A MUSICIAN BUILDS HIS FAVORITE SPEAKER

EIGHT: 1996

US$7.00
CANADA $8.00

# Speaker Builder

THE LOUDSPEAKER JOURNAL

## HOW TO GET SYSTEM PHASE ABSOLUTELY RIGHT

ANDY LEWIS

## Testing And Setup For The Miracle 3-Way

G.R. KOONCE & R.O. WRIGHT

## Building A Subwoofer Test Box

BILL FITZMAURICE

SYSTEM DESIGN WITH *TOPBOX*


D6G
Nominal Impedance(Z):5Ω
Resonance Frequency(Fs):47Hz
Sensitivity(F):85dB
Voice Coil Diameter:76 mm
DC Resistance(Re):4.5Ω
Voice coil Length:14.5mm
Force Factor(BL):6.5N/A
Linear Excursion(Xmax):5.5mm
SUSPENSIONCOMPLIANCE:(Cms):690uM/N
Mechanical Q Factor(Qms):5.3
Electrical Q Factor(Qes):0.54
Total Q Factor(Qts):0.49
Moving Mass(Mms):16.3g
Effective Piston Area(Sd):109cm²
Equivalent Air Volume(Vas):11.6L
Hi-Vi RESEARCH®
100 SPY COURT, MARKHAM, ONTARIO L3R 5H6
TEL:001-905-475-3100, FAX:001-905-475-8226

# Good News

## ■ A WOOFER TO WATCH

Model 162 PBM is a vented-box powered subwoofer from Atlantic Technology International. With a built-in 75W power amplifier and 8″ long-throw polypropylene driver, the 162 PBM boasts a 20Hz–150Hz operating range; a 24dB/octave low-pass filter, which is variable between 60Hz–150Hz; and frequency response of 30Hz–270Hz at ±6dB. The tower-style 162 PBM meets UL/CSA and European safety standards with its externally switchable 120/240V AC power supply, external fuse holder, IEC AC power socket, and detachable power cord. For the dealer nearest you, please call Atlantic Technology International, 343 Vanderbilt Ave., Norwood, MA 02062, (617) 762-6300, FAX (617) 762-6868.

***Reader Service #105***

## ■ IT'S WHAT'S INSIDE THAT COUNTS

Xecon Technologies' Letros model L-105 is a complete audio system, including eleven miniature speakers and four amplifiers, inside of a hand-crafted solid-oak lectern. Cordless operation is enabled by a rechargeable battery pack, providing twelve hours of use. Boasting 270° of sound distribution, the L-105 is designed for an audience of up to 250 with a slim-line microphone; volume, bass, treble, and power controls; a built-in reading light; and a light display indicating the ideal volume of speech. Xecon Technologies Inc., 819 Yonge St., Toronto, ON, Canada M4W 2G9, (416) 967-5050, FAX (416) 960-5435.

***Reader Service #103***

## ■ B+K PRECISION IN A DMM

B+K Precision's Model 2880 digital multimeter (DMM) with an RS-232 interface comes complete with computer software and hook-up cable, a rubber holster, test leads, and instruction manual. With a selectable measurement interval from 1–999 seconds, the 2880 offers an LCD display with 4,000 count resolution, analog bargraph, and the capability to display minimum, maximum, and preset readings or AC voltage and frequency simultaneously. This DMM measures DC voltage to 1kV at 0.3% accuracy, AC voltage to 750V and 20kHz, and AC and DC current to 10A, as well as continuity, diode test, frequency, and capacitance. B+K Precision, 6470 W. Cortland, Chicago, IL 60607-4098, (773) 889-1448, (773) 794-9740.

***Reader Service #104***

## ■ UNIQUE Q-SERIES

KEF Audio's Q-series of shelf- and floor-standing speakers comprises six new models: the Q15, Q95C, Q35, Q55, Q65, and Q75. Each unit employs KEF's Uni-Q driver, a design incorporating a ¾″ soft-dome tweeter, which is cooled by ferrofluid liquid and located at the apex of a polypropylene midrange/woofer. All Q-series speakers, housed in slim, furniture-quality structures, are magnetically shielded for use in musical and home-theater setups. KEF Electronics of America, Inc., 89 Doug Brown Way, Holliston, MA 01746, (508) 429-3600, FAX (508) 429-3699.

***Reader Service #102***

## ⊂ BANDORA AND MORE-A

The Bandora compact two-way speaker system, offered by Bandor Miniature Loudspeakers, features two full-range, metal-coned speakers. For use with amplifiers up to 120W, the Bandora speakers are enclosed in low-coloration cabinets of 25mm MDF, accentuated by an angled front panel, polymer damping, and finished wood veneer. Bandor's Mora serves both as a stand for the Bandora and as a bass system, providing a 125Hz active-crossover unit, an equalization network, and aluminum-cone drivers mounted back-to-back. Bandor Miniature Loudspeakers, 11 Penfold Cottages, Penfold Ln., Holmer Green, BUCKS, UK HP15 6XR, phone/FAX (+44) 1494-714058.

***Reader Service #101***

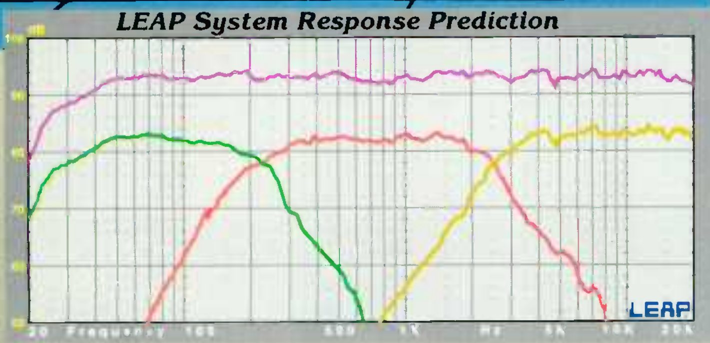


*Reader Service #36* →

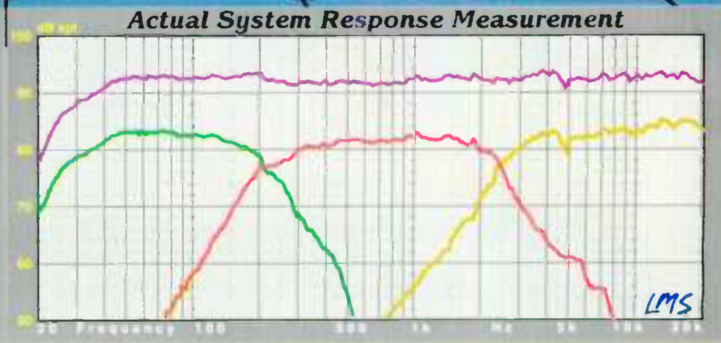
New! LEAP *Version 4.5*

# Precision Development Tools for Precision Loudspeaker Designs

LEAP System Response Prediction




Actual System Response Measurement



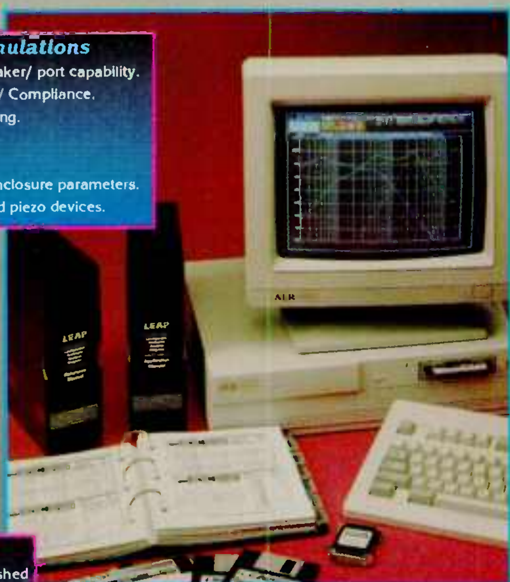

**The Art and Science...** of loudspeaker system development today has become more complex than ever before. Competition is tough, and to compete each design must perform to the best of its ability, and make the most out of every dollar's worth of transducer cost. The simple approach of choosing a combination of seemingly appropriate transducers coupled with ordinary networks and filters, has given way to a painstaking process of meticulously blending selected transducers in combination with carefully devised and matched crossover designs.

■ Seminars/Workshops available, call for details.

**LEAP** (Loudspeaker Enclosure Analysis Program) is a complete full range analysis package which provides virtually *all* of the tools necessary to develop precision loudspeaker systems, for today's demanding audio markets. Whether your applications are consumer audio, car stereo, professional audio, or custom esoteric marvels, LEAP provides the power, flexibility, and accuracy to investigate every possible design permutation. The open architecture and broad spectrum of features provided will dramatically reduce your development time, while improving the quality of the final result... and demonstrates why LEAP has become the #1 choice of professional loudspeaker designers world-wide!

### Advanced Transducer/Enclosure Simulations

- ✔ Sealed, Vented, Bandpass, PR Simulations with multiple speaker/ port capability.
- ✔ Large signal analysis of TempVC, and Non-Linear BL/ Ports/ Compliance.
- ✔ Acoustic Parallel or Acoustic Series (Isobaric) Driver Mounting.
- ✔ Port Standing Wave resonance modeling.
- ✔ Frequency Dependent Revc and Levc modeling.
- ✔ Library storage of 36 transducer parameters, and over 24 enclosure parameters.
- ✔ Generic transducer modeling of electro-dynamic, ribbon, and piezo devices.



### Advanced System Analysis Features

- ✔ Use simulation or imported actual measured SPL/Z data.
- ✔ 5-Way crossover system modeling, and more.
- ✔ Time offset between transducers.
- ✔ Active or Passive based crossovers.
- ✔ Hilbert-Bode transform for deriving phase.
- ✔ 22 Passive components per xover section.
- ✔ 16 Active filter blocks per xover section.
- ✔ Passive Network Optimizer for single/system response.
- ✔ Active Filter Optimizer for single/system response.
- ✔ Frequency ranges from 1Hz to 100kHz.

### Extensive Documentation

The two volume manual set comprises almost 1,000 pages of documentation which thoroughly covers the operation of the program and provides numerous examples of how to maximize your use and understanding of the program's many features. The Reference Manual describes all graphs, menus, commands, and their operation. This manual explains the unique and special non-linear speaker and port models, as well as proper use of the optimizers, importing data, and the many other utilities. The Application Manual provides many exciting examples showing how to use the powerful features of the system in a combined manner to perform both simple and complex design tasks. Both novice and experienced users alike will find this information invaluable for exploiting the full power of the system. Additional information is also provided on loudspeaker measurements, design tips, filter calculations, and complete crossover system development for both passive and active based systems.

✔ 502 Page Reference Manual ✔ 436 Page Application Manual

### Printer/Output Formats

When you wish to produce a hardcopy output of your finished designs and graphical data, LEAP supports a large number of printer standards, and even supports numerous desktop publishing graphic formats in both black & white and color! Portrait/Landscape orientations in any custom size and aspect ratio are user controllable.

