative plastic cap, and therein lies the problem. Both plastic caps on my samples rattled noticeably, and the resonance frequency of the caps could easily be located by sweeping the generator through the lower midrange. On one sample, the plastic cap buzzed most severely at around 500Hz. The other sample's resonance point was around 450Hz. My recommedation to anyone using these drivers is to remove the plastic caps. Finally, according to Audax's own specifications, these woofers have the same power handling limitations as the other two mentioned above.

When I returned the driver samples to Polydax in January 1986, I wrote a letter explaining these problems, and offered to examine another pair. I never received any reply from them. I also explained that the driver's impedance curve in their data sheet contradicted the F_S specification. The curve shows a peak in the 50-55Hz region. This has been a

FIGURE 3: Impedance and frequency response curves for the Audax TX2025RSN-2CN12 TPX woofer.

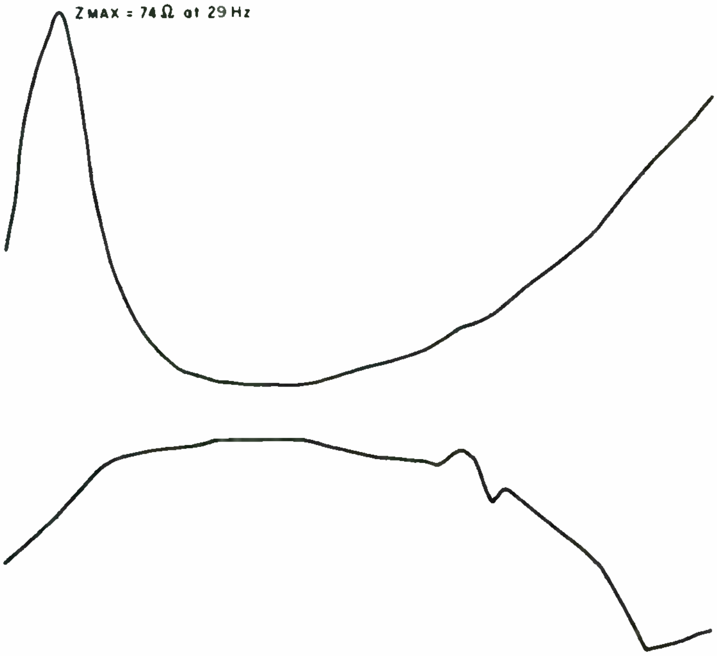

FIGURE 4: Impedance and frequency response curves for the Madisound M8154 polypropylene woofer.

typical problem in Audax woofer documentation. Numerous examples of impedance peaks are as much as an octave away from the F_S specification. How unfortunate the TPX drivers exhibit such serious problems since the frequency response measurements show an unusually smooth midrange response in the 1–5kHz region. Until these problems are solved, I cannot consider it a finished design.

The Madisound M8154 was designed for use in three-way systems, so the rolloff above 800Hz should not be a problem. Madisound does offer the M8152 version of this driver for use in two-way systems. I did not test it for this report, but Madisound's data shows response extending to 2kHz. The M8154 gave a free-air resonance of 29Hz without break-in, which is within the ±2dB tolerance Madisound specifies. Frequency response is smooth up to 800Hz, and the low-end performance is the best of all the 8″ drivers tested. Power handling is also excellent. These are very rugged drivers. I subjected them to a fair amount of abuse and they survived admirably. At $23 each, they are a steal, and are the current best buy in 8″ drivers.

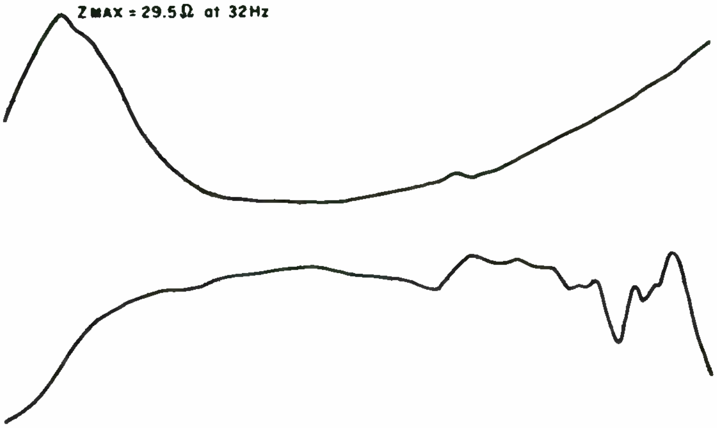

FIGURE 5: Impedance and frequency response curves for the Meniscus Eclipse W083R-LE polypropylene woofer.

The Meniscus Eclipse W0838R-LE is suitable for use in two or three-way systems. The response is quite smooth (within 2dB) up to 2kHz. Free-air resonance was 32Hz, not quite as low as Meniscus claims, but still low enough for any application in which an 8″ driver is likely to be used. As with the Madisound driver, power handling is superb and the construction is excellent. Subjectively, I would rate it among the best 8″ drivers available, easily worth the asking price of $35. Although the Madisound drivers are a bit more efficient in the 40Hz region, the Meniscus drivers are better defined in the bass region and have better transient response.

Your ultimate choice between the Madisound and Meniscus drivers will depend on your preferences as system designer and builder. I happen to prefer rubber surrounds and rear vented pole pieces, so my preference is for the Meniscus woofer. If you like the added efficiency in the 40Hz region you will probably prefer the Madisound. Either way, you will have to spend two to three times as much to equal the performance of these fine drivers.

I used the Meniscus Eclipse W1038R in my third generation TL-10 loudspeaker for over a year, on which an extensive update is forthcoming. The Meniscus 10″ drivers easily met the manufacturer's specification for free-air resonance; my samples showed the impedance peak at 22Hz. Frequency response is very smooth up to 400Hz and acceptable up to 1.5kHz. Meniscus specifies an upper limit of 1kHz, but I normally would not set a crossover point for a 10″ driver above 700Hz. In the current version of my TL-10, these woofers cross over to Dynaudio D-76 midrange drivers at 400Hz, with a fourth-order Linkwitz slope. The Meniscus woofers have superb impact and definition in the bass region. They are my current first choice among available 10″ woofers. The

Madisound M1054 is a fine driver, but I prefer the Meniscus. In terms of value, my comments regarding the 8″ drivers from these two firms apply here as well.

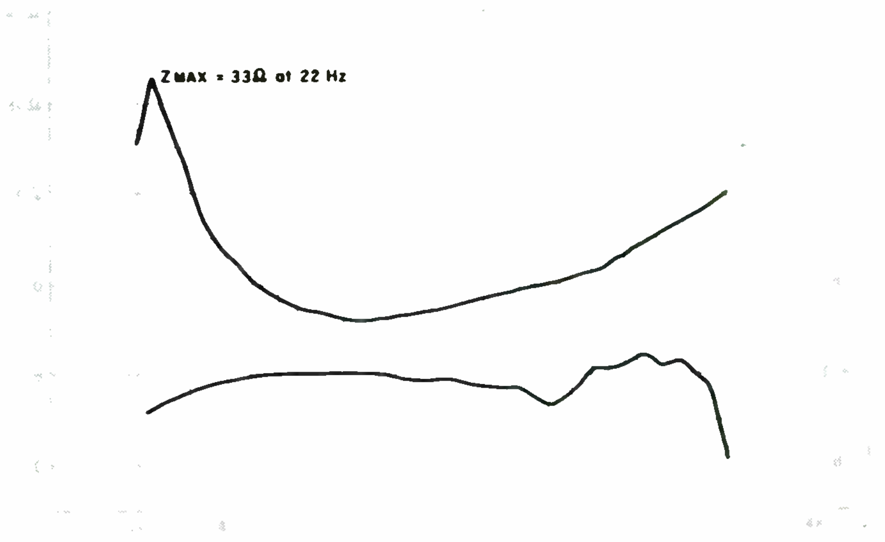

FIGURE 6: Impedance and frequency response curves for the Meniscus Eclipse W1038R 10″ polypropylene woofer.

Since I acquired the review sample of the Audio Control Richter Scale Equalizer/Analyzer, (*SB*, 2/87), I have relied on it for all my low-frequency measurements. As I pointed out in my review, the low-frequency analyzer provides the best measurement system I have seen for this purpose. I measured the W1038R woofers with the Richter Scale Analyzer below 250Hz. Above that, I used a Schoepps MK-2 omnidirectional condenser microphone. This will probably be my procedure in the future.

I am not especially concerned with how a 10″ woofer performs above 1kHz, especially when I use crossovers higher than first order. (I do not normally use first-order crossovers, and am in complete agreement with the reasons Robert Bullock has outlined for not doing so.) I believe in this general rule of thumb regarding building two-way loudspeakers: never build one with a woofer larger than 8″. Ten-inch drivers cannot be expected to behave in a linear fashion in the 1-3kHz region. If compromises must be made when designing a two-way loudspeaker, it is best to sacrifice performance on the extremes of the audible spectrum. Accuracy in the critical midrange is more important than floor rattling bass or crystalline highs at 30kHz. If the latter two criteria are important, then a three-way design will probably be necessary. I am continually amazed to hear demonstrations at AES conventions of "studio monitor" loudspeakers employing 15″ woofers crossed over at 1.5kHz. Sheer volume is apparently the requirement in these cases.

TABLE 2

IMPEDANCE COMPENSATION VALUES

	R (Ω)	C (μF)
Audax HD20B25H-4C12	8	20
Audax HD21B37R-2C12	8	15
Madisound M8154	8	27
Meniscus W0838R-LE	8	15
Meniscus W1038R	8	20

All woofers normally require impedance compensation for the rising inductive reactance of their voice coils at frequencies higer than 500Hz to 1kHz. *Table 2* gives the required values for R and C for all the woofers discussed in this report, with the exception of the Audax TPX driver. Since I consider the TPX samples to be unrepresentative of a finished product, and since I hope to obtain new samples to test, I did not determine proper impedance compensation values for these drivers. For a more complete discussion of impedance compensation, please refer to the latest edition of Vance Dickason's *Loudspeaker Design Cookbook*. Dickason's book is a must for anyone serious about loudspeaker design and construction.

FIRST LOOKS. Before concluding this report I will comment on a few other drivers, including midranges and tweeters. Some of these I use in my designs. Others were submitted for testing and I have complete evaluations in progress.

The Meniscus 6″ mid-bass (W0620R-LE) appears to be virtually identical to one used in Fried's satellite system, part of his most expensive transmission line. Superbly constructed, it has a rear-vented pole piece and sells for $25. The 12″ (W1238R) woofer bears a family resemblance to other Eclipse drivers and appears to be a best buy. Those looking for a 12″ woofer as affordable as the classic Peerless, but with rubber surround, should consider this Meniscus offering.

Recently I designed an aperiodic bookshelf system using the Norwegian SEAS midrange and tweeter. Their 10F-M midrange has a 4″ treated paper cone driver and comes with a plastic sub-enclosure which should be loosely filled with Dacron polyester. Operated between 600Hz and 3.5kHz, this is perhaps the finest midrange driver in the $15 price class. Remarkably detailed and transparent, I prefer it to the Philips dome drivers I reviewed in *SB*, 2/86.

The SEAS H297 is their most expensive tweeter, but is still reasonably priced at around $17. This 1″ driver employs a soft polyamide dome nd has an foam anti-diffraction ring. Although it has a slight rise above 10kHz, it is otherwise smooth and detailed. I prefer it to the Audax HD100D25, which I have used in several different systems.

Continued on page 67

SOURCES

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Special Report

SUMMER CES 1987

I'm a speaker freak. Sure, there are times that a new amp or preamp brings your system alive in a way it never was before. Still, speakers remain the weakest link in the chain. The quest for superior and marketable (i.e., profitable) designs continues; sometimes there's even a legitimate advance. The press contributes to this state of affairs by focusing on major advances and different-for-their-own-sake designs, rather than moderate progress, which isn't much fun to read about. Where do you think my emphasis is?

This year's SCES, Summer Consumer Electronics Show, confirmed the movement toward ribbon, planar magnetic, and electrostatic designs, with a surprise or two from conventional electrodynamic systems. Several firms are also offering new or improved raw drivers. The first part of this report covers components, the second discusses systems. A list of manufacturers' addresses and phone numbers is at the end. When you write or call, be sure to say you saw the product mentioned in *Speaker Builder*.

ATC drivers imported by **Audio Ecstasy** are nominally professional products, yet have found their way into a number of consumer speakers, (Proac, Nelson-Reed), which speaks well of their quality. It's a long-standing joke in the industry that most studio monitor speakers don't even begin to approach minimum audiophile standards of reproduction.

I talked with the importer and listened to their penultimate Studio Control Monitor speakers. (ATC also makes complete systems, two of which have integral tri-amping.) They were quite good, with impressive dynamics (qv. my comments on Nelson-Reed), though at $5,500 a pair, rather pricey.

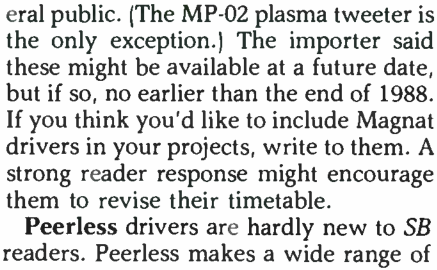
On the other hand, I've heard far more expensive studio systems with considerably worse sound. When you consider their ability to play cleanly at high levels, and the built-in amplification, they might be a good choice for the studio designer who doesn't want to start from scratch. He'll also get a speaker that serious audiophiles would approve.

Unglued Surrounds

ATC seemed especially proud of their SM75-150 series of 3″ dome drivers. These cover the 300Hz to 4kHz range with a capacity of 75W, and are supposedly designed for good clarity at high levels (which I confirmed at both ATC and Nelson-Reed). A fine system might be built around this driver, though the $169 and $263 tags (for the regular and super versions) may be disheartening, even for the hobbyist.

Audio Ecstasy is happy to help the home constructor. Once you've bought the drivers, they'll supply cabinet and midrange crossover designs, if you think you need them. They'll also help with specific design questions or problems. Write for literature.

Until **Magnat** began importing their own speaker systems, they were best known for their drivers, which are used in the DQM series of **Dahlquist** speakers. Magnat has a wide range of drivers that are available to OEMs, but not to the general public. (The MP-02 plasma tweeter is the only exception.) The importer said these might be available at a future date, but if so, no earlier than the end of 1988. If you think you'd like to include Magnat drivers in your projects, write to them. A strong reader response might encourage them to revise their timetable.



Peerless drivers are hardly new to *SB* readers. Peerless makes a wide range of components that are used by speaker manufacturers world-wide. My eye was caught by a woofer/midrange/tweeter combo which all use the same construction technique.

Difference Marketing

The diaphragms are plastic (a compound of polypropylene and other materials) and, except for the woofers, nearly flat. The edge of the cone is bent over to form the surround. This has several advantages. It removes the problem of gluing the surround to polypropylene, a so nearly-ungluable material that each company making polypropylene cones has its own proprietary technique. The surround now has the same acoustic properties as the cone, so edge reflections are reduced. The dustcap is also part of the cone, which reduces the chance of it flapping away on its own. the driver is less expensive to manufacture, and should have more consistent characteristics.

Best of all, the construction similarity suggests a similarity of residual colorations. This should simplify getting coherent sound. I've always advocated three-way systems, partly because it's easy to design a look-alike woofer/midrange pair. Peerless has taken this idea and extended it to the treble. This line includes the 1726 tweeter (2.5″), 1628 midrange (4″) and 1650 woofer (8″). The midrange and tweeter have liquid-cooled voice coils. Peerless will be glad to send you literature.

Before discussing speaker systems, I'd like to focus on what I consider an unfortunate trend in the speaker business. I realize that my point of view is rather rigid—even doctrinaire—and that I may be less than fair to the firms I'm criticizing. Still, I have good reasons for the criticism, and I would be less than responsible if I didn't—uh . . . speak up.

Product differentiation is the name of the game. You cannot sell your product unless you can convince the customer that it's different from your competitors'. In the bad old days, when everyone thought speaker sound was strictly a matter of taste, and only a handful of British and New England firms made speakers that even tried to be flat, it was no trouble to create a distinctive sound and let the product find its audience.

Image Wars

Unfortunately, as drivers improved, and firms promoting flat response had an "unhealthy" influence on the rest of the industry, marketers discovered that most listeners, when given a chance, actually preferred flat response. Horrors. If every speaker is flat, you need a new form of product differentiation to get people to buy yours.

Ever since the Bose 901, the most common form has been multi-directional sound. But this was always looked on by the "better" companies as gimmicky (because it's correctly perceived as an excuse for a lack of good basic sound quality). Bose products have been the only ones to gain market acceptance.

The "video revolution" provided the impetus to revive multi-directional sound. With stereo sound, first from LaserDisc, then hi-fi tape, and big-screen video projection, listeners needed speakers that maintained a stereo image for a large group of listeners. Speakers with a broad but carefully-contoured dispersion pattern could do that.

The first salvo in the stereo imaging war was fired by dbx. Using listening tests to determine exactly how much compensation was needed at each off-center listening position, Mark Davis designed a speaker pair whose rise in off-axis output exactly compensates for the tendency of the image to shift toward the closer speaker. It worked extremely well (though I found the overall sound of the first model rather blah). The success of the dbx Soundfield Imaging speaker sparked a spate of models from other companies, and cheaper/costlier versions from dbx.

Axis Max

I have no objection to the basic concept of a broadly-imaging speaker. Unlike older multi-directional designs that just add ersatz spaciousness (which is better done by ambience systems, anyway), wide-stereo speakers meet a real need. My objection is that, at a given price point, they discard basic sound quality for the cost of extra drivers. Worse, there is a tendency to consider wide imaging as an inherently-desirable feature, whether one needs it or not.

As a bachelor accustomed to monopolizing my hi-fi system, this bothers me. Why should anyone pay money for a feature they rarely (or never) use? Although such speakers do an exceptional job of maintaining an off-axis image, "conventional" speakers aren't necessarily much worse.

I recently reviewed a $900/pair of speakers from Angstrom and Spectrum. Both were two-way designs whose bass/midrange driver is larger than the separate midrange one would find in a three-way. The result is poorer off-axis dispersion in the midrange, which is actually an advantage. If the speakers are toed-in to cross their on-axis "beams" in front of the listener, moving to the right, say, will cause the output of the left speaker to rise, since one is moving into the driver's on-axis response, compensating for the listener's increased proximity to the right speaker. It doesn't work as well as does a speaker specifically designed to create this effect, but it works. And these two speakers are by no means the only ones that can be set up for good off-axis imaging.

The correct way to select a speaker is for basic sound quality. Period. Anything else is gravy. If you often play your stereo or video system for friends, try a number of "conventional" speakers to see whether they can be set up for a broad image. Remember that most non-critical listeners will tolerate merely "good" off-axis imaging. If it's "acceptable" to you, it'll sound "great" to them.

ESL Subdivision

Here follows one of the more ignorant things I've read in recent manufacturers' literature. It's for a new planar magnetic speaker.

"You may be asking yourself how your living room can hold a speaker 66″ high. The answer is because our planar is just 1.5″ thick and can be placed almost flat against the wall. One advantage of this design is that it's passive. Other flat panel designs rely on fragile drivers which can't tolerate a powerful reflected backwave. However, ours has been designed to be almost totally impervious to the degradation caused by strong reflected waves."

If it isn't obvious . . . . The problem with placing a dipole near a wall is acoustic, and has nothing to do with the driver type or its ruggedness. And need I explain that any driver can take what it dishes out?

I finally heard **Acoustat's** new SPECTRA [S]ymmetric-[P]air [E]lectrically-[C]urved [TRA]nsducer system. Acoustat was finishing the design just as Polaroid announced their Spectra System. Acoustat considered changing the name. It's difficult to do justice to this breakthrough design in a few paragraphs, and I won't try. Basically, Strickland and company have found a way to electrically subdivide a set of six full-range electrostatic panels so that the lows are reproduced by all panels, the mids by three and the highs by one.

The wire grid is divided into three groupings. The "treble" section is fed directly. The "midrange" section is fed through a 150k resistor, which creates a low-pass filter when combined with the drivers' intrinsic capacitance; this attenuates the highs. The "bass" section is fed through 830k, which kills both the mids and the highs.

This arrangement produces a progressively-narrower radiating surface with rising frequency. The drivers' spacing, and the phase shifts from the bass-mid/mid-treble rolloffs are calculated to produce interference effects that create an asymmetrical dispersion pattern angled towards the listening area and away from the side walls. This gives a wider, better-maintained listening window and even less room interaction than with conventional bipolar systems. This all works with a flat-panel array; there's no need to curve the driver.

The Yoo Factor

The SPECTRA also incorporates an integral subwoofer. It's supposed to closely match the basic sound quality of the electrostatic section (which I can't confirm or deny, as I spent less than half an hour listening). By lifting the bass burden from the main drivers, it permits them to play at higher levels. You can switch the woofer out, for the most coherent sound at moderate levels, and switch it back when you want to "get down." You can bi-amp, or substitute your own subwoofer. The SPECTRA is a significant product that will have a profound influence on future electrostatic designs.

One of the silliest new speakers comes from **Aero Holosonic Speaker Systems,** of Jessup, MD. Their slick brochure was immediately off-putting: these designs were created by a "young, gifted inventor named Sam Yoo." To Yoo, (i.e. to him), "the sound of even the most highly regarded, most expensive speaker systems left him with the feeling that something very important and organic was missing from the music. Where, he wondered, were the timing, phase, and amplitude cues? There seemed to be a flatness, almost a squashed quality, with none of the airiness and openness of a live performance. It was as if the music was [sic] being held captive, rather than being reproduced with all its depth, spaciousness, and inner harmonics intact. When Sam listened to systems that were supposed to be "three-dimensional," the[ir] lack of accuracy was even more distracting. Instruments seemed to float aimlessly [sic: sound cannot be aimless], as if the musicians were playing a macabre [obviously not a "live" recording] game of musical chairs. Clearly[,] reflective devices with their "aim and scatter" sound create, at best, a confusing illusion. There had to be a better way." "The Genius of Matthew Polk" is now apparently available to all Maryland-based speaker designers.