- ✔ IBM/Epson 8 Pin Dot Matrix
- ✔ Epson 24 Pin Dot Matrix
- ✔ HP LaserJet Series Printers
- ✔ HPGL Compatible Plotters
- ✔ PostScript EPS/TIF- B&W,Color
- ✔ AI-Adobe Illustrator B&W,Color
- ✔ NEC 24 Dot Matrix
- ✔ TOSHIBA 24 Dot Mat
- ✔ HP DeskJet 500C
- ✔ PostScript Printers
- ✔ DXF AutoCAD
- ✔ TIFF, BMP, PCX Plots

**Call for a free Demo Disk!**
**TEL: (503) 620-3044**

### Development Utilities

- ✔ Quick Cabinet Box Designer
- ✔ Conjugate Network Designer
- ✔ Wire Table Calculator
- ✔ Multi-Curve Averager
- ✔ Import Data from ASCII Files
- ✔ Crossover Network Designer
- ✔ Spkr Parameter Measurement
- ✔ Voltage/Current/Imp Calculator
- ✔ Motor Constants Calculator
- ✔ Export Data to ASCII Files

LINEARX ™


LinearX Systems Inc 7556 SW Bridgeport Road Portland OR 97224 USA Tel (503) 620-3044 Fax: (503) 598-9258


**International Dealers** **Agentina** [illegible]erface SRL (54-1)741-1389/**Australia**:ME Technologies 61(0)65-50-2200/**Austria**:Audiomax 49(0)71-31-162225 **Belgium** [illegible] **Canada** [illegible] 416-696-2779 **Denmark Finland**:A&T Ljudproduktion 46(0)8-623 08 70/**France**:Belram 32(0)2-736-50-00/**Germany**:Audiomax 49(0)71-31-162225/**Indonesia** Ken's Aud[illegible] **Italy** [illegible] 39 30 3581341 **Korea** Sammi Sound 82(02)463-0394/**Luxembourg**:Belram 32(0)2-736-50-00/**Malaysia**:AUVI 65-283-2544/**New Zealand**:ME Technologies 61 65 50 2254 **Norway** A&T Ljudproduktion 46(0)8 623 08 70 **Philippines** Daiichi Denshi (63) 2631 69 80/**Poland**:Inter Americom 48(22)43-23 34/**Singapore**: AUVI 65-283-2544 **Sweden**:A&T Ljudproduction 46(0)8 623 08 70 **Switzerland** Audiomax 49 71 31 162225 **Taiwan** Gest[illegible] Taycan Intl 886-2 786 3468 **Thailand**:AUVI 65-283-2544/**The Netherlands**:Duran Audio 31-41-80-15583/**UK(England)**:Munro Assoc 44(0)171-403-3808

# Speaker Builder®

## The Staff

Editor and Publisher
**Edward T. Dell, Jr.**

Regular Contributors
**Joseph D'Appolito** **Robert Bullock**
**Richard Campbell** **John Cockroft**
**Vance Dickason** **Bruce Edgar**
**Gary Galo** **G.R. Koonce**
**Richard Pierce** **Bill Waslo**

Vice President
**Karen Hebert**

**Dennis Brisson** Assistant Publisher
**Swain Pratt** Associate Editor
**Courtney E. Howard** Assistant Editor
**Karen Chivallati** Editorial Assistant
**Linda Cardone** Graphics Director
**Diane Luopa** Assistant Graphics Director
**Joan Ahern** Production Assistant
**Gary Duke** Production Assistant
**Laurel Humphrey** Marketing Director
**Robyn Lasanen** Circulation Manager
**Doris Hamberg** Customer Service Supervisor

### Advertising Rates & Schedules

**Peter B. Wostrel** National Advertising Director
**Linda M. Guyette** Advertising Sales
**Lisa DiRusso** Advertising Coordinator
**Barbara Morris** Advertising Assistant
**(603) 924-7292** **FAX (603) 924-9467**


***The peculiar evil of silencing the expression of an opinion is, that it is robbing the human race; posterity as well as the existing generation; those who dissent from the opinion, still more than those who hold it.***

John Stuart Mill


*Speaker Builder* is published eight times a year in the interest of high-quality audio reproduction.





### Subscription Inquiries

A one year subscription costs $32. Canada please add $8. Overseas rate is $50 per year.

To subscribe, renew or change address write to the Circulation Department (PO Box 494, Peterborough, NH 03458-0494) or telephone (603) 924-9464 or FAX (603) 924-9467 for MC/Visa/Discover charge card orders. **E-mail: audiotech@top.monad.net.**

For gift subscriptions please include gift recipient's name and your own, with remittance. A gift card will be sent.

### Editorial Inquiries

Send editorial correspondence and manuscripts to *Speaker Builder*, Editorial Dept., PO Box 494, Peterborough, NH 03458-0494. **E-mail: audiodiy@top.monad.net.** No responsibility is assumed for unsolicited manuscripts. Include a self-addressed envelope with return postage. The staff ***will not*** answer technical queries by telephone.




# About This Issue

Before the door closes on 1996, we must take a moment to recognize the contributions of the many authors who have provided this year's reading enjoyment for *SB* readers. Their efforts, insights, and designs have helped to make 1996 a banner year. We thank them for sharing their experiences and knowledge and look forward to more contributions in the new year.

We continue this tradition of speaker-building excellence as **Jesse W. Knight** shows you how to build the box for his woofer/midrange/tweeter design. His project is well-suited for the beginner, since port tuning and variation considerations are kept to a minimum. You have your choice of several designs using 10″ or 12″ drivers, sealed or ported versions, any one of which promises to be an inexpensive solution to harsh-sounding systems ("A Musician's Speaker," p. 10).

Is your multiway system out of phase, resulting in a dramatic loss of balance? **Andy Lewis**'s simple phase tester helps you to accurately measure time alignment data. The author demonstrates how this simple, inexpensive device measures phase differences between drivers to achieve phase linearity in your multi-speaker design ("A Simple Phase Tester," p. 16).

**Bill Fitzmaurice**, with his "series-vented" design, once again exhibits a talent for design based on imagination and experience, rather than computer-aided design ("An Eight-Inch Subwoofer Test Box," p. 28).

We couldn't end 1996 without bringing to a conclusion the magical multiway speaker system by **G.R. Koonce**. We've discussed its design and construction; so, how does it sound? Part 3 answers this question—with Bob Wright and Ed Dell's descriptions and aural reactions to this sweet-sounding system—and examines the effects of grille frame and cloth on tweeter performance ("A Modest-Cost Three-Way Speaker," p. 34).

With the introduction of the TopBox loudspeaker modeling program, Mac users needn't take a back seat to the IBM masses. Designed by big-name talent in the loudspeaker design industry, this easy-to-use program calculates and graphs design responses ("Software Review," p. 45).

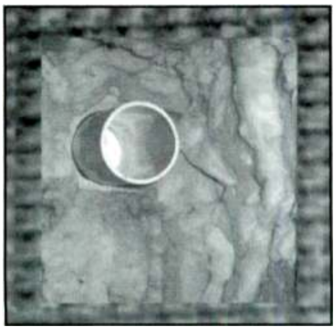

*Speaker Builder* (US USSN 0199-7929) is published every six weeks (eight times a year), at **$32** per year, **$58** for two years; Canada add $8 per year; overseas rates **$50** one year, **$90** two years; by Audio Amateur Corporation, Edward T. Dell, Jr., President, at 305 Union Street, PO Box 494, Peterborough, NH 03458-0494. Periodicals postage paid at Peterborough, NH and an additional mailing office.

**POSTMASTER:**
**Send address change to:**
Speaker Builder, PO Box 494
Peterborough, NH 03458-0494

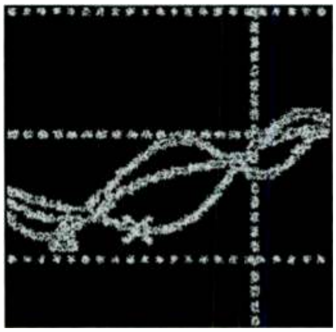
# Speaker Builder

THE LOUDSPEAKER JOURNAL

VOLUME 17 NUMBER 8 DECEMBER 1996

10



34



## DEPARTMENTS




**KEEP IN TOUCH**

**EDITORIAL** — Send letters, questions, and comments to: Speaker Builder, Editorial Dept., PO Box 494, Peterborough, NH 03458 USA, FAX (603) 924-9467, E-mail: audiodiy@top.monad.net.

Be sure to reference the issue, title, author, and page number of the article or letter in question; and if you request an answer from an author, please include a self-addressed envelope (and your FAX number and/or E-mail address, if applicable), with a loose stamp or postal coupon.

Due to the volume of correspondence, we cannot personally acknowledge or respond to each letter or query. All letters to the editor will be considered for publication unless you indicate otherwise. *Speaker Builder* reserves the right to edit your letters or technical queries for length and clarity.

Author guidelines are available by sending a self-addressed envelope with loose postage to the above address.

**CIRCULATION** — For subscriptions, renewals, back issues, or address changes, write to the Circulation Department (PO Box 494, Peterborough, NH 03458) or call (603) 924-9464 or FAX (603) 924-9467. E-mail: audiotech@top.monad.net.

**ADVERTISING** — Address advertising inquiries and information requests to the Advertising Department, Audio Amateur Corporation, PO Box 494, Peterborough, NH 03458-0576, voice (603) 924-9464 or 1-800-524-9464, FAX (603) 924-9467.

**OLD COLONY SOUND LAB** — For product information and ordering, contact Old Colony Sound Laboratory, PO Box 243, Peterborough, NH 03458-0243, voice (603) 924-6371 and (603) 924-6526, FAX (603) 924-9467.

# Good News

### ■ CAN'T STAND YOUR AUDIO RACK?

Euro Furniture audio equipment stands, offered by Sanus Systems, are available in audio and audio-video widths of 22″ and 40″, respectively. The open-architecture design isolates parts and prevents overheating, and the columnar sandwich construction ensures rigidity and damping. These modular/stacking furniture systems, constructed of steel supports and heavy composite shelving, come standard with adjustable carpet spikes and a wire-management path. Sanus Systems, 619 W. County Road E., St. Paul, MN 55126, www.sanus.com, (800) 359-5520, FAX (612) 636-0367.

***Reader Service #107***

### ■ RIBBON HYBRID

Newform Research has announced release of the R8-1-30, a ribbon hybrid with a new-technology 30″ mono-polar ribbon and 8″ poly mid-bass. The R8-1-30 is a full-range system for use in high-resolution stereo and home-theater systems. Its 88dB sensitivity allows it to match well with any amplifier of 30–150W per channel in average-to-large rooms. With solid response down to below 30Hz, it requires no subwoofer. Assembly time is ten minutes per side. Newform Research, Inc., P.O. Box 475, Midland, ON L4R 4L3, Canada, (705) 835-9000, FAX (705) 835-0081.

***Reader Service #110***

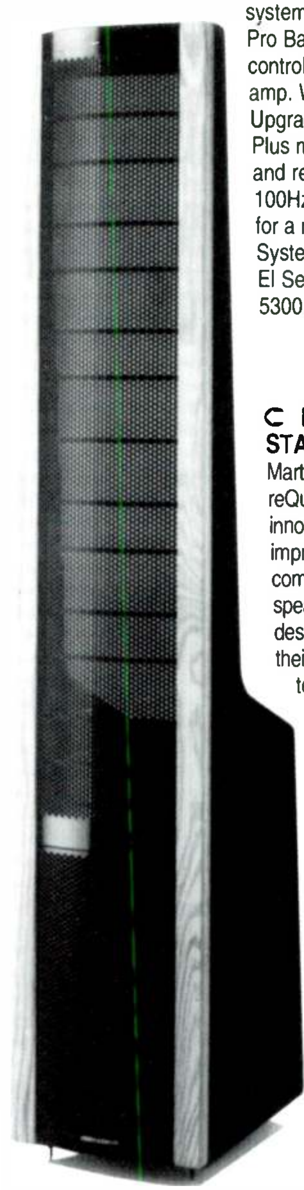
### ■ LOUDSPEAKER DESIGN CHALLENGE II

The West Michigan Chapter of the Audio Engineering Society announces its second Amateur Loudspeaker Design/Construction contest, open to anyone who is not a "professional" loudspeaker designer, builder, or employee in the industry. The blind listening tests will be conducted according to AES guidelines by three judges. Three prizes will be awarded for sound quality and one for aesthetic appeal. The guidelines limit entries to any non-self-powered three-way (or less) system weighing less than 100 lbs./side. The contest will take place in May 1997. For details, call Mark Sayer at Meniscus, (616) 534-9121.

### ■ SHAKE IT UP BABY

The Bass Shaker Plus is a new addition to the Bass Shaker™ product line from Aura Systems. This car-audio bass-enhancement system incorporates a pair of Aura Pro Bass Shakers, a remote level control, and a 100W Class D digital amp. Winner of the 1996 Best OEM Upgrade Award, the Bass Shaker Plus mounts under your car seat and responds to frequencies from 100Hz down. Call (800) 909-AURA for a retailer in your area. Aura Systems Inc., 2335 Alaska Ave., El Segundo, CA 90245, (310) 643-5300, FAX (310) 643-8719.