I don't know what speakers Mr. Yoo has been listening to, but there are more than a few forward-radiating speakers that create a sharply-focused image with good depth and spaciousness—assuming the recording has these things. The fundamental problem with reproduction, as I have

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†CD-24 *Stravinsky: The Firebird Suite (1910) DeBussy: Afternoon of a Faun.* Erich Leinsdorf conduting the Los Angeles Philharmonic. This recording features the expanded orchestration of the original *Firebird Suite*, complete with the finale. *"One of the very best orchestral records I have ever heard.—Hi-Fi News & Record Review*

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‡CD-26 *The Moscow Sessions* The Moscow Philharmonic. Shostakovich: Symphony No. 1; conducted by L. Smith. Piston: The Incredible Flutist. Barber: First Essay for Orchestra; conducted by Dmitri Kitayenko. Recorded in Moscow in 1986. First recording by a Soviet orchestra of American music.

‡CD-27 *The Moscow Sessions* The Moscow Philharmonic. Shostakovich: Festive Overture. Glazunov: Valse de Concert in D; conducted by L. Smith. Copland: Appalachian Spring, Gershwin: Lullaby (for string quartet), Griffes: The White Peacock, Ives: The Unanswered Question, conducted by Dmitri Kitayenko. Recorded in Moscow in 1986.

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Telephone Charge Orders: (603) 924-6371 or 924-6526, Monday-Friday, 9-4 EST pointed out *ad nauseum*, is that stereo is incorrectably flawed; it is inherently incapable of accurate spatial reproduction. Not only doesn't Sam Yoo understand this, but he's fallen for the Bose Fallacy: the speakers must compensate for the errors and omissions of the recording. Down that path lies madness—or at least serious inaccuracies.

Modulated Midrange

Yoo's "better way" is called a Controlled Image Expansion enclosure. It's a conventional-looking box with two rectangular holes, one on either side of the midrange. The holes are framed with plastic inserts. Three terribly-square engineers are pictured standing to the rear, one of whom is peering skeptically through an insert. We know they are engineers because they wear white lab coats, rather than Yoo's Don Johnson-approved sports jacket. The rear, anti-phase output of the drivers is supposed to emerge in such a way as "to create a specific pattern of timing and phasing information." (Well, not that specific. The brochure portrays three different enclosures, each with a different size and shape of hole.)

In effect, each speaker has two extra ports, of unknown effect. The rear wave is obtained (if you believe the brochure drawings) by [not] isolating any of the drivers! This is generally considered bad practice, because it lets the woofer's output modulate the midrange driver's motion. No attention seems to have been paid to time alignment or diffraction effects, either in terms of driver placement or cabinet edge contouring. In fact, those holes form a nice extra set of diffraction edges.

The sound was of no particular distinction, though that could be easily blamed on the cramped hotel room. The manufacturer is obliged to demonstrate his product convincingly. The reporter is not obliged to forgive any and all sonic problems. I heard nothing that suggested the Aero Holosonic might have superior imaging. This looks like an attempt to copy the Polk SDA system, without using extra drivers. It doesn't seem to work.

Magnets Maxed

For the second year in a row, this writer's award for "best sound in the show" went to **Apogee**. Last year it was for the Calipers. This year it was the new, $7,000 per pair Divas.

Part of Apogee's good sound is careful selection of program material. Jason Bloom plays only LPs, and spends the preceding year finding the best analog recordings. His time is well-spent; his taste is impeccable. His favorite classical piece this year was Bellini's *Messa di Gloria*, an exquisite work. Alas, neither the Schwann nor MHS catalogs list it.

Another reason is the superb electronics: all Krell mono components. But the principal reason must be the speakers. Up through the original Duettas, I was not wildly impressed with Apogee products. Their sound was either unbalanced, or had a lush, romantic quality that, though "musical," was inaccurate.

Then came the Caliper. It was realistic in a way that one expected from only $30,000+ systems, at about 1/20 the price. The Divas are even better. My reaction was of clinical accuracy, extreme realism, and intense musical involvement, all at the same time. I don't think I've heard a system, with the possible exception of the WAMM, that gave so much of the illusion of hearng a live performance.

The Divas are about 10dB more sensitive than previous models, permitting their 3Ω load to be driven with a high-quality 100W/channel amplifier. This improvement was made possible by a more-efficient layout of the magnetic structure, larger drivers, which are inherently better-matched to the air load and electrical changes which permit the amp to couple better to the system. Leo Spiegel, Apogee's chief designer, was quite proud of the *Stereo Play* (a German publication) declaration that Apogee speakers have the lowest distortion of any speaker they've tested.

The Diva's price tag is high, but less than the cost of a decent family car. Though I often protest against high-priced components as bad values (because they are obsoleted so quickly), the Divas are an exception. Don't listen unless you can afford them.

Eros Implied

Rigid Riser speaker stands, with continuously-adjustable center posts, are the latest accessory from the fertile imagination of Ray Shab at **Arcici**. There are two models, the R1220 and R2036. As the numbers suggest, the bottom of the speaker can be set from 12–20″ from the floor, or from 20–36″. The maker claims extreme stiffness and sand or lead shot may be poured into the hollow center column for additional rigidity and acoustic deadening. Three support legs stick out from the bottom, each with its own spike. And, yes, the sexual allusion of the product name is intentional.

One of the most startling demonstrations came from the new Audio Pro Ace Plus system, distributed by **Sonic Research**. Remember that remark from the early days of acoustic-suspension systems: "a quart of bass from a pint pot?" Well, how about a pint of bass from a thimble?

The Ace Plus speakers are about the height of a beer bottle, and about the volume of a six-pack of cans. They use the same design principle as Audio Pro's previous subwoofers. The driver's mechanical, electrical and acoustic characteristics are treated as though they are an equivalent electrical circuit being driven by the amplifier. Altering the amplifier's frequency response, phase, and output impedance gives the designer control over the total system response. This is not a technical snow job. Electronic, mechanical and acoustic systems are all described by the same differential equations. This fundamental similarity allows their characteristics to be combined and controlled systematically. For this reason, all Ace systems have an integral amplifier.

The designer (Karl-Erik Stahl) says the voice coil's series inductance is the stumbling block to producing more bass from small enclosures. He claims it isolates the amplifier from the driver's mechanical inertia (also an inductance), making it impossible to increase that inductance and thus lower the system resonance. At this point, I get lost, because his explanations (and the schematics) lack the details which would enable me to confirm or deny his claims.

Monitor Tote

I'm also bothered by the claim that all this is achieved with little sacrifice. It's one thing to force the driver to behave the way you wish. But the driver/air interface problem remains which no quantity of electronics can modify. A given-size driver has to pump a certain volume of air to produce a given SPL at a given frequency. Small drivers have excursion limits that set a practical bound on peak output level and distortion. The sound, though, seems to justify the claims. It's big and full, and from two dinky (1.7 liter) boxes. Anechoic response is not bad −3dB at 60Hz into half-space. Hardly any trace of boxiness or honkiness was present, always a problem when you shoehorn a driver into a small cabinet. The only problem is the price—a pair of speakers and the required amp run about $1,100. But for someone whose space is really limited or who has lots of money, and wants a stereo in every room, they might be a good choice.

The usual accessories—floor stands, wall brackets, and the like were plentiful. The most important, though, is an attache case to hold the amp, speakers, and a program source, such as a cassette deck or CD player. This is smart marketing, since neither the AR nor the Bose portable amplified speakers have any convenient way to tote a full system. The Ace-Plus could thus become the '80's version of the classic KLH Model 11-FM portable stereo. Serious recordists (amateur or pro) may want to give the Plus a close look, as an in-the-field monitor.

Winged Walls

Beveridge's original electrostatic panels used an unusual ceramic plate as the stator. They have switched over to a printed circuit design, which not only costs less, but allows them to tightly control spacing. This translates into increased sensitivity and improved signal handling.

The **Dahlquist** DQ-20 is significantly improved this year. Previously a rather bland and retiring speaker, it's now showing some fire and life. Coincident with the discontinuation of the legendary DQ-10 comes an announcement from **American Audio Labs** of an update package for the 10s. The package includes a new crossover network, gold-plated binding posts, and a number of items to damp resonance and reduce diffraction. The UD-10 kit is $700; the assembled version is $200 more.

"Ah, pity the fool that don't own these speakers!"

Believe it or not, Mr. T is a principal shareholder in the **Electro Magnetic Corporation**, whose new flat-panel speakers were on display. He was at the CES, making occasional appearances. I passed him at the zoo, and noted how much smaller he is in person. Though hardly less threatening; a phalanx accompanied him. He wasn't smiling; he must think it hurts his image. The gold jewelry is real, but it looks like it came from Murphy's Mart.

The speakers are yet another of those "you-can't-see-them-with-a-Walter-Keane-original" types we're subjected to every few years. The literature boldly proclaims that the EMC panels are new, and work on principles different from every other planar-magnetic design. Whoever wrote the brochure claims that conventional speakers have a narrow, directed dispersion (which is not true of the better designs) and that EMCs, being large, flat panels, necessarily project a broad planar wavefront. Which isn't true, either.

The—uh . . . apogee of the EMC line is a "mythic" (their description) product, The Wall. It's just what the name says it is—eight 2 x 8′ EMC panels. The Wall is usually covered by artwork, which for the show was eight silk-screened angels, each expressing a different holy attitude. The artist (whom I will not embarrass by naming) was unable to get any differentiation into the expressions; they all fall somewhere between Doris Day-cuteness and celestial constipation. If anybody justifies their purchase of this system and the artwork on the assumption that it will serve as a spiritual role-model—well, they'd be better off reading Doctor Strange comics.

Fried Jump

The sound was okay, but nothing to write home about. Some people hated it utterly; I simply found it flat and colorless. Each panel runs $1,000+, and I have no hesitation stating there are several planar systems in that price range including Acoustat, Apogee, and Magnepan that run sonic circles around the EMCs.

Eminent Technology's first speaker is a three-way planar-magnetic design. They call it the Linear Field Transducer, because it appears to be the first push-pull planar magnetic. Other planar magnetics have magnets on only one side of the voice grid. (There is an exact parallel with electrostatics, which can be either single-ended or push-pull.)

Although any of the three drivers in each speaker is supposedly capable of operating up to 20kHz, three different-width drivers are used for good dispersion and minimal interference. The impedance is a nominal 4Ω but there is a special-order 16Ω version for use with OTL tube amps. Although the speaker itself is built into a steel frame, the system is covered with handsome oak panels.

The LFT-3s (their designation) were making some very agreeable sounds. The price, about $2,500/pair is also attractive. Worth auditioning.

Bud Fried has an outstanding track record of steady, significant improvements. This year was no exception. Like myself, Bud does not care for wimpy, insipid-sounding, "musical" speakers, and all his models have taken a big jump forward in immediacy and aliveness. Tom Norton (another [*Stereophile*] reviewer) was with me, and he was equally impressed.

Precise Pop

I especially liked the tiny Betas. When Bud switched to the Betas from a fine-sounding pair of floor-standing speakers, the only difference was a very slight increase in boxiness. They were otherwise indistinguishable. This is remarkable performance from a $325 pair of "shoebox" speakers. Fried speakers are among the best dynamic systems, and are worth audi-

Acoustat
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Fort Lauderdale, FL 33315
(305) 462-6700
Fast Reply #GB323

Aero Holosonic Speaker Systems
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Jessup, MD 20794
(301) 953-3040
Fast Reply #GB1130

American Audio Labs
Suite B 1001 North Pleasantburg Dr.
Greenville, SC 29607
(803) 271-4252
Fast Reply #GB1129

Apogee Acoustics
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(617) 963-0124
Fast Reply #GB1128

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Electro Magnetic Corporation
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Fort Smith, AR 72903
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Fast Reply #GB349

Lantana
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Garden Grove, CA 92642-1958
(714) 530-4993
Fast Reply #GB1123

Magnat America
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Marblehead, MA 01945-3038
(617) 639-1400
Fast Reply #GB1122

Nelson-Reed
15810 Blossom Hill Rd.
Los Gatos, CA 95030
(408) 356-3633
Fast Reply #GB1121

Paredaks
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GAFB, CA 92394
(619) 246-4887
Fast Reply #GB9

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Chantilly, VA 22021
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Sonic Research
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New Milford, CT 06776
(203) 354-9332
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Thiel
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Lexington, KY 40511
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Fast Reply #GB397

tioning. Some of the more expensive models are also available in kit form.

Speakers that use multiple drivers to cover a single frequency range are not uncommon. If the drivers are (very roughly) farther apart than the wavelengths they reproduce, there will be interference between them, creating peaks and nulls in the response. **Lanata** has a new approach called "critical alignment" which produces an "elliptical" wavefront. What it boils down to is that they claim they have found a way to arrange two drivers in a way that all nulls caused by interference are outside the listening window. This principle is applied to the woofers in their "Laug" subwoofer, and the mid/bass units in their "Tad" system.

Nelson-Reed was playing their "Pro" speaker at enormous volume levels, without breakup, distortion, or dynamic "gagging." The sound was both effortless, and truly high-fidelity. They ascribe much of this performance to the ATC 3″ dome midrange. They also describe their 8″ woofers as "brutal." I think they mean "brute."

They claim tremendous transient-handling ability for this driver, and proved it with the Telarc recording of the "Champagne" polka. I knew what they were playing, and when the "pop" would come, but I still jumped out of my chair. Interestingly, this was the dullest reproduction of the pop I have yet heard. This confirms that the driver really does have exceptional transient behavior, and is not "hyping" the sound by overshooting on the leading edge.

Flux Foil

The **Paredaks** speaker is a nearly 7′ tall system that, except for a subwoofer that crosses over at 100Hz, is claimed to be a true full-range ribbon. The distinction between a planar magnetic and a ribbon is simple. With a planar magnetic, the voice coil is unwound and bound to a flat diaphragm. With a ribbon, the voice coil isn't bound to anything; it is the driver.

The system consists of six ribbon elements, 12.25″ high by 4″ wide, stacked vertically. The grille cloth was in place, so I could not confirm that they were true ribbon drivers. The described design bears some similarity to the Strathearn ribbons. The sound reproduction seemed both very "fast," and authoritative. Paredaks was, unfortunately, in one of those smaller rooms with poor acoustics, so the speaker is probably even better-sounding than it seemed.

Quad was demonstrating an export version of the ESL-63, with a strengthened, heavier frame. The program material was organ; the FREDs took it in their stride, and with reasonable bass extension. This was the best demo of the 63s I'd heard since Quad introduced them six years ago. The sound was clean and full, without the harsh, pinched quality I hear when anybody else plays them.

Acoustical Manufacturing's latest brochure is subtitled "The First 50 Years," as 1987 is the 50th anniversary of their founding. Betcha didn't know they once made a corner horn/ribbon speaker (1949). There are also several pages of endorsements from famous musicians. The photo of Neville Marriner made me realize that, besides being one of the world's greatest conductors, he also has exquisite taste in sweaters. This is a marvelous memento of one of the great names in hi-fi. Maybe they'll send you a copy. Can't hurt to write.

Thiel has added a copper ring to the voice coil assembly of their woofers. The current induced in this coil creates a magnetic field which compensates for the reduction in the magnetic flux from the permanent magnet caused by the field from the voice coil itself. (Got that?) They claim improvements in sensitivity, distortion and high-level dynamics. I believe Jon Dahlquist invented this about 10 years ago. At least, he told me about it then; I don't know whether or not he patented it.

When you write or call these firms, be sure to say you saw their product mentioned in *Speaker Builder*. Some of them will say "Huh?," but don't let that worry you.

SB Mailbox

CORRECTION: LMP 2/87

The only significant errors I saw in my LMP article in *SB* 2/87, p. 49, were in the box labeled, "How To Get Copies of LMP." The Macintosh diskettes are, of course, 3½″; and my address for software support is: Box 54, Newark, DE 19711.

It has been brought to my attention that I may have been unclear on the use of impedance compensation circuits with LMP. For the LMP's results to be valid, your drivers must be nearly resistive near the crossover frequency (i.e., the manufacturer's impedance curve should vary little with frequency), *or must be compensated to appear so.* The impedance compensation should be placed between the crossover and the driver. For example, note the extra resistor and capacitor behind the woofer in *Figure 2d* of my *SB* 2/87 article. Also note the impedance compensation circuit does not appear in the LMP model itself.

It would be useful to be able to find the response of a driver/crossover combination *without* making the assumption of a resistive driver. However, when designing passive crossovers using impedance compensation circuits, you also have a few advantages.

1. It is easier to decide what crossover with which to experiment if you have some idea of its effect, and this is much more likely if each of your drivers has a compensated impedance near the crossover frequency.
2. A passive crossover which was designed with resistive drivers in mind can readily be translated into an *active* version.

In fact, you may use LMP to evaluate the suitability of a stock *active* crossover, as follows. First, calculate the component values and driver polarity required for a *passive* crossover of the same type (e.g., a second-order Linkwitz-Riley), assuming 8Ω *resistive* drivers. Enter these values with LMP, along with the corner frequencies, sensitivity, depth displacement and so forth of your drivers. These characteristics influence the performance of active and passive crossovers in the same way in spite of the active crossover's immunity to driver impedance variations. Don't be surprised if LMP indicates that your stock active crossover combines with your drivers to give ±6dB at the crossover frequency. Thus, LMP may help you select an active crossover which gives good results with your choice of drivers. In the future, LMP subroutines which allow the direct modeling of active crossovers may be available. Any volunteers?

Last, if you don't have IBM or Apple computers, LMP for other machines may be available soon.

Ralph Gonzalez
Philadelphia, PA 19143

OUT OF THE CLOSET

Reading the article, "A More Compact Transmission Line Subwoofer," by Craig W. Cushing in *SB,* 1/78, reminded me of some drivers I have stored in a closet since 1985. Mr. Cushing's TL subwoofer seems to be an excellent project for these drivers.

They are: Dynaudio D-21AF tweeters, Dynaudio D-52 midranges, and Peerless TD 255 F 10″ woofers with an F_S of 23. My question is, can I install these woofers to Mr. Cushing's line without modification to the TL or is there some kind of adjustment necessary?

Vincent Perez
Santurce, PR 00915

Mr. Cushing replies:

All of your drivers are of high quality, and you can use them to build an excellent system. Dynaudio recommends 6dB/octave slopes for their drivers, so it seems reasonable to incorporate those slopes between the midranges and the tweeters, although steeper slopes are always a possibility, and many excellent designers recommend them.

Although I prefer to use sharp cutoff slopes with subwoofers (18dB/octave or greater at 100Hz or less), you will probably have to use your woofers at a considerably higher cutoff point (700-800Hz or so) than the normal subwoofer range. The Dynaudio D-52s simply can't operate down to 100Hz (a "normal" subwoofer crossover point) in anything resembling linear fashion. Therefore, given the necessary high midrange/woofer crossover point, I wouldn't recommend that you build a three-piece system. Instead, either design cabinets patterned after my subwoofer design which incorporates the midranges and tweeters, or as an alternative, give considera-

tion to a four-piece system with separate woofers. The tweeter/midrange units could be truncated, and quite small, which minimizes diffraction effects. Like Gary Galo, I prefer electronic crossover networks with bi- or tri-amplification; however, SB has published a variety of passive crossover articles which will enable you to successfully realize networks that will do nearly as well for a lot less money.

I don't think you'll encounter any problems installing your woofers in the cabinets as designed. If you do decide to make the cabinets smaller, they can be downsized by approximately 15%. Keep the height of the cabinets the same as given in my article to take advantage of the low F3 of your woofers.

Please let me know how your project comes out.

IMAGE ENHANCEMENT

On seeing Mr. Reiber's letter in *SB*, 2/87 I looked through my "Image Enhancement" file accumulated over the last few years. While I haven't tried the arrangement he describes (using a second pair of "outside" mid-woofers to cancel crosstalk), I did some reading a few years back ("Stereo Enhancement," *Audio*, May 1983) and planning about this very arrangement. Responding to his question, I believe no time delay circuit would be required since it is already produced by the slightly greater distance from your ear to the outside speaker (*Fig. 1.*) That is, the R and −R signals must strike your *left* ear simultaneously for proper cancellation. Another important note is the crosstalk signal (e.g., R channel heard in the left ear) is *filtered* somewhat by traveling around your head. Hence, for proper cancellation, the same filtration should be applied to the −R signal. Usually this amounts to a gently decreasing high-frequency response. The bass of −R is usually rolled-off early as well because at long wavelengths (low frequencies) the cancellation has the effect of intefering with the main stereo signal as well.

An electronic time delay is necessary when you try to simulate the four-speaker effect (described above) by using only two speakers. In Carver's sonic Hologram device the −R signal is delayed slightly, filtered as described above, and mixed with the L signal before reaching one power amplifier (*Fig. 2.*).

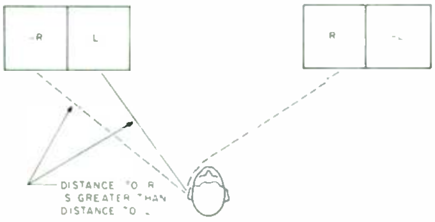

FIGURE 1: The arrangement in Carver's sonic Hologram.

Polk takes a slightly different approach, he uses L − R instead of −R to cancel the crosstalk. The advantage is that the bass need not be filtered out of the −R signal, since most low frequencies are nearly mono and are nonexistent in L − R (*Fig. 3.*) [*This is true for 45/45 grooved stereo long-play disks but not for compact disks where separation of the two signals is complete to 20Hz.—Ed.*]

In spite of the extra L signal, this approach seems to work well. Sound Concepts' IR2200 Image Enhancer simulates this approach using a time delay so only two speakers are required.