***Reader Service #106***



### ⊂ NEW SPEAKERS STAND TALL

Martin-Logan has released the reQuest and the Aerius i, two innovative speakers that are improved versions of the company's Quest and Aerius speakers. New woofers are designed to better complement their electrostatic loudspeaker technology (ESL) components, producing more detailed bass and more focused imaging. Both speakers occupy tall, slim cabinets and employ Martin-Logan's curved diaphragms and stators that disperse sound across a broad, 30° soundstage. Martin-Logan, Ltd., P.O. Box 707, Lawrence, KS 66044, (913) 749-0133.

***Reader Service #109***

### ■ VIBRATION DAMPERS

The Ultimate Isolation System 2, from Bright Star Audio, achieves vibration control through three technologies: Air Mass 2 is a pneumatic mount placed on the shelf surface; Big Rock 2 is a sand-filled platform set on top of the Air Mass and under the component; finally, you mount the Little Rock 2 isolation pad on top of the component. The 1.5Hz resonance frequency of the Air Mass/Big Rock combination restricts floor-borne vibrations, while the mass loading of the Little Rock/Big Rock combination (almost 65 lbs.) enhances the rigidity of the component's chassis to more effectively repel air-borne vibrations. Bright Star Audio, 2363 Teller Road, Unit 115, Newbury Park, CA 91320, (805) 375-2629, FAX (805) 375-2630.

***Reader Service #112***

### ⊃ LOOKS LIKE GRANITE

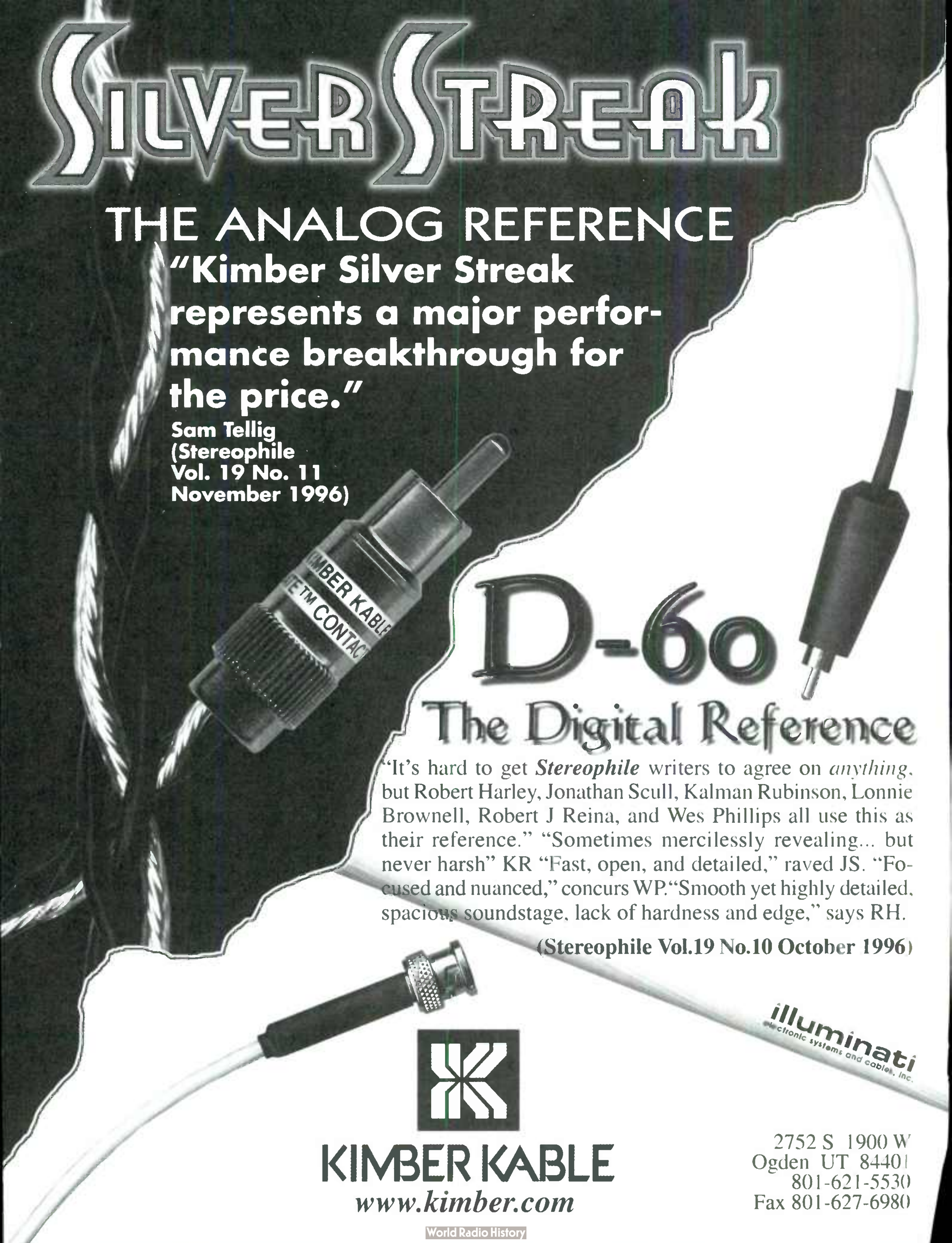
Environ™ is a cabinet-building material that looks like granite but works like hardwood. Produced by Phenix Biocomposites, Environ offers high density almost twice that of MDF (80 lbs./ft³). The color and pattern are solid throughout, and it is available in ten colors and four thicknesses. Unlike many particleboards, Environ is nontoxic and uses no free formaldehyde, being a composite manufactured from 40% soy flour and 40% recycled newsprint. Phenix Biocomposites, Inc., P.O. Box 609, Mankato, MN 56002, (507) 931-9787, FAX (507) 931-5573.

***Reader Service #111***

### ■ MULTIMEDIA SPEAKER SYSTEM

MIDI Land, Inc. announces the MLi-370Q, a new three-way multimedia speaker system that utilizes QSOUND® to deliver dynamic multidimensional audio, 55W of output power, and a separate tweeter, midrange, and four-inch woofer. In addition to internal crossover circuitry, the tweeter and midrange are mounted in a sealed enclosure separate from the woofer, thus minimizing interference between the drivers. The internal amplifier delivers 40W to the woofer and 15W to the tweeter and midrange speakers. Separate high- and low-level inputs are provided as well as headphone and microphone jacks. MIDI Land, 440 South Lone Hill Ave., San Dimas, CA 91773, (909) 592-1168, FAX (909) 592-6159.

***Reader Service #108***



Silver Streak
THE ANALOG REFERENCE
"Kimber Silver Streak represents a major performance breakthrough for the price."
Sam Tellig (Stereophile Vol. 19 No. 11 November 1996)
KIMBER KABLE
TM CONTACT
D-60
The Digital Reference
"It's hard to get Stereophile writers to agree on anything, but Robert Harley, Jonathan Scull, Kalman Rubinson, Lonnie Brownell, Robert J Reina, and Wes Phillips all use this as their reference." "Sometimes mercilessly revealing... but never harsh" KR "Fast, open, and detailed," raved JS. "Focused and nuanced," concurs WP. "Smooth yet highly detailed, spacious soundstage, lack of hardness and edge," says RH.
(Stereophile Vol.19 No.10 October 1996)
illuminati
electronic systems and cables, inc.
KIMBER KABLE
www.kimber.com
2752 S 1900 W
Ogden UT 84401
801-621-5530
Fax 801-627-6980

# A MUSICIAN'S SPEAKER

By Jesse W. Knight

Thirty years ago, I tried to learn the bass part of the Bach B-minor mass by following a vocal score while listening to a recording. For the most part, it was inaudible. For several years I purchased new recordings as they came out, but none reproduced the inner parts well.

Many years later, I spent all my free time singing in choirs for several seasons. A recording project with the best of these choirs provided several insights into the problem:

1. Choir directors often don't notice a lack of tuning in the bass section of a choir; even well-known choirs can be quite sloppy when it comes to inner parts.
2. Microphones must be extremely flat in response or corrected to flat; otherwise, inner parts are lost in recording. Slopes of more than 2 or 3dB per octave are not correctable due to difficulties in correcting phase shifts. Off-axis response must be smooth.
3. The playback speaker must have an $f_3$ below 40Hz and use drivers that are flat to ±2dB or better, based on pure tone measurements.
4. You must set midrange and tweeter levels by ear to match the balance of live music. These settings will be several dB below calculated levels. As an alternative, you can adjust all parameters for maximum resolution of inner parts in heavily scored music. When you are using many recordings and adopt an average setting, the balance will usually be good.

Musical standards have tightened up in the last 30 years, and so have microphones. Differences due to analog and digital recordings, amplifiers, or cables are trivial compared to the above factors. Speakers have regressed in some ways during this period as a result of market pressures to reduce size.

Ideally, you could use a Dynaudio tweeter and midrange with an 18″ woofer to obtain these specs, but the cost would be well over $1,000 for the drivers in such a system. My musician's speaker uses Peerless and Madisound components for greatly reduced cost. The major loss incurred is power handling—you will get some dynamic compression. If you live in an apartment, bear in mind that this problem occurs at levels that tend to bring the police. The high-frequency rolloff will start at 15kHz, and the transient response will not be quite as good, but these are minor drawbacks considering the lower cost of this project.

The speaker system can be built with either a 12″ or 10″ woofer. I have included specifications for both.

## THE BOX

Building a cabinet that will maintain the extremely low coloration of the Peerless and Madisound components is not a simple matter. Cabinet resonances can easily produce 6dB spikes in the overall system response far in excess of the driver's contributions. You should explore all possible solutions. Two-inch-thick butcher block made from hardwood flooring scraps might be excellent, and you can find the tools and instructions for making it in woodworking classes given at some high schools. Warfedale cabinets contain a layer of sand between plywood walls, and experiments with concrete are also promising.

Cabinets with only two or, even better, no parallel walls are superior to rectangular ones for reducing standing waves. My next cabinet will likely be a non-parallel-wall butcher-block design. After building three triangular cabinets for sale, I have returned to using my prototype boxes from 1973, made from butt-joined AC plywood (*Photo 1*). The system still sounds good, but not as good as it might.

For those wishing to build conventionally, I include internal dimensions for rectangular boxes (*Fig. 1* and *Table 1*). I recommend the maximum size. If total series resistance (amplifier + cable + L 101) exceeds 0.4Ω (*Fig. 2*), you should consider even larger cabinets. The drivers are arrayed vertically, with about 1″ of space between them. I based the calculations on a tilt-back of 15° for the front board.

**PHOTO 1:** Prototype enclosure with Pyle W12C700F woofer, Peerless 821385 midrange, and Peerless 811815 tweeter, retrofitted to an old box that is slightly smaller than the 90 ltr box. A removable front panel permits me to use this box for testing other drivers. Painting the front panel black will prevent it from being visible behind the grille cloth.

## PORTS

The best locations for ports are at the bottom or back of the cabinet, which directs port noises away from the listener. Since I always put my speakers diagonally in the corners of a room, the port can overhang the rear of the cabinet, thus allowing it to be larger and longer (*Fig. 3*). A port should be tuned to the stated frequency, regardless of what length is calculated.

Port length is affected by box quality, which is somewhat tedious to measure. PVC pipe is cheap; you might even get scraps


## ABOUT THE AUTHOR

Jesse W. Knight has designed speaker systems for home and church use, and now works on sound systems for courthouses which use electronic recording. Jesse designed and constructed a phono disc recorder and produced audition tapes for student musicians and choirs. He is a member of the Audio Engineering Society and leads the bass section in a local church choir.

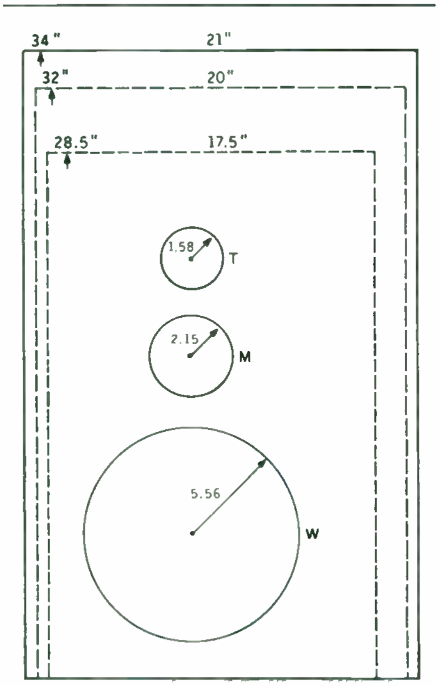



**FIGURE 1:** Front panel.

from a plumber free, as I did. You can fasten pieces together with duct tape to get a length for test purposes, and then cut a new piece to that length. If you don't have test equipment, use your ears. If box resonance is too high and the bass is boomy, the pipe may be too short; if box resonance is too low and the bass is weak, it may be too long.

To recess the rear terminals when using a terminal strip, I like to make a 1½" radius hole in the rear panel behind the woofer (*Fig. 4*). Then I place a 3/8" thick scrap of plywood over the hole on the inside of the rear panel, thus providing a recessed surface for the terminal strip. The piece of wood should be about 6" × 6" and glued to the rear panel as shown.

## FRONT PANEL POSITIONING

I set the front panel in ¾" so the grille frame can fit inside the overhanging top and sides (*Fig. 5* and *Photo 2*). Many regard this as a mistake, since it results in some unwanted high-frequency reflections, but I have not found these to be audible in large cabinets with the controlled-dispersion 811815 Peerless tweeter. If I were making a small system with a Dynaudio D-21 tweeter, this would be of concern. An inset grille is much easier to make, and it will last longer if you have cats. Only the face of the grille will show, so how you wrap it over the frame is not critical.

## STUFFING

R-25 unfaced fiberglass from a building-supply outlet is less costly than other materials, but messy to work with (*Photo 3*). It's best to do this outdoors with a mask and gloves. Cover all but the front board, using 16 9/16" staples per square foot to produce the desired compression of the fiberglass. I have never had fiberglass fall into a woofer when I used this many staples, so don't leave the top bare.

**TABLE 1**

**DIMENSIONS (IN INCHES)**

| **BOX** | **90L** | **126L** | **152L** |
|---|---|---|---|
| Front and rear panels | 28½ × 17½ | 32 × 20 | 34 × 21 |
| Side panels | 28½ × 13½ | 32 × 14½ | 34 × 15½ |
| Top and bottom panels | 19 × 13½ | 21½ × 14½ | 22½ × 15½ |
| **GRILLE FRAME** | | | |
| Two horizontal pieces | 17 3/8 × ¾ sq. | 19 7/8 × ¾ sq. | 20 7/8 × ¾ sq. |
| Two vertical pieces | 26 7/8 × ¾ sq. | 30 3/8 × ¾ sq. | 32 3/8 × ¾ sq. |

**DRIVER CUTOUTS** (radius, not diameter) — for all 12" systems

| **WOOFER (W)** | **MIDRANGE (M)** | **TWEETER (T)** |
|---|---|---|
| 5.56 | 2.15 | 1.58 |

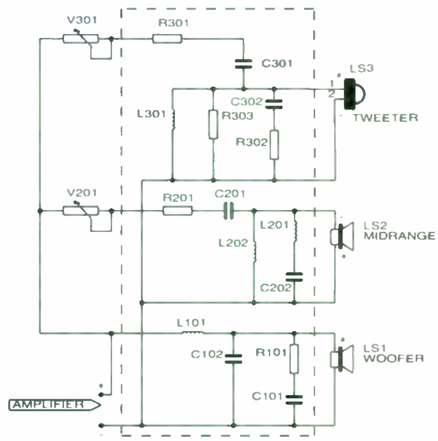



**FIGURE 2:** Crossover design.

## THE WOOFER

Most people will choose the woofer based on available space, but there is another factor to consider. Although the Swan 305 will move much more air than the 10″ 1052 DVC, the latter has a flatter response curve, and as a result will outperform the Swan at low levels. This is not to criticize the Swan, but to point out that the 1052 DVC is an exceptional speaker as regards freedom from coloration. If you use the 1052 DVC, wire it for 4Ω. Then, since the voltage sensitivities of the two speakers are the same, no midrange or tweeter component changes are required.

*Table 2* lists crossover parts separately for each woofer. Most amplifiers will not be affected by the impedance rise from 4Ω to 8Ω with increasing frequency, unless it is a low- or no-feedback amplifier.

## THE TWEETER

In early versions of this system, I used a Peerless KO-10 DT tweeter, which is a handmade predecessor to the 811815. It costs more and is not as good, but if you have one, you can use it by making these changes: short out R301 and reset V301 to 2Ω (*Fig. 2*). This tweeter has a substantial peak at 13kHz that increases tape hiss and stylus mistracking sounds. It is all right when playing cassettes, but is too bright for CDs. Older listeners with high-frequency hearing loss often like the sound of these tweeters. Note, however, that the KO-10 DT does not fit in a round hole, which complicates cutout work. Equalizing the peak helps, but the sound goes from zippy to fuzzy.

## CROSSOVER

This crossover is impedance corrected and different values are shown for the two woofer choices. You should wire level controls V201 and V301 and then set them for 4Ω across the controls. Four ohms is the reference value that will sound best under most circumstances. You may want to provide an external test point so you can set both speakers to precisely the same levels.

## CROSSOVER MOUNTING

Most people mount crossover networks inside the cabinet, but other options are worth considering. In my system, the only tone control when I'm playing classical music is the crossover, so having it with its level controls at the listening position during setup speeds the process of balancing the system. Advanced builders may prefer to try lowering the woofer midrange crossover to 450Hz if no sustained high levels are demanded (no rock music).

I think nothing in a crossover is sacred, and if you have an oscilloscope and signal generator, by all means experiment. In my opinion, no woofer, no matter how small, should be crossed over above 600Hz. If, after much listening, you find no need to use the controls in the crossover, it is best to

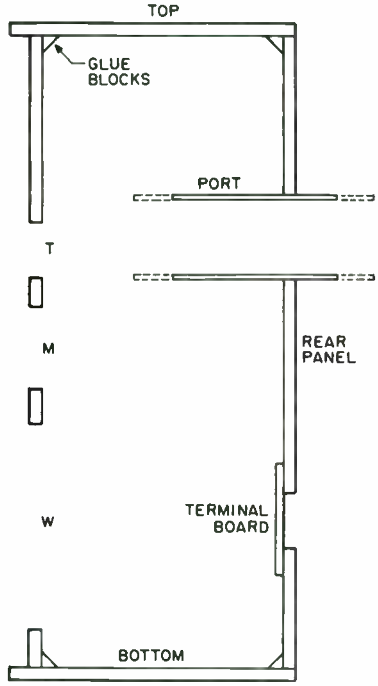



**FIGURE 3:** Side view, cross-section.

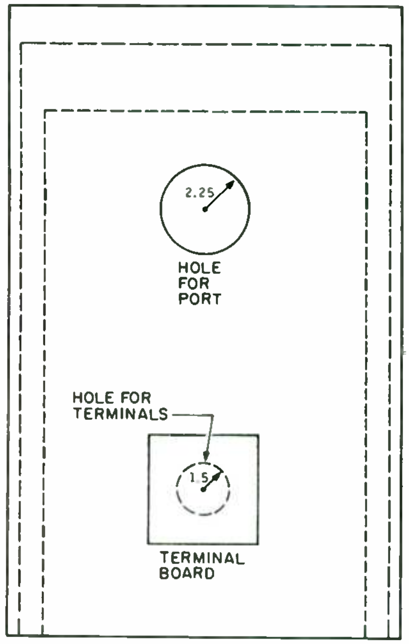



**FIGURE 4:** Rear panel.

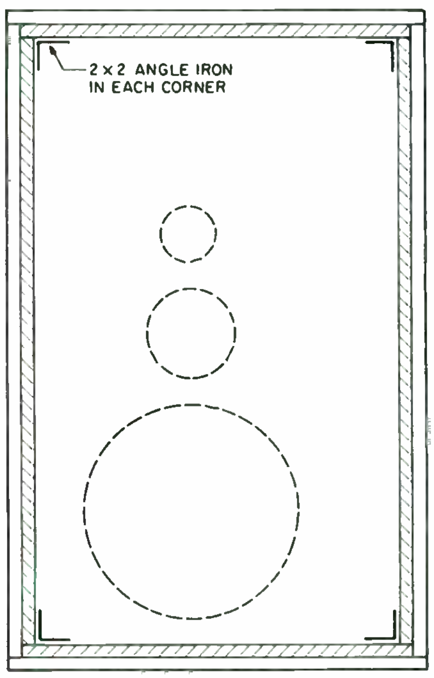



**FIGURE 5:** Front panel with grille frame.

## SEALED BOX

If a ported box is more work than you want to tackle, consider building a sealed system. Madisound lists a 91.3 liter cabinet that would be excellent for anyone who wants to avoid the cabinet work. If you order this cabinet, be sure to specify blank, otherwise you will have holes in the wrong places.

This cabinet has a cutout for the VL cup (rear connecting terminals). If you don't order the cup, you'll need to cover this hole with a small board. Use the template to locate the driver-cutout positions.

I have found that if you aim for a system Q half-way between 0.707 and 0.577, a non-flat alignment results with the Swan 305 that you can correct by simply turning up the bass control on the preamp. A setting of 1:30 o'clock works fine with the Hafler 101 preamp. If you have an equalizer, try setting the 64Hz lever to +2½dB and that of the 32Hz to +4dB.

According to many authorities, sealed boxes have better transient response than ported ones, but I disagree. To me, the closed box is not as clean on drums as the ported box. Other listeners agree with me on this, suggesting that the greater cone motion in the sealed-box mode creates far more distortion than ports, and that less turbulence is present in a ported box. Nevertheless, the sound is still very good. For many, the availability of a factory-made cabinet is an important plus for the sealed box. — **JWK**



*Reader Service #91* →

measure the resistance and replace them with fixed resistors of matched values. Finally, you can mount the crossover to the floor of the speaker box.

Do not mount the crossover near system components, because of the large radiated field from the inductors. Mounting the crossovers two or more feet from the components should be all right when you desire long-term access. Also, wires to the drivers must not share a common ground.

## CROSSOVER CONSTRUCTION

Only three layout considerations are important:

1. Mount the four inductors as far from each other as possible, perhaps at the corners of a mounting board. Alternatively, mount the coils at right angles.
2. Keep the wiring of the tweeter circuit compact.
3. Do not mount the inductors on metal, or with iron or steel fastenings.