My personal conclusion was to purchase the Sound Concepts kit for $99. Although the four-speaker approach may be slightly more accurate, the electronic approach takes up less space. The effect only applies if you are seated facing forward directly sitting between the speakers. Anyone else in the room may find the "cancellation" signal confusing. For this reason I tend to use the image enhancer infrequently, and it is nice not to have the extra pair of unused speakers.

Another important realism factor is the reverberant response. If you have highly directional speakers or an acoustically "dead" listening room (such as an anechoic chamber), you would hear only the reverberant response of the recording site. This is "realistic." However, in most

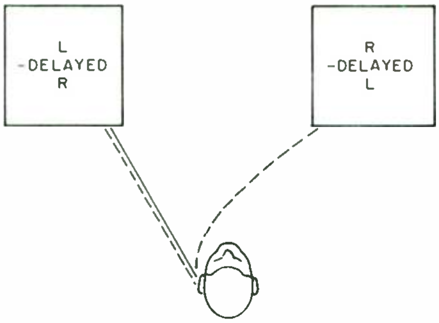

FIGURE 2: The −R signal slightly delayed, filtered, and mixed with the L signal.

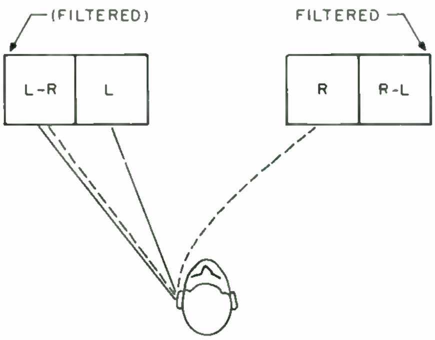

FIGURE 3: The Polk technique using L − R to cancel the crosstalk.

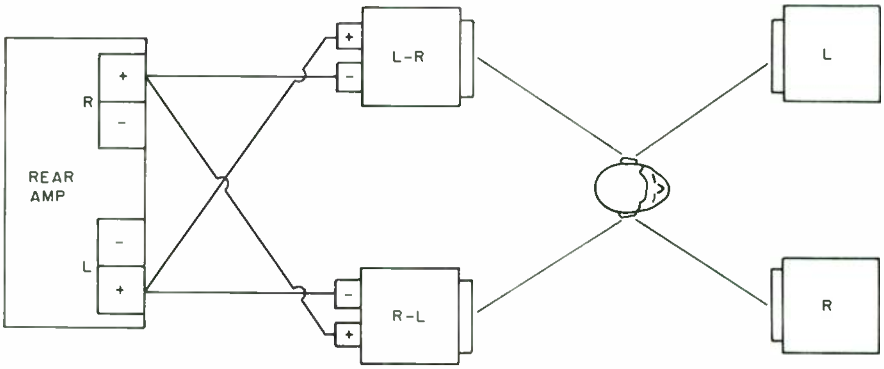

FIGURE 4: Rear speakers wired with L − R and R − L signal.

cases, you also hear the recording's reverberation in your listening room. This may prevent your ear from imagining it is in a large concert hall. Partial solutions are: (1) apply acoustic foam to your walls and carpet your floors heavily, and/or; (2) sit closer to your speakers to decrease the relative loudness of your room's response, and/or; (3) add more reverberation to your recording via a time delay/reverberation device. For (3), I have experimented with adding rear speakers wired as below, *Fig. 4*, since the L − R and R − L signal contains much of the reverberation of the recording. (Actually you can make do with a single rear speaker with L − R.) More sophisticated approaches to (3) are used in commercial units made by Sound Concepts and in the new Yamaha DSP-1 (reviewed everywhere in recent months).

Let me know if you find any of this useful and if you have any success.

The following articles may be useful: "Sonic Holography" *Audio*, March 1982, "Sound Concepts IR2200" *Radio Electronics*, June 1982, "Polk SDA" *Audio*, June 1984, "Image Enhancement" *Audio*, February 1985. (Their matrixing scheme is a little half-baked) "The IR2200 Stereo Image Expander," a review in *Audio Amateur*, 1/86.

Ralph Gonzalez
Philadelphia, PA 19143

COZY SONICS

The "near field" listening arrangement is too good to be ignored. I described it in my "Modified Daline" article, *SB*, 4/85 though in a somewhat compact style.

A marvelously lucid and convincing presentation of this arrangement appears in *Opus* magazine, April '87. The author, Peter W. Mitchell, wrote about it for the first time ten years ago in *The Boston Phoenix*. His article induced me to try it with particularly good results.

My best speakers for it are the DIY LS3/5a. In this arrangement they are sonic dynamite.

Carlos E. Bauza
San Juan, PR 00936

PRO SUPPLIER

I need a supplier of sound reinforcement cabinet hardware such as flush-mount handles, corner plates, and ¼" phono terminal cups. Any help will be appreciated.

Dan Wasmuth
Hope, AR 71801

GALO'S RICHTER

I congratulate Gary Galo on his excellent report on the Audio Control Richter Scale in *SB*, 2/87. I have owned a Richter Scale for some time and can second his recommendation on this useful component.

I would like to share my experience with you. My unit is an original model, different from Mr. Galo's in some respects, but the same in most. I made three modifications to mine, each of which effected an audible improvement.

First, I replaced all the 4136 op amps with Texas Instruments' TL-075 chips. Previously I used the TL-075, which is pin-compatible with the 4136 to improve a Jung rumble filter configured as a crossover with good results. Perhaps we could prevail on Old Colony to stock the TL-075 for amateurs wanting to modify circuits that have 4136s.

Second, I bypassed all electrolytic coupling capacitors and replaced all the Mylar capacitors in the crossover with polystyrene or polypropylene types. Originally my unit had two crossover frequencies which were switch selectable. This change is significant because if all of the original capacitors for both frequencies are removed, there is enough space to comfortably fit the larger new capacitors for one frequency. All I gave up was an unused second frequency. I have no idea whether the Richter Scale Series Three has enough space to make this modification, but if it does, it is well worthwhile.

I have some bad news and some good news about the third modification. The bad news is that it is rather extensive, involving cutting lands and adding wires to change the circuit topology. The good news is that the Series Three may not need it. Let me explain. In the original topology the signal entered the unit and passed through the equalizer, rumble filter, and all the other bells and whistles before being split in the crossover. The crossover was hard-wired to the previous section, with no provision for an external input to it.

The irony is the high frequencies had to pass through all of this circuitry in order to process the low frequencies. Since I do not like extra stages in the chain that do nothing, I modified the topology so the crossover is first, and the processing circuitry is attached to the output of the low-pass filter. This is particularly important because with a crossover of 100Hz most of the signal passes through minimum circuitry: an input buffer, and a high-pass filter.

From Mr. Galo's report, it appears Series Three has separate inputs to the crossover. If this is true, I suggest configuring a system as follows: connect the output of the preamp to the input of the crossover. Connect the high-pass output of the crossover to the input of the main amplifier. Connect the low-pass output of the crossover to the input of the equalizer. Connect the output of the equalizer to the input of the subwoofer amplifier. If this is possible, perhaps Mr. Galo would try it and let us know how it works.

My unit does not have a switch to mute the bass, so I use a modification of Procedure B for setup. I set the warble-tone generator to the crossover frequency, unplug the cables from the low-pass outputs, and adjust the system level so the meter reads 0dB. Then I plug in the low-pass cables and unplug the high-pass cables. I adjust the low-frequency level control until the meter reads 0dB.

In closing, I must say a warble generator is by far the best way I have found to adjust the balance between my subwoofer and the main speakers. I would go so far as to say that even if you do not need the crossover and equalizer, the warble generator's usefulness and the sound level meter in setting up a system alone justifies the price of a Richter Scale.

David W. Davenport
Raleigh, NC 27615

Mr. Galo replies:

Thanks for your letter and nice comments on my Richter Scale review. Your capacitor and op amp changes are exactly what is needed to raise the unit's performance level. My only additional suggestion (alluded to in the review), is to regulate the power supply. A low-impedance supply in combination with the changes you've made, should make the unit sonically worthy of the best associated equip-

ment. More on this in a moment.

Your third modification raises questions I dealt with when I evaluated the unit. I agree with you. I don't like putting unnecessary circuitry into the signal path either—particularly for the high frequencies. My initial inclination was to connect it as you described, so I phoned Audio Control and questioned them about it. They said the equalizer section of the unit was designed to receive tape output levels only, which are lower in level than a preamp's main output, and also independent of the volume control setting. Running the preamp's output into the equalizer section via the crossover raises the equalizer section's distortion level because of the slight overloading that may occur at high volume settings.

Your letter prompted me to investigate this further. My measurements indicate you should have no problem connecting the unit as you describe. The equalizer's clipping level is between 7.6 and 7.8V, measured at 20Hz, 100Hz and 1kHZ (the highest frequency likely to be passed to the equalizer from the crossover; most crossover frequencies will be well below this). Harmonic distortion just below clipping is .016% at 100Hz and .045% at 20Hz. Apparently the equalizer section is not prone to the overload problems Audio Control believes. Its performance seems identical to the crossover section. On this evidence, I recommend connecting the unit as you describe.

The supply voltages (which are ±13V in my sample) limit the clipping level of the equalizer and crossover. The maximum ratings for TL075 op amps are ±18V. When you replace the unregulated supply in the Richter Scale with a regulated supply of ±15 to ±16.5V, you raise the clipping and performance levels.

The space on the right hand side of the circuit board in the Richter Scale chassis is large enough to add a regulated supply. When you remove the power transformer, you free a space measuring approximately 3″ x 7″ x 2¾″. You cannot use Audio Control's transformer since the secondary voltages aren't high enough. Mount the new power transformer in an external box, then feed the secondary AC voltages to the rectifiers and regulators mounted in the free chassis space. The Gately supply circuit board (Old Colony KF-3) will fit here.

If you want more brute force regulation as in the Jung PAT-5/WJ1A preamp supply (TAA, 1/78, 3/79), the power transformer, rectifier bridges and input filter caps can be mounted in an outboard chassis. A parallel set of input filter caps, the regulation circuitry and the output filter caps can then be mounted in the free space in the Richter Scale chassis. With a judicious layout everything should fit. I did this in my own electronic crossover.

The Audio Control power supply schematic has two errors. The 22Ω resistors between the 470µF filter capacitors are not shown. The schematic shows the capacitors connected in parallel. The same error exists in both the positive and negative supply sections. The resistors labeled 22Ω, connecting the 470µF output filter caps to the zener diodes, should be labeled 2.2kΩ. Again, the same error is repeated for the positive and negative supplies.

Your procedure for setting the woofer level should produce exactly the same results as my Procedure B. I agree with your assessment of the worth of the Richter Scale; its value as a piece of test equipment alone justifies the expense.

PIPES, PETS & PORTS

About your TTT Test—I've been thinking of adding an equalizing circuit to reduce the roll-off.

I was quite interested in David Weems' cathouse—I mean tapered pipes, (but the man does seem to have a way with animals). I was interested because what he created must be a relative to a little system I designed and built last November. Undoubtedly I was anticipating Thanksgiving when the idea occurred to me to make a stuffed version of the Bose Acoustic Wave enclosure. I had inadvertently thrown away the article describing it, but as I recall it was a six foot pipe, open at both ends, with the speaker placed a third of the way from one end.