## CONCLUSION

The benefits of the peak-free tweeter with impedance leveling are dramatic. Tape hiss and bias noise modulation are greatly

*to page 60*

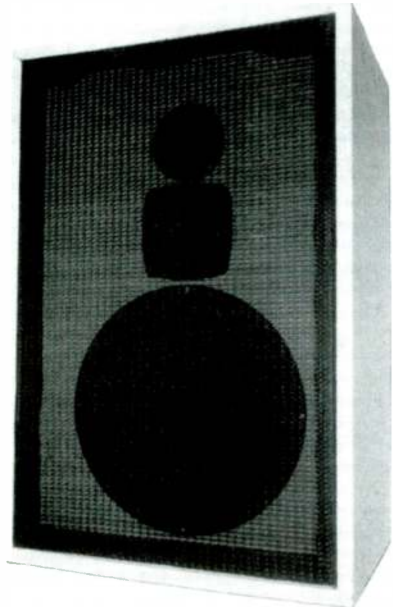


**PHOTO 2:** Speaker with grille frame in place.

**PHOTO 3:** Stuffing the box.

**TABLE 2**

**PARTS LIST**

**TWEETER AND MIDRANGE COMPONENTS COMMON TO ALL VERSIONS**

Peerless 821385 midrange
Peerless 811815 tweeter
(available from Madisound)

| CAPACITORS | | |
|---|---|---|
| C201 | 30 | poly or Mylar® cap |
| C202 | 10 | poly cap |
| C301 | 4.7 | poly cap |
| C302 | 2 | poly cap |

| RESISTORS | | |
|---|---|---|
| R101 | 8Ω | 15W sand cast resistor |
| R201 | 1Ω | 15W sand cast resistor |
| R301 | 2Ω | 15W sand cast resistor |
| R302 | 8Ω | 15W sand cast resistor |
| R303 | 14Ω | 15W sand cast resistor |

| INDUCTORS | | |
|---|---|---|
| L201 | 0.67 | MH air core inductor |
| L202 | 1.75 | MH air core inductor |
| L301 | 0.15 | MH air core inductor |

| MISCELLANEOUS | | |
|---|---|---|
| V201 | 8Ω | L-pad control |
| V301 | 8Ω | L-pad control |

**12″ SYSTEM WITH SWAN WOOFER**

| | |
|---|---|
| W12 | Swan 305 woofer |
| C101 | 40μF capacitor; poly, mylar, oil, or nonpolar electrolytic |
| C102 | 50μF capacitor; poly, mylar, oil, or nonpolar electrolytic |
| L101 | 3.00 MH ferrite core inductor |
| Port: | 4″-diameter PVC schedule 40 pipe; tune to 23Hz (try 16″ length for 152 ltr box) |
| Box: | minimum: 126 liter, inside dimensions in inches: 12 × 20 × 32 |
| | recommended: 152 liter, inside dimensions in inches: 13 × 21 × 34 |
| Sealed box: | 90 liter, inside dimensions in inches: 11 × 17½ × 28½ |

**12″ SYSTEM WITH PYLE WOOFER**

| | |
|---|---|
| W12 | Pyle W12C700F |
| C101 | not required (no impedance compensation needed) |
| R101 | not required (no impedance compensation needed) |
| C102 | 50μF capacitor; poly, mylar, oil, or nonpolar electrolytic |
| L101 | 3.00 MH ferrite core inductor |
| Port: | 4″-diameter PVC schedule 40 pipe; tune to 33Hz (try 9″ length) |
| Box: | minimum: 90 liter, inside dimensions in inches: 11 × 17½ × 28½ |
| | maximum: 126 liter, inside dimensions in inches: 12 × 20 × 32 |

**10″ SYSTEM**

| | |
|---|---|
| W10 | Madisound 1052 DVC woofer |
| C101 | 20μF capacitor; poly, mylar, oil, or nonpolar electrolytic |
| C102 | 56μF capacitor; poly, mylar, oil, or nonpolar electrolytic |
| L101 | 2.70 MH ferrite core inductor |
| Port: | 3″-diameter schedule 40 PVC pipe; tune to 28–29Hz (try 6″–9″) |
| Box: | minimum: 63½ liters, inside dimensions in inches: 9½ × 16 × 25½ |
| | maximum: 72 liters, inside dimensions in inches: 10 × 16½ × 26½ |

**STUFFING**

| | |
|---|---|
| R-25 | Unfaced fiberglass from building supply store |

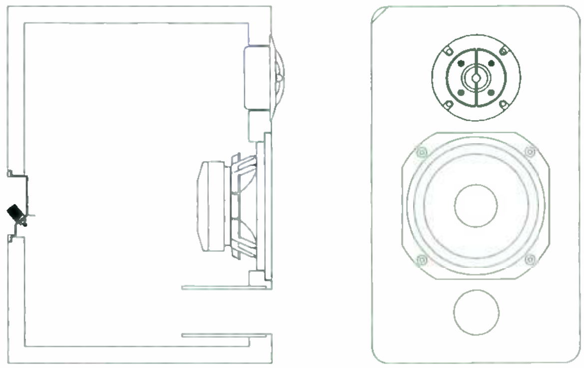
# AUDAX SIGNATURE SERIES KITS

Over the last 3 years, Audax Loudspeakers has recreated its product line. The new products utilize space age materials including Carbon Fiber, Aerogel, Kevlar and Titanium. The new products look better and perform at a level that is state of the art.

To demonstrate this higher quality achievement, Audax asked Vance Dickason, author of *The Loudspeaker Design Cookbook*, to create kit designs that show the product potential.

Madisound is grateful for this serious commitment to the kit builder from Audax. We have built these kits and can recommend them without reservation. Madisound has also created custom Oak cabinets with rounded solid corners and full grills. They are Audiophile kits that can be assembled in a single evening.

## Signature Series A651 Kit

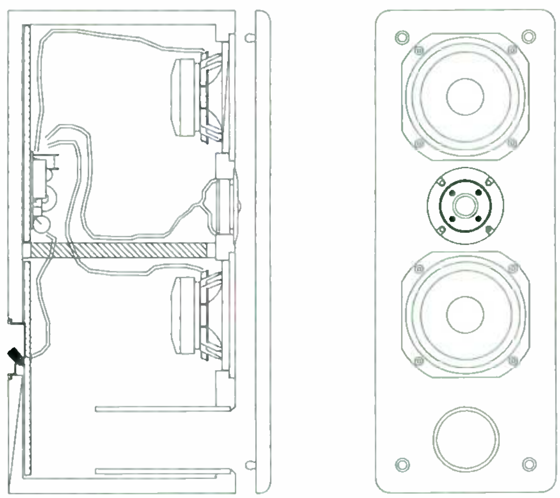


Dimensions: 16.4" T x 9" W x 11.75" D

The A651 is a two way design using an Audax HM170Z0 6.5" Aerogel HD-A cone woofer with phase plug and as AW025S3 1" Aluminum dome tweeter with phase diffuser. The enclosure is computer optimized for a vented QB3 type of response yielding an F3 of about 55Hz. This enclosure provides maximum damping for bass detail and produces an output of 100dB, remaining linear down to 40Hz.

The crossover is computer optimized (using LEAP) as a 4th order Linkwitz-Riley type at 3kHz which yields an overall efficiency of 86.5dB. Third order networks couple with the natural rolloff of the drivers to achieve the desired 4th order slope.

## Signature Series A652 Kit



Dimensions: 26.4" T x 7.5" W x 10.75" D

The A652 is a 2-way design using two Audax HM170C0 carbon fiber 6.5" woofers and a TW025M0 1" textile dome tweeter, mounted in the popular D'Apollito configuration with the tweeter placed between the two woofers. This technique produces a smoother vertical frequency response above and below the listening axis. The enclosure is optimized for a modified QB3 type of response yielding an F3 of about 53Hz. This volume provides a well damped group delay profile for bass detail and produces an output of 105dB, remaining linear down to 37Hz.

The crossover is computer optimized (using Leap) as a 4th order Linkwitz-Riley type at 2.8kHz, which yields an overall efficiency of 90dB. The 4th order slopes are achieved by using 3rd order networks and the natural rolloff of the drivers. The response of the speaker is 60Hz - 20kHz +/- 2.2dB with a very flat off axis response.

Both the A651 and A652 will perform best when used on stands of about 24" in height. As with any quality 6.5" woofer system, the low-frequency response does not produce much output in the lowest octave between 20Hz and 40Hz. For this reason, this speaker makes an ideal satellite speaker to be used in conjunction with a powered subwoofer, or bi-amped with an electronic crossover, separate amplifier and subwoofer.

**Prices: A651 with Cabinet $490.00 / pair**
**Without Cabinet $328.00 / pair**

**A652 with Cabinet $685.00 / pair**
**Without Cabinet $490.60 / pair**

**Madisound Speaker Components; P.O. Box 44283, Madison, WI 53744 USA; Tel:608-831-3433, Fax:608-831-3771, e-mail: madisound@itis.com**

*Reader Service #38*

# A SIMPLE PHASE TESTER

By Andy Lewis

Unfortunately, in order to reproduce the entire audio spectrum with moving-coil drivers, it is generally necessary to use several drive units of different sizes. The human ear simply responds to a wider range of frequencies than any single driver is capable of reproducing. Consequently, you are forced to rely on multidriver systems, using woofers, tweeters, and sometimes one or more midranges as well.

## PHASE COHERENCE: A LITTLE BACKGROUND

As early as 1935, listening revealed that when the drivers in a system were separated by a distance in space, they tended to be perceived as separate sources of sound, rather than as parts of a whole.[1] Experimentation then demonstrated that when the drivers were aligned properly, the perception changed to one of a single, full-range source.

Ever since, designers have disagreed about both the threshold of audibility of this problem and the best way to overcome its ill effects in their designs. Most agree, however, that phase distortion is audible and that some degree of phase linearity is an important design goal in any multiway speaker system. If you accept this notion, a design question is how to align your drivers to most effectively compensate for their differences in phase.

Some manufacturers have concentrated on their systems' capacity to be phase coherent, or in phase with themselves. They have also taken different approaches to solving the phase-response problem. You may remember the systems from Rectilinear Research in the '60s and early '70s. Notable was a bookshelf-sized 10″ three-way system that Rectilinear claimed was able to pass a square wave virtually undistorted.

It accomplished its touted phase linearity in a very clever way: the design avoided midband-crossover phase irregularities by simply avoiding a midband crossover! The crossover frequency from the woofer to the midrange was very low, and from the midrange to the tweeter very high. Interestingly, a sample I examined achieved the low crossover from woofer to midrange by using an enormous coil in series with the woofer.

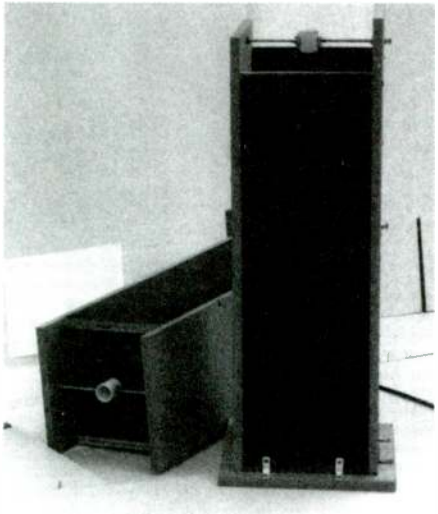


**PHOTO 1:** Test jigs.

Unfortunately, the DC resistance of this coil undermined the outstanding damping characteristics of the Rectilinear woofer, adversely affecting the bass. Although it wasn't rocket science, it had a fundamental correctness of approach. The design was important because of its early attention to phase coherence in a home-speaker system.

## PHASE-LINK SYSTEMS

In the '70s, phase alignment really came into its own. Another interesting approach was the "phase link" system introduced by Bang & Olufsen. The designers, recognizing that precise second-order filters would result in an out-of-phase condition at the crossover point, inserted a driver with a very narrow pass band to "fill the hole" exactly at that point.

Some of these systems had, to my ears, a remarkably smooth and uncolored midrange. Such a system would necessarily be a little top-heavy in terms of crossover cost, and although this concept never sparked widespread imitation, the design was significant in that it acknowledged the unruly nature of crossovers with respect to phase.

Also introduced in the early '70s was the celebrated Dahlquist DQ-10. This important design accomplished phase coherence through the use of "staggered" drivers. Rather than mounting all the drivers on a common baffle, as was then customary, Dahlquist chose to displace the drive units with respect to each other on the horizontal axis.

The idea was to physically compensate for the drivers' inherent time differences by altering the positions of the individual sources. When carefully positioned, the drivers would become "time-aligned®" and behave more as a unit.

This concept has withstood the test of time. Not only are a great many DQ-10 systems still around 20-odd years later, but legions of hobbyists and professionals alike have endorsed the concept of staggered drivers through their imitation of Dahlquist's principle.

## THE NEED FOR PHASE TESTING

Everyone has seen the "stairstep" enclosures used to physically "time-align" the speakers in a multidriver system (*Fig. 1*). Most of these, of course, owe a debt to Dahlquist.

While they might look strange at first, the concept is simple. Each driver, when considered as a source of sound, has an apparent exact location in space, the point on the speaker's axis where the sound wave is exactly in phase with the input voltage. This apparent location is sometimes referred to as the drive unit's "acoustic center."

In this illustration, assume that the

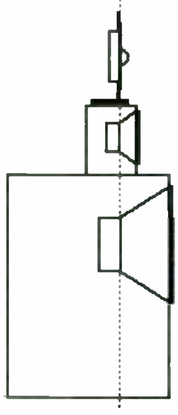
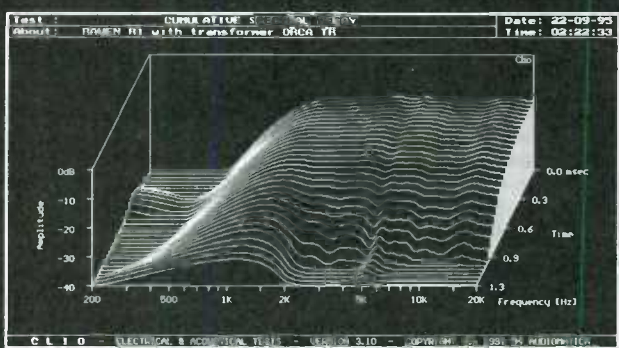


**FIGURE 1:** A "stairstep" time-aligned system.

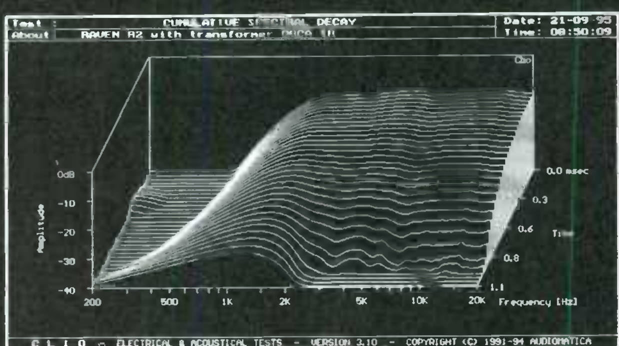
# RAVEN

## HIGH EFFICIENCY PURE RIBBON TWEETERS

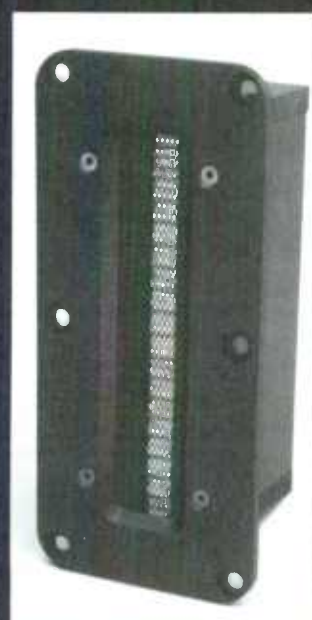
ORCA is sincerely proud of introducing these exceptional high frequency transducers from France. The RAVEN tweeter is a true ribbon tweeter, possibly the purest transducer available today. In a dome tweeter the signal is carried through the voice coil wire, and the sound is radiated by the dome attached to the voice coil. Here, the carrier of the electrical signal and the radiating diaphragm are one and the same part: the ribbon itself. Furthermore, the RAVEN ribbon is 100% pure conductive material, no metalized film. To have an idea of the high frequency performance of the RAVENs, imagine that the moving mass here is about 30 times less than a high quality dome tweeter. The music comes through effortless, almost immaterial. The special and massive NeFeB magnet of the RAVENs is five times more powerful than a conventional magnet. The result: the RAVEN R1 is capable of 118 dB peak with no measurable distortion (R2: 120 dB). At 10WRMS, that is continuous power now, R1 reaches 105 dB with less than 1% distortion, and R2, 107 dB. The RAVENs come with a specially designed matching transformer (very low distortion, low loss and wide bandwidth) for optimum coupling with your power amplifier. Now look carefully at the decay of these units !




**RAVEN R1**
KGS 1.14
LBS 2.5
92 x 80 mm
3.63 x 3.15 in.
Moving mass:
0.0061 g
0.0002 oz.
dB/W/m 95
2 KHz to 40 KHz




**RAVEN R2**
KGS 2.22
LBS 4.9
166 x 76 mm
6.54 x 2.99 in.
Moving mass:
0.013 g
0.0005 oz.
dB/W/m 98
2 KHz to 40 KHz



**RAVEN TRANSDUCERS are distributed worldwide exclusively by ORCA Design & Manufacturing Corp.**
**1531 Lookout Drive, Agoura, CA 91301 - USA**
**TEL (818) 707 1629 FAX (818) 991 3072**
**E-Mail: orcades @ aol.com**
**OEMs, stocking distributors and importers inquiries welcome. Goods now in stock in America.**

acoustic centers of the three drivers are in the vicinities of their voice coils. The enclosure then is built in such a way that the drivers are physically offset by the precise amounts necessary to "time align" the system.

The assumption that a driver's acoustic center is located approximately where the voice coil meets the cone or dome is sometimes considered the default rule of thumb among designers when empirical data is unavailable.[2] Without arguing the merits of this assumption, the inherent correctness of staggering the drivers seems obvious. But wouldn't it be nice if you could perform a simple test on your drive units that would allow you to stagger your enclosures, if necessary, with confidence that it was doing more good than harm?

Little has been offered to help the low-budget designer in this area, and designing systems to be in-phase with themselves has generally been a matter of guesswork and reliance on assumptions. While sophisticated equipment may be available to provide phase-alignment information, hobbyist builders have been left in the cold, aware that phase alignment is a design consideration worthy of attention, but ill equipped to measure the effects and precisely compensate for them.

I have devised a simple and inexpensive gadget, the phase tester, to measure phase differences between drivers. I will describe my method of testing for phase alignment to show how you can make your own phase measurements as you design your systems.

## REINFORCEMENT AND CANCELLATION

All of you have probably had the experience of accidentally connecting your speakers out of phase with each other. In most cases, the resulting loss of bass is dramatic. This is the result of wave cancellation. When two sources a short distance from one another produce the same signal at the same amplitude, but 180° out-of-phase, they work against each other. One source produces a positive wavefront, while the other produces a negative one. As a result, the sound pressure is reduced to zero in an ideal case, and often to near zero in the real world.

This is the nature of wave activity—to add and cancel with respect to phase. It is a source of phase problems and a reason you must consider phase accuracy in the first place. Ironically, however, this very property can become a tool for measuring the apparent distance between two drivers mounted on the same plane.

It also makes possible my method of phase-testing. The cancellation and reinforcement of in-and-out-of-phase sine waves provides a "sonic ruler" that you can use to simply and precisely measure phase differences between drivers you wish to use together.

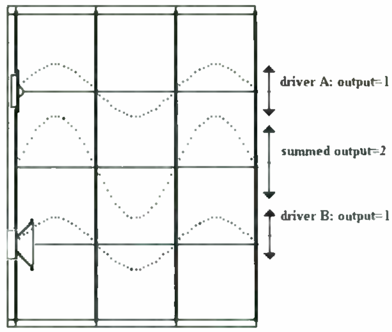



**FIGURE 2:** Wave reinforcement when drivers are in phase.

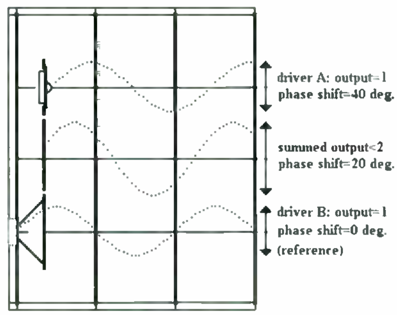



**FIGURE 3:** Incomplete cancellation and resulting phase shift.

## HOW IT WORKS

To see how this is done, first consider the case of two drivers mounted on a common plane and electrically in phase with each other (*Fig. 2*). In this diagram, assume that the acoustic centers of the two drivers are aligned. The two separate sources are working together. The summed amplitude, represented by the middle sine curve, is double that of either individual driver's output, and the phase of the summed outputs is the same.

Now consider a second situation (*Fig. 3*) where the two drivers are mounted on a more-or-less common baffle. They are not time aligned, and the acoustic centers of the drivers are separated by a distance that is less than half a wavelength. Each driver reproduces the same sine-wave signal, individual outputs are identical, and the output of each is represented by its own sine curve.

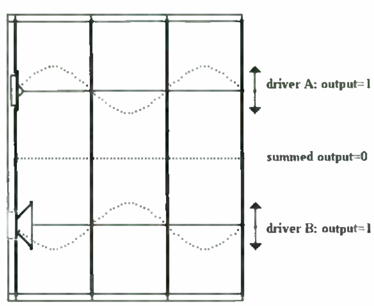



**FIGURE 4:** Complete cancellation using out-of-phase drivers.

In this case, the waves tend to cancel, but not completely, and the result is the summed waveform shown, which has a smaller amplitude than the summed output in *Fig. 2*. Note that when the outputs of the two drivers are added, the resulting curve is shifted in phase with respect to those of the individual drives. As effective displacement between the two sources becomes one-half wavelength, the summed output drops to zero (*Fig. 4*).

## LONGITUDINAL VS. TRANSVERSE WAVES

I have represented sound waves in *Figs. 2–4* with mathematically generated sine curves. This is a common practice, and in fact is a good graphical representation of the varying amplitudes of the compressions and rarefactions that comprise a sound wave. But to represent a sound wave with a "wavy line" sometimes gives the false impression that there is some kind of side-to-side activity as a sound wave propagates. I have seen at least one commercial speaker-design how-to book "explain" that after leaving the vicinity of the driver, the in-and-out motion of the cone is somehow "transformed" into the side-to-side motion implied by the wavy lines often used to represent waves.

Transverse waves are those in which particle motion is as wavy lines would imply: in a direction perpendicular to the direction of propagation. A guitar string, for example, exhibits transverse-wave activity. As the wave travels up and down the length of the string, each individual tiny section of the string itself moves back and forth in a direction perpendicular to the length of the string. Electromagnetic waves are also transverse waves.

Sound, however, is an example of a longitudinal wave. The particle (air molecule) motion is parallel to the direction of propagation. So again, while the picture of the sine wave is representative of the mathematical model of the sound wave, it does not look anything like a sound wave would if it were visible.

## CANCELLATION

Consider the same two drivers mounted in a time-aligned configuration, but wired out of phase with each other (*Fig. 4*). Under this obviously adverse condition, the two drivers work in perfect opposition to each other. In this example, when the summed outputs are represented by a curve, the result is a constant zero, indicative of complete cancellation.

This leads to the observation that when

outputs are equal, phase is reversed, and drivers are time-aligned, cancellation is complete. When you electrically reverse phase to one driver with the goal of complete cancellation in a sine-wave test, there are only two variables involved: relative output level and time alignment. This is the key to simple at-home phase testing.

But how can you arrange these special circumstances? Where would you put a microphone? How could you possibly move drivers with respect to each other, correct output levels to achieve cancellation, and accurately measure time-alignment data? And what about room reflections?

These questions tend to make the default method of aligning the voice coils seem attractive by comparison. But if you could adjust the physical positioning of drivers to duplicate these special conditions, it might be possible to measure time-alignment data accurately.

## SIMPLE SOLUTIONS

Several adjustments occurred to me. First, by acoustically separating the speakers from each other, I could avoid interference and room reflections. Second, that changing the precise position of a microphone is much easier than moving a speaker. And, finally, that using a separate microphone on each speaker might enable me to control outputs precisely enough to imitate the ideal case represented in *Fig. 4*. Starting to make sense? The idea is really quite simple.