I decided to stuff the pipe to make it shorter and chose three feet. I placed the 4″ inch speaker 12″ in from one end. The cross section was about 25 square inches. I settled on a density of about .6 lbs/cu. foot.

Although I have spent very little time with this system, I hear natural sound similar to other Transmission Lines (TLs) I have built.

I made the pipe in a straight line and placed it in a horizontal position on a 27″ tall stool with the line about ¼ to ½″ from the back wall. The speaker is facing upward, as suggested by Roy Allison (a man who knows what he's talking about).

Mr. Weems and I both chose the same drivers for our projects, which appeared in the same issue of *SB*, 2/87. This should invite some comparisons. I have used these little units in many projects. Of all the Radio Shack drivers, the 40-1022 seems the most consistent, is also inexpensive and sounds good in a variety of applications. On a cost-for-sound basis they are high on my list.

The 40-1376 tweeter listed as ¾″, is really a ⅜″ tweeter. Its dispersion is exceptional, and in most rooms needs a diffraction ring to limit the dispersion and thus cut down on destructive room reflections. This unit is the closest thing I know of to a point source. It seems to be a silver colored version of the Audax Tw74.

About my project, the "Demonstrator," *SB*, 2/87 it isn't "a tiny double woofer" but a full-range system. This concept was created to help those trying to create woofers

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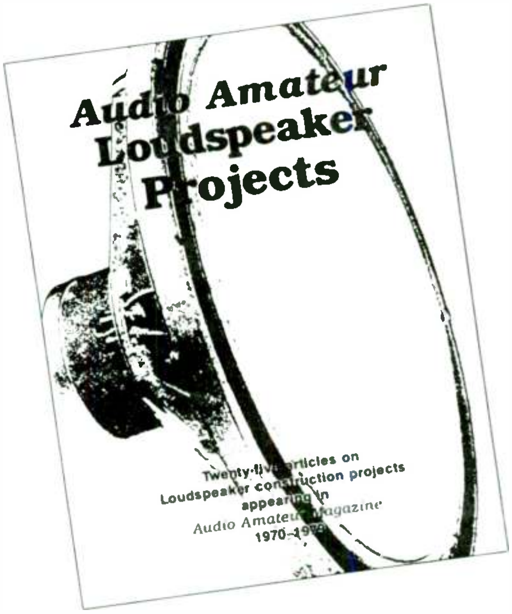

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OLD COLONY BOOKS PO BOX 243, Peterborough, NH 03458 and subwoofers, so I really have no quarrel with the way it was presented.

To get back to Mr. Weems' tapered pipes, the taper he uses is the reverse of the type generally used in TLs. It is actually more nearly a horn than a TL, whose function is to guide and lose the speakers' back radiation. I am reminded of the late Stewart Hegeman's split, conical slot loaded horns, made for Eico, Lowther, and for his own company. Of course they were different, but there may be a kinship. I have wondered how they might have sounded stuffed.

Just out of curiosity I would like Mr. Weems to place his line in a horizontal position to see whether he notices an improvement in the smoothness and solidity of the sound.

I don't understand his statement concerning the use of thinner material for undamped pipes (or maybe I just don't want to). I also believe his equation for optimum speaker placement is invalidated by stuffing only one side of his pipe. The stuffed side will appear longer. This is not a criticism, only a suggestion. Perhaps with a little more work he just might get out of the doghouse and produce a speaker system that is dog-gone good. And who knows, if he can find a long-haired cat he could even have dynamic damping! But leave the rabbits to Bruce Edgar.

John Cockroft
Mountain View, CA 94041

Mr. Weems replies:

Dynamic damping? Such a shameless suggestion must give "paws" lest the SPCA become involved. But I must admire such an original concept. It would surely catapult speaker design to a higher category of science. As to long-haired breeds, try Persian, it should work as well as rug padding.

In regard to your suggestion of putting tapered pipes in a horizontal position, 27" high, that would, of course, lower the driver and elevate the port. Unfortunately, having spent my time and energy in speaker experiments instead of more lucrative goals, my old house lacks enough wall space to do that without moving large pieces of furniture. And that would alter the acoustic environment. Room position always seems to be a major influence.

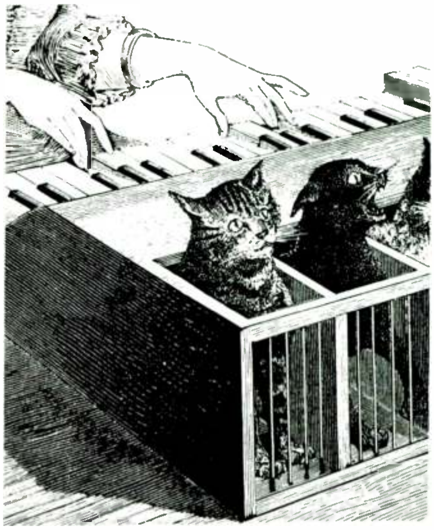
I agree with you on the two Radio Shack drivers, 40-1022 and 40-1376. They are better than most of the larger and more expensive models.

I think the tapered pipe owes something to Voigt's early designs. I'm not familiar with the internal anatomy of Hegeman's horns, but I remember the speakers.

Both sides of the pipe should be stuffed. The stuffing in the throat was not shown in the drawings, but it is specified in the article.

As to undamped pipes, I don't understand anything at all about them. Or maybe I just don't believe them. They were popular in England a generation ago and authors were adamant about using thin materials.

I still have my pipes for the 6½" Peerless woofer but, sad to say, I did not follow my own advice about screening the ports to keep critters out. The small pipe, for the 4½" woofer, became a mouse house. Even worse, a morgue. The mouse mother perished, perhaps by a heart attack induced by the high SPL. The death of the entire family followed but I didn't find the source of the odor until the pipe was saturated with it. The enclosure had to be burned. A Viking's funeral for the little fellows.



WARRANTY WOE

In Gary Galo's "Transmission Line Loudspeakers, Part II: Application" (*SB*, 2/82) he states, "Solder leads (*never* use slip-on speaker connectors!)"

In Audio Concepts instructions for its Quartz kit (which uses the excellent Dynaudio drivers) the builder is warned to use the slip-on connectors provided with the kit and *not* solder the speaker connections. Further, they state the warranty is void if the leads are soldered.

What gives? These are the only two instances I can recall addressing the question and they definitely are not in agreement.

I always soldered the connections until being warned against the practice in the Audio Concepts instructions. Help!

Dave Schneider
Marion, IA 52302

Audio Concepts is talking about warranty. Galo is talking about sound. Mr. Galo's advise is consonant with Walt Jung's advice on this matter. Audio Concepts, rightly, is being conservative in advising against a practice that, also rightly, voids a warranty. Of course, careless or inept soldering could damage a driver's leads where they attach to the cone. Galo's advice assumes prudence and care, as well as a desire for good sound that is more important than warranty cards.—Ed.

TTT TEST STANDARD

I enjoyed the TTT Test editorial (*SB*, 2/87) very much but I'm afraid you've opened the door on another forum of hot debate. Having considerable experience in this particular field, I'll jump in.

While I support your tissue theory and agree wholeheartedly with your preferred roll mounting methodology, we must remain open-minded, remembering there is always an occasional situation where what seems to be the norm becomes otherwise and a rolarity reverse is desired.

For example, when the roll's radius is larger than the distance between the center of the support roller and the lower frame of the mounting, and when the tissue is pulled down in the front, it causes a considerable drag coefficient. If reverse rolarity is applied, the action of the tissue being pulled from the back, and thus under the bottom of the roll, causes a lifting action to significantly reduce this drag.

Perhaps one of the more learned *SB* readers can supply a mathematical representation to explain this theory in more detail.

Another consideration for rolarity reversal happens in households where a playful feline paws the front of the roll and produces a large pile of soft paper on the floor. This is fun to roll and frolic in, and fun to drag to other rooms. Obviously, the reversal is called for here so when the feline paws the roll downward it will actually wind upward and the feline's interest will soon wane.

However, my personal preference is consonant with your editorial original reasoning.

Perhaps now would be the time to insure proper control of this challenge by making the off-the-top and down-the-front (OTTADTF) a recognized standard. With this in mind we may need to form a recognized organization to set such a standard before this gets out of hand. Shall we call it, The International Half Moon Society (IHMS), an organization to be made privy to the setting of such standards?

We must move quickly. Who knows? At this very moment someone may start marketing a vertical roll mounting for the home. You can readily see this could get out of hand in a hurry, and we all know what happens to a market flooded with conflicting formats with inadequate standards!

But I must stop writing. My cat just went into the bathroom. . . and I don't remember which way the roll is installed.

Rodney E. Cavin
Altamonte Springs, FL 32715-0507

Other readers having small anthropoids in the house also report a preference for the reversed roll mount, for reasons similar to those where kittens alter the equation. I trust the IHMS board of directors will place the issue of double-blind tests near the top of their agenda.—ETD.

LOUDSPEAKER DESIGN

continued from page 20

have some resemblance to practical reality. All in all, though, the results are gratifying.

I believe the spreadsheet approach's most important advantage is that it frees the model developer from many of the subtle annoyances of programming. Most of the work is spent developing the model from the applications standpoint. As a software engineer, it has long been my opinion that one of the worst things to have happened to engineering is the original birth and continued resuscitation of languages such as BASIC and FORTRAN. To have to learn the silly idiosyncracies of languages like these is tantamount to cruel and unusual punishment, and a spreadsheet goes a long way toward eliminating these problems.

ACKNOWLEDGEMENTS

Many of the actual algorithms were borrowed from the work Small and Margolis did for programmable calculators[5], but the general concepts, of course, owe their existance to Thiele, Small, Ashley and all the rest. The actual time to develop both the spreadsheet models and this article was ruthlessly stolen from my family.

REFERENCES

1. Thiele, A. N., "Loudspeakers in Vented Boxes," *JAES*, Vol. 19, May 1971, pp. 382–392; June 1971, pp. 471–483.
2. Small, R. H., "Direct Radiator Loudspeaker System Analysis," *JAES*, Vol. 20, June 1972, pp. 383–395.
3. Small, R. H., "Closed-Box Loudspeaker Systems, Parts I and II, "*JAES*, Vol. 20, December 1972, pp. 798–808; Vol. 21, January 1973, pp. 11–18.
4. Small, R. H., "Vented-Box Loudspeaker Systems, Parts I-IV *J AES*, Vol. 21, June 1973, pp. 363–372; July/August 1973, pp. 438–444; September 1973, pp. 549–554; October 1973, pp. 635–639.
5. Margolis, G and Small, R.H., "Personal Calculator Programs for Approximate Vented-Box and Closed-Box Loudspeaker System Design," *JAES*, Vol. 29, No. 6, June 1981, pp. 421–441.
6. Bullock, R. and White, R., "BOXRESPONSE: An Apple Program for the Thiele/Small Models," *Speaker Builder*, Vol. 5, No. 1, March 1984, pp. 13–18.
7. Lampton, M. L., "Program WOOF: A Numerical Evaluator of Loudspeaker Systems," *IEEE Transactions Audio Electroacoustics*, Vol. AU-20, December 1972, pp. 354–366.