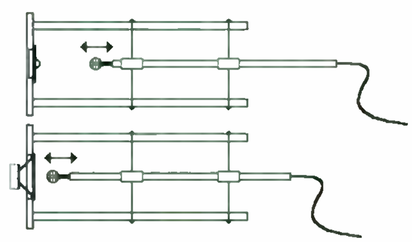


**FIGURE 5:** Phase-testing jigs. Note the PVC-tube guides supported by the eight carriage bolts.

**TABLE 1**

**PARTS LIST—JIGS**

| QTY | ITEM |
|---|---|
| 4 | plywood or particleboard, 27″ × 9 1/8″ × ¾″ (short sides) |
| 4 | plywood or particleboard, 30″ × 10 5/8″ × ¾″ (long sides) |
| 2 | plywood or particleboard, 15″ × 15″ × ¾″ (end pieces) |
| 8 | 4½″ × ¼″ carriage bolts |
| 8 | ¼″ nuts |
| 8 | ¼″ washers |
| 8 | ¼″ T-nuts |
| 16 | 1″ L-brackets |
| 32 | #8 × 5/8″ wood screws |
| 2 | lengths 1″ steel tube 36″ long "EZ Pull 1″ EMT" |
| 4 | 1½″ lengths 1″ PVC tube (guides), 1″ PVC 1120 125 PSI irrigation pipe |
| 2 | matching microphones (Radio Shack #270-092 or similar) |

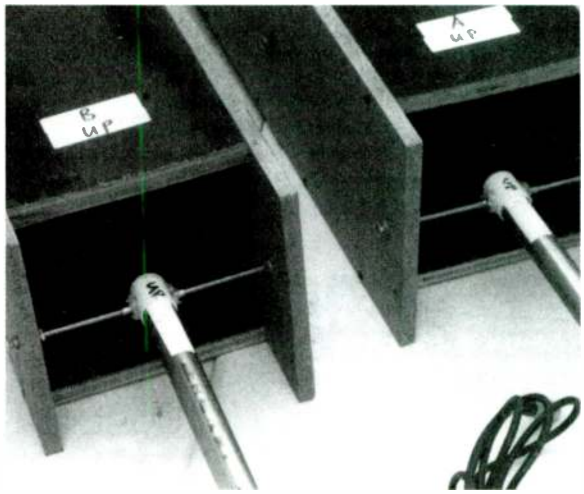


**PHOTO 2:** Steel pipes in PVC guide assembly in wooden tunnels.

The phase tester is also very simple. It consists of two large wooden jigs designed to separate a speaker and a microphone by a precise distance, and a flexible electronic system that connects everything together to make it work. There is nothing complicated or expensive, assuming you own an accurate sine-wave generator, a stereo, and a voltmeter.

*Figure 5* is a schematic representation of the two jigs that hold the speakers and microphones. A drive unit is mounted at one end of each wooden tunnel. Microphones are installed in such a way that you can move them closer to or farther away from the speakers, thus adjusting the distances as desired. In theory, if you can achieve cancellation and the microphone positions are accurately measured, the device will provide phase-alignment data at any chosen frequency.

The microphones you use must match, but the demands on them are very slight, so the cheapest ones imaginable will give excellent results. I have used the Radio Shack electret capsule for applications much more demanding than phase testing, and this cheapie will do nicely.

## CONSTRUCTION

After gathering the necessary parts (*Table 1*), construction of the test jigs is simple. First, assemble two wooden tunnels from the eight long pieces of wood. For ease of construction, I used glue and screws to assemble mine. The tunnels don't necessarily have to be airtight, as in the case of a speaker enclosure, so do whatever's easiest for you.

Notice that the pieces are of unequal length (*Photo 1*). This is to provide access to a good reference point for making measurements, as described later. One end of each tunnel will then have extended "lips" and the other end will be flush.

At the flush end of each tunnel, use #8 × 5/8″ wood screws to mount eight "L-brackets" for easy installation and removal of the end pieces that will hold the speakers you're testing. After installing the brackets on the tunnels, stand each tunnel upright on its end piece and use the remaining wood screws to attach the end pieces to the main assemblies (*Photo 1*).

It will be necessary to remove and reinstall the end pieces to calibrate the phase tester, so don't glue the end pieces in place. Do, however, use a felt pen to mark which way the end pieces are oriented so you can easily line them up when reinstalling them.

Now mount the two microphones in the ends of the 36″ steel pipes that slide back and forth in the PVC guides. The guides are supported by the carriage bolts that run through opposite sides of the wooden tunnels (*Photo 2 and Fig. 5*).

## OBLIGING STORE

When I built my prototypes, I was fortunate to find a lumber store with a wide variety of diameters of stock to choose from, and the patience to let me experiment for a while. The steel pipe and PVC tube I selected work perfectly, without any play, but with enough space between the inner pipe and outer tube to make it possible to stick computer labels on the steel pipe for calibration marks (*Photo 2*). In the parts lists, I have included, verbatim, the manufacturers' labeling of the pipe and tube. If you can find exactly these same materials, it will save you some trouble.

When cutting the four 1½″ PVC guides, be careful to saw the ends as straight and cleanly as possible. The ends of these guides provide reference points for making measurements, and a little early care will pay dividends later. Also, it's a good idea to cut a few extras. I ruined several before I mastered the art of gluing T-nuts to them.

For each PVC guide, use a ruler to mark the center, ¾″ from the each end. Drill a 1/16″ hole in that spot. Use the "eyeball" method to locate the spot diametrically across the tube from the first hole, and drill a second 1/16″ hole. Using the ruler, check the locations of the holes for uniformity in distance from the ends of the guide.

When you're satisfied that you've located two spots on the PVC guide directly oppo-





Reader Service #24 →

# Speaker Components

AIRBORNE

LA PASSION DU HAUT-PARLEUR

AUDAX

DYNAUDIO®

ETON

LPG

MB

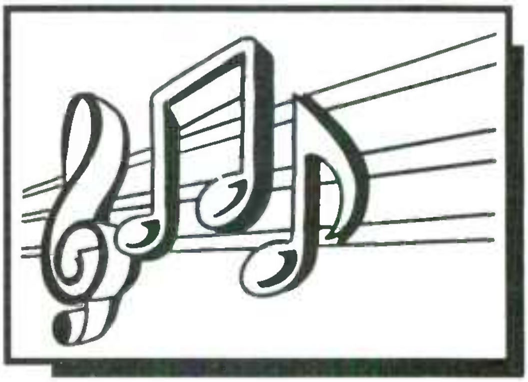
morel®

Peerless

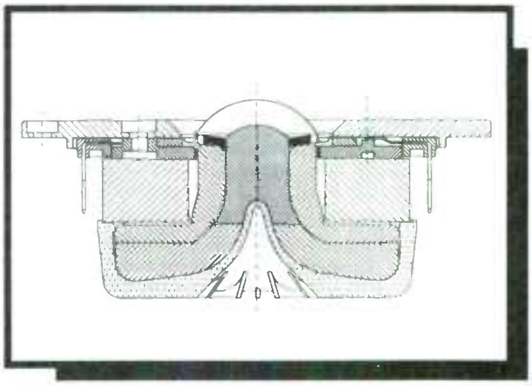
scan-speak

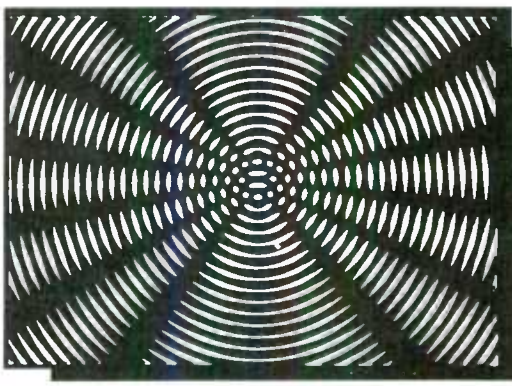
seas

vifa

*Music Forever*





**SOLEN** INC.
4470 AVENUE THIBAULT
ST-HUBERT, QC J3Y 7T9
CANADA
Tél.: (514) 656-2759
Fax: (514) 443-4949

**Catalogue 1996 • $ 8.00**

Solen crossover components catalog included

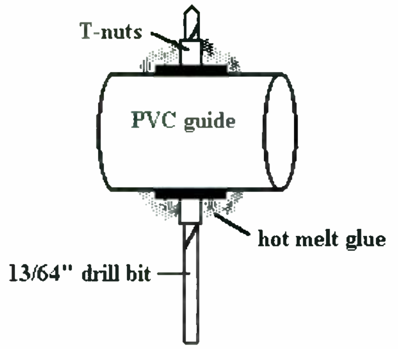



**FIGURE 6:** Drill bit being used to line up T-nuts.

**TABLE 2**

**PARTS LIST—ELECTRICAL**

| QTY | ITEM |
|---|---|
| 2 | microphones matched (included in *Table 1* as well) |
| 1 | sine-wave generator |
| 1 | frequency counter (optional) |
| 1 | stereo amplifier |
| 1 | double-throw switch |
| 1 | L-pad (optional) |
| 1 | microphone mixer (or stereo preamp) |
| 1 | voltmeter |
| 1 | load resistor, 8Ω or similar |

site one another, increase the size of the holes to 13/64″. A drill bit of this diameter fits nicely through a ¼″ T-nut. Remove the 13/64″ bit from your drill and insert it through both holes in the tube. This provides a straight axis to precisely line up two T-nuts as you glue them to the tube (*Fig. 6*).

To a T-nut, apply a small amount of hot-melt glue on the outer edge of the flange (away from the threads), and affix the T-nut using moderate pressure. Be careful you don't press so hard that you distort the shape of the tube. Mount all eight T-nuts in this fashion.

## GLUE LIBERALLY

After the glue has had several minutes to set, you can remove the drill bit and apply more glue. Although hot-melt glue adheres tenaciously to PVC, you must apply enough so it extends over the flange of the T-nut, or the metal nut can easily fall off, particularly under stress.

After you've glued the T-nuts to the PVC guides, you can mount the guides in the tunnel assemblies using the 4½″ carriage bolts (*Photo 2*). Drill a 5/16″ hole 2″ in from the end of each long side, centered with respect to the short dimension. Drill a second hole 12″ back from the first. It is important to measure carefully when drilling these holes. The holes on opposite sides must be lined up exactly, so the PVC guides will be straight.

After you've drilled the holes, mount the carriage bolts from one side only. Use the washers and nuts to hold them in place, and tighten them finger-tight. Then, carefully mount the PVC guides, using the T-nuts, on the ends of the carriage bolts. Don't overtighten them, or you will break the glue holding the T-nuts to the guides. Now insert the remaining carriage bolts from the opposite side, using the washers and nuts, and thread the bolts into the waiting T-nuts. Again, be careful not to tighten them too much.

Next, tighten the first hex nut against the internal wall of the tunnel to hold the first carriage bolt. Then readjust the opposite bolt and insert one of the 36″ steel pipes to see if everything lines up. If it does, tighten the remaining hex nuts and washers holding the bolts in place. When carefully constructed, the assembly is fairly rugged.

## MICROPHONE INSTALLATION

A simple sine wave presents a very easy sound for a microphone to transduce, and virtually any matched mikes will do nicely. Again, if you don't own any, it's not much of a problem. Cheap high-impedance models are readily available for portable tape recorders, and should work fine.

I recommend using a microphone that has a smaller diameter than the PVC guides. If it's too big to fit through the guides, the entire metal pipe must be inserted from the speaker end before you install the end piece. A mike of smaller diameter can be inserted and removed from either end, making the process easier.

Once you have selected your microphones, you mount them in one end of each steel pipe, with the cords coming out the other end (*Photo 3*). How you choose to fasten the mikes depends on their shape and whether or not you will want to remove them when you're done. I chose to use duct tape. Be creative.

## CALIBRATION

With the microphones installed and the steel tubes sliding freely, you must calibrate the phase tester. First, define a reference point along the axis of the speaker, with respect to which you can make measurements. Since any differences in apparent locations will ultimately be expressed as a distance between the drivers' mounting surfaces, I chose to use those surfaces as the references. This makes calibration very simple.

So, with the microphones installed, I attached the end pieces to the speaker ends of the testing jigs before cutting the holes for the drivers. Then I simply moved both microphones toward the speakers until they came into contact with the end boards.

The PVC guides at the open ends provide excellent reference points (*Photo 2*). I simply stuck a 1″ × 3″ computer label on each steel tube, and indicated the calibration points on these labels by marking the ends of the guides with a fine-tipped pen. When both testing jigs have their reference lines even with their PVC guides, both microphones are at exactly the same point with respect to where the drivers will be mounted, and calibration is complete. You can then measure any differences in position between the two microphones against these marks, thus accurately determining each microphone's position.