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KK-3: THE WARBLER OSCILLATOR. [1:79] Switches, IC's, transformer and PC board for checking room response and speaker performance without anechoic chamber. Each **$62**

KL-6: MASTEL TIMERLESS TONE BURST GENERATOR. [2:80] All parts with circuit board. No power supply. Each **$22**

KM-3: CARLSTROM-MULLER LOG/LINEAR FUNCTION GENERATOR [2, 3:81]. The Sorcerer's Apprentice is a versatile swept function generator and forms the heart of an audio measuring system. The output frequency range is 20Hz–20kHz. A wide variety of outputs are possible. With the controls provided over 26,000 unique combinations may be obtained. Some uses are: testing amplifier overload characteristics, room and amplifier response, speaker damping, two-tone intermodulation and amplifier overload recovery. The article reprint included with the kit covers the design and use of the generator. The kit includes all parts except chassis and knobs. Power supply components and four circuit boards (two $2\frac{5}{16}$" × 5"; One each 2" × $2\frac{1}{8}$"; $2\frac{5}{8}$" × $3\frac{3}{8}$") are included.

This log response amplifier is designed to work with the Sorcerer's Apprentice function generator as part of an audio measurement system. The input is switchable between a 40dB microphone amplifier or a line input from an amplifier under test. The output section includes a switchable attenuator of six steps. A switch is also provided for displaying the log or linear signal from the microphone or other input.

The kit comes with two article reprints, which outline the design and use of the generator. It contains six circuit boards, all parts, including all necessary power supplies. No chassis or knobs included. The kit may be used with the KP-5 kit and/or KP-2 to make a unique and powerful audio test and alignment device. Each **$280**

SBK-D2 WITTENBREDER AUDIO PULSE GENERATOR. [SB 2:83] All parts, board, pots, power cord, switches and power supply included. Each **$77**

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SBK-C1A: JUNG ELECTRONIC TWO-WAY CROSSOVER. [SB 3:82] 30Hz filter with WJ-3 board & 4136 IC adapted as 1 channel crossover. Can be 6, 12 or 18dB/octave. Choose frequency of 60, 120, 250, 500, 1k, 2k, 5k or 10k. Each **$28**

SBK-C1B: THREE WAY, SINGLE CHANNEL CROSSOVER. [SB 3:82] Contains 2 each SBK-C1A. Choose high & low frequency. Each **$55**

SBK-C1C: TWO CHANNEL, COMMON BASS CROSSOVER. [SB 3:82] Contains two each SBK-C1A. Choose 1 frequency. Each **$60**

SBK-C2: BALLARD ACTIVE CROSSOVER. [SB 3,4:82] three-way crossover with variable phase correction for precise alignment. Kit includes PC board ($5\frac{3}{8}$ x $9\frac{1}{2}$"), precision resistors, polystyrene & polypropylene caps. Requires ± 15V DC power supply—not included. Can use KL-4A with KL-4B or C. Two channel **$140**

SYSTEM ACCESSORIES

KH-8: MORREY SUPER BUFFER. [4:77] All parts, 1% metal film resistors, NE531 ICs, and PC board for two-channel output buffer. Each **$18**

SBK-D1: NEWCOMB PEAK POWER INDICATOR. [SB 1:83] All parts & board. No power supply required. Two for **$11** Each **$7**

SBK-E2: NEWCOMB NEW PEAK POWER INDICATOR. [SB 2:84] All parts & board, new multicolor bar graph display; red, green & yellow LEDs for one channel. No power supply needed. Two for **$19** Each **$13**

KC-5: GLOECKLER 23-POSITION LEVEL CONTROL. [2:72] All metal film resistors, shorting rotary switch & two boards for a two-channel, 2dB per step attenuator. Choose 10k or 250kΩ. Each **$40**

KR-1: GLOECKLER STEP-UP MOVING-COIL TRANSFORMER. [2:83] Transformers, Bud Box, gold connectors, & interconnect cable for stereo. Each **$350**

KL-2: WHITE DYNAMIC RANGE & CLIPPING INDICATOR. [1:80] One channel, including board, with 12 indicators for preamp or crossover output indicators. Requires ± 15V power supply @ 63 mils. Single channel. Each **$54**
Two channels. **$108** Four channels. **$193**

What's Included? Kits include all the parts needed to make a functioning circuit, such as circuit boards, semiconductors, resistors and capacitors. Power supplies are not included in most cases. Unlike kits by Heath, Dyna and others, the enclosure, faceplate, knobs, hookup wire, line cord, patch cords and similar parts are not included. Step-by-step instructions usually are not included, but the articles in ***Audio Amateur*** and ***Speaker Builder*** are helpful guides. Article reprints are included with the kits. Our aim is to get you started with the basic parts—some of which are often difficult to find—and let you have the satisfaction and pride of finishing your unit in your own way.

SPEAKER COMPENSATION

continued from page 32

tered response. The data, processed as indicated, is shown in *Fig. 5*. You can see how the true behavior of the filtered response closely follows the electrical performance (*Fig. 3*).

Is driver impedance compensation worthwhile? For preventing amplitude response regularities, the answer appears to be "yes."

Since writing the article, I have built four speaker systems. Subjective evaluations of each system, with and without impedance compensation, always resulted in my strong preferance for the compensated system.

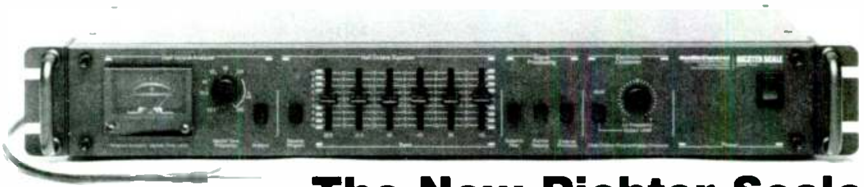
During these evaluations, I discovered another interesting effect: with some systems, further improvements resulted from increasing the value of the corresponding resistor.

WOOFER PERFORMANCE

continued from page 51

I am now using **Dynaudio D-28AF** and D-21AF tweeters in my TL-10 transmission line loudspeaker. These dome drivers are not cheap (around $33 each) but are worth the price. They are refined perfectionist drivers worthy of the finest loudspeaker systems. The D-21AF should not be operated lower than 5kHz. In my system it is crossed over at 10kHz, and thus operates as a super-tweeter. The D-28AF can operate as low as 2kHz. I operate mine between 3 and 10kHz. Since my system is tri-amplified with a 24dB/octave Linkwitz-type crossover, I employ a passive 6dB/octave crossover at 10kHz to cross the D-28AF to the D-21AF. If you purchase these drivers, be sure to specify the AF version. They have a flat flange, in contrast to the short horn loading format of those without the AF designation. The flat versions have a much flatter response than the horn-loaded units.

All the drivers discussed in this report (with the exception of the SEAS), are available from Madisound and Meniscus. The SEAS and Dynaudio drivers can also be purchased from Audio Concepts.



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TRADE

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LONG HAIR WOOL carded, cleaned for stuffing speakers. $13.50/lb. including shipping. ***J. EBBERT***, 431 Old Eagle School Rd., Strafford, PA 19087, (215) 687-3609. TTF

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FOR SALE

Unused pair of Strathearn ribbons without transformers. Suitable for Spangler/McKenzie modification, *SB* 3/85, $250. Dean Price, 1616 Millbrook SE, Grand Rapids, MI 49508, (616) 241-5324 evenings.

Klyne 2A pre-preamp, $400; Revox A-700, $995; Grado Signature 8MR (20 hours) cartridge, $100; Dynavector 17DR cartridge (30 hours), $200; KEF B139 woofers, $125; KEF T27 tweeters, $30; Philips 8" woofers, $20; Sequerra T-1 ribbon tweeters with crossover, $500; ADS 300i auto speakers, $125. Doug Robinson, 104 Lincoln Ave., Waterloo, NE 68069, (402) 779-2589 days, 779-2531 evenings.

Dale high power resistors: (14) 250W 4Ω, 1% non-inductive. Like new, $8 each. Chuck Hobrecht, 1574 Magpie Lane, Sunnyvale, CA 94087, (408) 733-9679.

Four Electro-Voice AT38 8Ω L-pad level controls with knob, dial and mounting hardware, $10 each; two Electro-Voice 8HD midrange horns, $12.50 each. Michael Beasley, 332 S. Calderwood, Alcoa, TN 37701, (615) 984-0748 before 5 p.m.

Klipschorn bass with 75Hz electronic crossover, bass mix, and 50W amp made by Dayton-Wright, $900; Dayton-Wright SPS-MK-II preamp, $250; Esterline-Angus paper-puller multi-speed recording milli-ammeter, $200. All in US dollars. B.O., FOB Toronto. Ben Barkow, (416) 653-9326.

Pair Tannoy Monitor Gold 12" loudspeakers, model LSU/HF/12/8, very good condition, $275 or best offer; Technics integrated amp, model SU7100, good condition, $100. Charles Mann, RR 2, Lively, Ontario, P0M 2E0, (705) 692-3693.

JBL 2404 tweeters, $225/pair; 25x29x41" horns and 2221 drivers, $400 (pick up); Edcore PA-250 mono amps, $350/pair; EV Sentry SEQ boost at 27Hz, $35. Steve, (203) 397-4965.

dbx model 224 tape noise reduction unit, mint condition, used less than 8 hours, includes rack mounts, $120; Dual CS-5000 turntable, brand new, (factory sealed), $349. Fred Janosky, (215) 693-6167 after 6:00 p.m.

Acoustilog Impulser device for speaker alignment, etc. Measures time-off set and requires triggered scope and microphone. Very accurate readings, $200; (3) Sennheiser ME-80 condenser shotgun microphones, $125 each or $330 for all three. Tom Young, (413) 586-3465.

B&K audio frequency spectrometer, type 2112 includes microphone, printer, $1,500 US dollars or best offer. Speaker City, 1599 W 4th Ave., Vancouver BC V6J 1L6, (604) 736-2077.

Two Dynaco output transformers, A-420; (2) A-431; (4) Mullard EL34/6CA7 matched tubes, $25 plus shipping for lot. V. Parker, 473 Chase Rd., Lunenburg, MA 01462, (617) 582-4204.

Hartley 24″ woofer in factory carton, $250. Dennis Green, 20039 Murray Hill, Detroit, MI 48235, (313) 836-7062 home, (313) 224-1813 office.

Two Altec woofers model 414-8C, 12″ with accordian surround and heavy cast frames. Ideal for ported enclosures, $100/pair plus shipping. Jeff Dames, 119 W. Walnut, #2, San Diego, CA 92103, (619) 543-9953.

Two Dynaudio D21-AF tweeters; two D54-AF midranges, two crossovers between high midrange; 12″ Dynaudio 30W54 MPS woofer, never used. All for $200 plus shipping. Two Goldrigger enclosures, walnut, $75 plus shipping. Emil Stan, 217 Glenview Dr., San Francisco, CA 94131, (415) 550-2624.

WANTED

Audio Research SP-6/SP-8 circuit board left over from Curcio Daniel modification. Mike, PO Box 82566, San Diego, CA 92138, (619) 463-6272.

Would like to hear from anyone who has replaced original paper drivers in a 1970 Empire Grenadier three-way column system with a down firing 10″ woofer. Write to William Miles, 373 Borough Line Rd., Trappe, PA 19426.

Wanted to buy and or obtain circuit diagram for Stax SRA-4S/6S (OTL phone amp) as well as Stax SRA-3S hybrid OTL amp. M.J. Campbell, 2011-107 Ave. SW., Calgary, Alberta Canada T2W 1V6.

Dynaco Mark VI vacuum tube amps or parts, complete or incomplete kits. Need badly output transformer and choke. Will pay top dollar. Jeff Goldman, (215) 628-2000 during working hours.

I would like to upgrade the output capacitors in a Yamaha R-50 35W receiver. If any *SB* readers are familiar with this receiver I would appreciate hearing from you. Mark Thompson, 194 St. David Rd., St. Catharines, Ontario L2T 1R4.

Pioneer SF-850 electronic crossover network. Tim Eding, 2113 Charger Dr., San Jose, CA 95131, (408) 923-6953 evenings.

One Wharfedale 15″ woofer, model W15FS, must be in good condition. J. John Dilworth, FP 55 M.A. Costalo St., Levittown Lakes, PR 00949, (809) 784-7675 anytime.

Dynaco C-100 energy storage (cap) banks for ST-416 amp. Will pay top dollar. Jeff Goldman, (215) 628-2000 during working hours.

Working Eico 2050 tube amp, kit or factory model. John White, 910 Ash, Burlington, IA 52601, (319) 753-2957.

CLUBS

Space in this section is available to audio clubs and societies everywhere free of charge to aid the work of the organization. Copy must be provided by a designated officer of the club or society who will be responsible for keeping it current. Send notices to Audio Clubs in care of the magazine.

THE CONNECTICUT AUDIO SOCIETY is an active and growing club with activities covering many facets of audio—including construction, subjective testing and tours of local manufacturers. New members are always welcome. For a copy of our current newsletter and an invitation to our next meeting, write to PO Box 346, Manchester, CT 06040 or call Mike at (203) 647-8743.

SAN FRANCISCO BAY AREA AUDIOPHILES. Audio constructors society for the active, serious music lover. We are dedicated, inventive and competent. Join us in sharing energy, interest, expertise and resources. Send self-addressed, stamped envelope to S. Marovich, 300 E. O'Keefe St., Palo Alto, CA 94303 for newsletter.

THE BOSTON AUDIO SOCIETY INVITES you to join and receive the monthly B.A.S. SPEAKER with reviews, debates, scientific analyses, summaries of lectures by major engineers. The BAS was the first to publish info on TIM, effects of capacitors, tonearm damping, tuner IM distortion, Holman's and Carver's designs, etc. Sample issue $1, subscription $16/yr. PO Box 7, Boston, MA 02215.

CENTRAL FLORIDA AUDIO SOCIETY meets monthly in Orlando. Come and meet others who share your interest in music reproduction as we audition equipment and recordings or discuss audio related topics. Contact Ron Deak, 2404 S. Conway Rd., #162, Orlando, FL 32806, (305) 894-6784.

THE AUDIO SOCIETY OF HONOLULU cordially invites you to attend one of our monthly meetings and meet others like yourself who are interested in the how's and why's of audio. Each meeting consists of a lively discussion topic and equipment demonstrations. For information on meeting dates and location, contact Craig Tyau, 2293A Liliha St., Honolulu, HI 96817.

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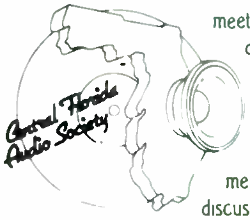

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THE NEW YORK AUDIO SOCIETY meets monthly with prominent guest speakers, discussions and demonstrations of the latest equipment. Its $20 annual membership dues includes a subscription to S/N, the society's quarterly publication. For a free invitation to our next meeting, call (212) 544-1222, (212) 289-2788 or (201) 647-2788 or write us at PO Box 125, Whitestone, NY 11357.

NEW JERSEY AUDIO SOCIETY meets monthly with the emphasis on construction and modification of electronics and speakers. Individuals at any level of electronics expertise are invited to join. Contact Bill Donnally, (201) 334-9412 or Bob Young, (201) 381-6269, 116 Cleveland Ave., Colonia, NJ 07067.

PACIFIC NORTHWEST AUDIO SOCIETY (PAS) consists of 50 audio enthusiasts meeting monthly, second Wednesdays, 7:30 to 9:30 p.m. at 4545 Island Crest Way, Mercer Island, WA. Be our guest, write Box 435, Mercer Island, WA 98040 or call Bob McDonald (206) 232-8130.

AUDIOPHILES IN CENTRAL PENNSYLVANIA (also eastern Pennsylvania and Delaware): Interested in forming a serious audio organization? Contact Steve Gray, 625F Willow St., Highspire, PA 17034 or phone (717) 939-4815.

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WOULD LIKE TO CONTACT experienced home builders of audio equipment in the southern Ontario area. I have built the Marsh preamp and head amp...they sound great. T. B. Palmer-Benson, RR 1, Ariss, Ontario N0B 1B0, (519) 837-3964.

THE ESOTERIC AUDIO RATING SOCIETY (usually known as EARS) is San Antonio's premier audio club. Its members consist of audiophiles and music lovers who share a mutual interest in enhancing their enjoyment of recorded music. EARS meets bimonthly and has been fortunate to offer interesting presentations on audio, recordings and music. The club also has an on-going project of recording local concert activities for radio broadcasts or other purposes. Additionally, EARS is currently trying to launch a club newsletter. Anyone interested in finding out more about EARS should write to the following address to obtain information on the next meeting date and location. EARS, PO Box 27621, San Antonio, TX 78227.

SAINT LOUIS AUDIO SOCIETY meets monthly for discussion and equipment audition. For information sheet send a stamped, self-addressed envelope to SLAS, 7435 Cornell, Saint Louis, MO 63130.

AUDIOPHILES IN THE NEW JERSEY and STATEN ISLAND areas interested in forming a club please contact Joe at PO Box 1588, Staten Island, NY 10314, (212) 698-2280.

TORONTO AREA AUDIO SOCIETY formed. Serious audiophiles contact Neelam Makhija (416) 842-2606 or John Sloan (416) 532-4387.

THE ATLANTA AUDIO SOCIETY started in October 1983 and has regular meetings on the third Sunday of each month as well as special programs with leaders in the industry, such as Mr. William Conrad of Conrad-Johnson and Mr. William Johnson of Audio Research. We are currently looking for additional members in the Southeast. All members receive the minutes of each meeting and program, as well as other relevant announcements and correspondence. For full information and membership packet, write Atlanta Audio Society, PO Box 92130, Atlanta, GA 30314, or call Howard Royal in Newnan, GA at (404) 253-6419.

WASHINGTON AREA AUDIO SOCIETY and CONSTRUCTORS CLUB (DC, MD, N. VA) in the process of formation. If interested, please contact Horace J. Vignale, 1540 Northgate Sq., #31B, Reston, VA 22090.

SARASOTA AUDIOPHILES interested in forming a club—write to Mark Woodruff, 5700 N. Tamiami, Box 539, Sarasota, FL 33580.

WASHINGTON, D.C. AREA AUDIOPHILES interested in forming an audio club please contact: Joseph Kmetz, 9861 Goodluck Road, Apt. #10, Lanham, MD 20706 or call days (301) 794-7296, eves. (301) 585-3186.

LONG ISLAND AUDIOPHILES: The Audio Syndrome is a Nassau/Suffolk county club dedicated to the pursuit of sonic excellence. Monthly meetings. Fred Masters, (516) 589-4260 or (516) 271-4408.

A CLUB FOR FM AND TV DXers, offering antenna, equipment and technique discussions, plus updates from FCC on new station data. Monthly publication "VHF—UHF Digest." Annual convention in August. For more info: Worldwide TV-FM DX Association, PO Box 97, Calumet City, IL 60409.

THE VANCOUVER AUDIO SOCIETY publishes a monthly newsletter with technical articles, humor and news of interest to those who share our disease. We have 50 members and meet twice every month. Dues are $15/year, which includes 12 newsletters ($15 US outside Canada). Write to the VAS c/o the Secretary-Treasurer, Box 4265, Vancouver, BC, Canada V6B 3Z7. We would like to be put on your mailing list.

THE COLORADO AUDIO SOCIETY is a group of audio enthusiasts dedicated to the pursuit of music and audiophile arts in the Rocky Mountain region. We offer a comprehensive annual journal, five bimonthly newsletters, plus participation in meetings and lectures. Membership fee is $10 per year. For more information, send SASE to: CAS, 4506 Osceola St., Denver, CO 80212.

AUDIOPHILES in the **RIVERSIDE-SAN BERNADINO** areas to form an audio club. Contact Frank Manrique, 1219 Fulbright Ave., Redlands, CA 92373, (714) 793-9209.

AUDIOPHILES IN YUGOSLAVIA interested in starting a Yugoslavian audio society contact JAS, Likob Matjaz, Stefanovaga, 61000 Ljubliana, Yugoslavia.

SERIOUS AUDIOPHILES interested in a **CENTRAL COLORADO** group (Denver, Boulder, Ft. Collins, Greeley area) contact James S. Upton, 2631 17th Ave., Greeley, CO 80631.

HI-FI CLUB OF CAPE TOWN, South Africa, issues newsletter monthly for its members and subscribers. Since our audio problems are the same as yours, we'd like to hear from you. Send 2 I.R.C.s for next newsletter ($16/year) to PO Box 6685, Roggebaai 8012 South Africa.

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Old Colony Sound Lab's

BOOK SERVICE

BKAA2 THE LOUDSPEAKER DESIGN COOKBOOK (3rd ED) *by Vance Dickason.* Everything you need to build the loudspeaker system you have always wanted but could not afford. Easy ways to pick the exact box size, the ideal drivers, the most pleasing finish and the correct way to feed your music to your new superb loudspeaker system. Proven designs, where to buy low cost parts and how to test the results for yourself. 75pp., softbound, 8½x11. Each **$14.95**

D-1 REPRODUCTION OF SOUND *by Edgar Villchur.* An elegantly simple 92-page paperbound primer on the subject by the man who invented the bookshelf speaker. Loan or give it to friends who want to build a system as good as yours. Each **$6.00**

D-3 MUSIC, PHYSICS AND ENGINEERING *by Harry F. Olson.* A thorough introduction to the physical characteristics of sound and the relationship of sound to musical instruments by the former head of staff at RCA's lab for acoustical and electromechanical research at Princeton, NJ. A classic by one of the giants in the audio field. Good, easy to read chapters on acoustics, mikes and recording, recording and playback systems, as well as an electronic music chapter. 2ND ED. (1967) 460pp., softbound. Each **$14.25**

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