## ELECTRONIC SETUP

Whereas the jigs are used to vary the location of the microphones relative to the speakers, the ancillary electronic setup is designed to control power to the speakers, compensate for levels present at the microphones if necessary, and measure relevant voltages. *Figure 7* shows a block diagram of the electrical setup. The parts list is in *Table 2*.

A sine-wave generator drives Channel A of a stereo amplifier. If you have access to a frequency counter more accurate than the indicator on your source, by all means use it. You use the amplified sine wave to power the drivers for testing, and the amplifier to drive both speakers. Don't forget that the two drivers must be connected electrically out of phase with each other.

Between the amplifier and the two drive

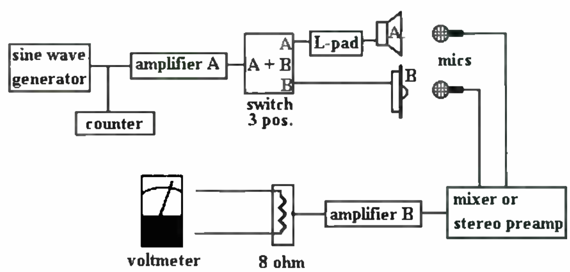



**FIGURE 7:** Block diagram of electrical test setup.

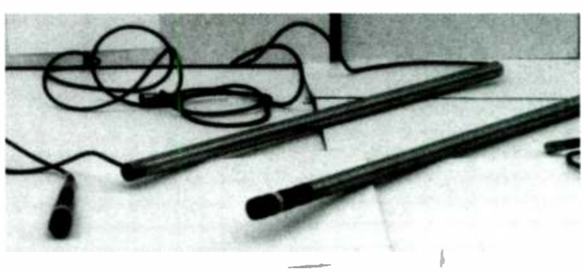


**PHOTO 3:** Installing the mikes in the steel pipes.

units is a three-position, double-throw switch. When you make a measurement of phase difference, it is necessary to equalize the test signal for levels before you can achieve complete cancellation. The easy way to do this is by switching from one speaker to the other. When levels are roughly equal, both speakers must be active simultaneously while you adjust the microphone positions. The switch makes it easy to go from A to B or to both.

When you're testing, one speaker will almost certainly be inherently louder than the other, and it can help to insert an L-pad attenuator in the path of the louder of the two drivers. You generally must attenuate tweeters with respect to midranges and woofers.

An opposing effect is the decrease in SPL as you move a microphone farther from a source, and the L-pad is useful in compensating for this as well. It may take a little experimentation with the drivers to determine which speaker to attenuate. As an alternative, you could use an attenuator on each speaker, sometimes attenuating one driver, and sometimes the other.

Each combination of drivers presents its own compensation problems, depending on their output levels and the microphone positions at the point of maximum cancellation, so you might have to experiment. As the L-pad is purely resistive, it has no effect on phase measurements in these tests.

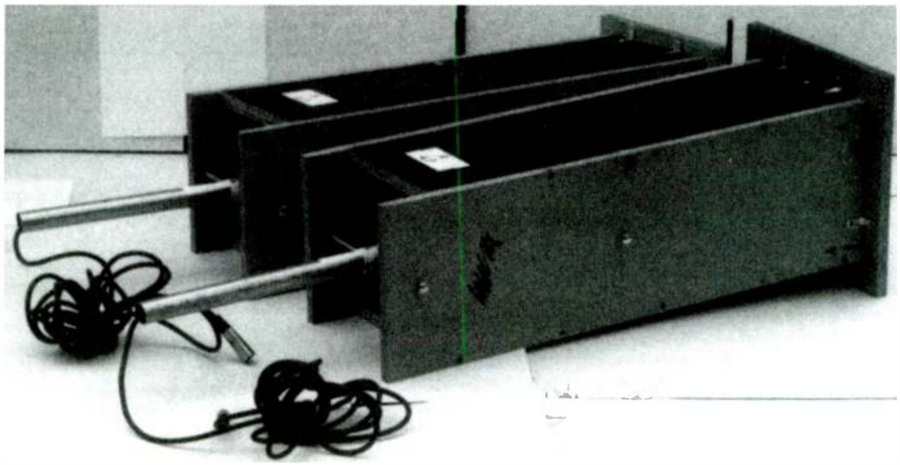


**PHOTO 5:** The phase tester ready for testing.

### THE MIXER FUNCTION

The two speakers, inside the two tunnels, provide their respective microphones with audible sine waves. The microphones are connected to a mixer, which serves as another point of level compensation between the two signals. I used an old Shure M68 for mixing. Again, the demands on the equipment are slight, and even a low-quality mixer can provide good results. Or you could use a stereo preamp, with the balance control adjusting relative microphone levels to a summed output.

Theoretically, if you use the L-pad carefully enough, this point of adjustment isn't necessary. I found it to be quite useful in my testing, however, and in any event, you must amplify the microphones' low-level signals to line level before they will be adequate to drive the second power amplifier.

This second power amplifier is the next stage. The second channel of the stereo amplifier (designated "Amplifier B" in *Fig. 7*) has one simple purpose: to boost the signals from the mixer to an adequate voltage for easy testing. This amplifier receives the summed signals from the microphones, and drives a simple resistor. The voltage as measured across this resistor indicates reinforcement or cancellation.

*Figure 7* shows an analog-style voltmeter, but in my tests I chose to use both an analog and a digital voltmeter at the same time. When searching for peaks and valleys in a changing voltage, an analog unit is nice, because a change in direction of the needle is very easy to see. A digital meter, on the other hand, is somewhat more precise when determining absolute minima. When switching between drivers to equalize levels, you achieve greater accuracy by using the digital unit as well. For fast, accurate testing, it's best to use both.

### USING THE PHASE TESTER

There follows a step-by-step description of the process of testing for phase difference between a ScanSpeak 13M/8621 cone midrange and a Dynaudio D28 tweeter. *Photo 4* shows these two units installed in the wooden tunnels, ready for testing.

After setting everything up, it makes the measuring and recording of data easier if you designate one test jig the "control" unit, and perform all the adjustments on the other one. Also, if you do all of the work on one unit, you can place the other as far away as the length of your cords will allow. (At one point, I actually moved my control unit to another room.) Although interference between the separate test jigs was at no time apparent, I felt that any step to avoid trouble was positive.

Following the default assumption—mounting the high-frequency unit behind the one with lower frequency—it should be easier to perform the tests with the lower-frequency driver as the control. You can pull the microphones far away from the drivers, but there is obviously a limit to how close

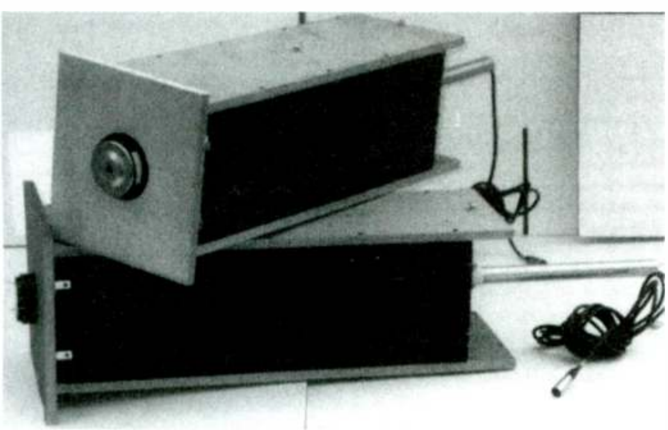


**PHOTO 4:** Testing the drivers.

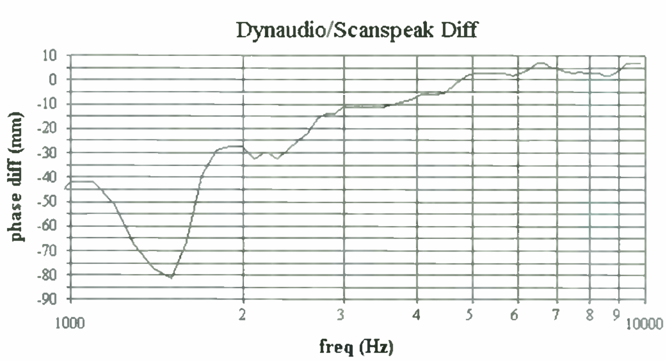



**FIGURE 8:** Phase difference vs. frequency for Dynaudio tweeter and Scanspeak midrange.

you can get them. With this midrange and tweeter, I found that testing was easier with the lower-frequency driver as the control unit. But this will not necessarily be the case with your drivers.

Once you've decided on a control unit (in my case the Scanspeak midrange), you must determine an initial position for the control microphone. Use extreme caution here. Inadvertently placing either microphone too close to its driver could easily damage the delicate cone or diaphragm. Be aware of the calibration mark made earlier, and stay away from it!

For safety's sake, a good place to start is with the microphone on the control unit pulled 1″ or 2″ back from the calibration mark. When you pull the microphone back to this resting point, carefully measure the distance between the calibration mark and the PVC guide, and make another mark at this point. Then you can pull the microphone on the "test" jig back to exactly the same point, and mark its position as well.

## WIDE FREQUENCY RANGE

I decided that phase-alignment data would be most useful if taken over a wide range of frequencies. At low frequencies, where the wavelength is quite long, you needn't worry about being off by a complete wavelength, but above, say, 10kHz, where the wavelength can be less than an inch, it's conceivable that you could be off by that much when you start. Your readings would seem correct, but the results would be flawed.

I therefore decided to start at the lowest frequency I could without damaging the tweeter, and work my way up. As the Dynaudio unit is fairly robust, I took a chance, and started at 400Hz. The wavelength at this frequency is over 2′, and it was unlikely I would miss the mark by that much.

With the control unit selected and the adjusted reference marks in place, testing can begin. For each frequency to be tested, the procedure is the same:

1. Switch the output of amplifier A from one driver to the other, using the double-throw switch, and correct levels as necessary so voltage on the load resistor stays the same as you switch back and forth.

2. Position the switch to connect both speakers at once.

3. Move the test microphone backward (away from its drive unit), and locate a minimum in the resistor voltage as clearly as possible. If you must move the microphone closer to the driver for the voltage to drop, swap control and test units.

4. Correct levels again, as in step 1.

5. Locate the position of maximum cancellation again, as in step 3.

6. Measure and record the microphone's position at this point.

## COMPLETE CANCELLATION

As you can see, this is a process of closing in on the exact point of maximum cancellation (minimum voltage) as you adjust changing levels. I found that after going through steps 1–6 twice, I was generally able to achieve near-absolute cancellation. For example, voltage on the resistor would start at about 4V for either driver individually, and decrease to 0.02V–0.04V in many cases.

The actual cancellation is so complete that the microphone position necessary for maximum cancellation is easy to determine with great precision, often well within a millimeter. You'll find that once you've done it a few times, it becomes quite easy.

When I first started the phase measurements, I made multiple marks on the computer labels affixed to the steel tubes. I found, though, that it was difficult to make sense of the many marks after the tests were done. It was much easier simply to measure the microphone displacement with a ruler as I proceeded, and to record the data separately. With a good ruler having fine gradations, in good lighting conditions, it is possible to make quite precise measurements—within .25 mm or so.

I made phase measurements on these two drivers at more than 70 different frequencies, from 400Hz to over 12kHz. *Figure 8* shows the results of the tests on these two speakers between 1kHz and 10kHz.

The effective difference in displacement of the acoustic centers of the drivers when mounted on a common plane is shown on the y-axis in millimeters. A positive number indicates how far in front of the midrange's effective location the tweeter's center lies. Over most of this range, the number is negative, meaning that the tweeter's acoustic center is located behind that of the midrange driver. This would, qualitatively at least, tend to bolster the assumption that lining up the voice coils can be helpful.

## THE IDEAL SITUATION

The ideal curve for such a graph would be a flat, straight line, indicating two speakers whose acoustic centers you could align at all frequencies simply by staggering their mounting surfaces by a distance equal to the displacement indicated by the line. With hundreds of woofers, midranges, and tweeters to choose from, it might in fact be possible to find combinations that would yield such a well-mannered curve. But alas, in the case of these two drivers, the curve is anything but flat!

Any information, however, is better than none. A close look at this curve can still be helpful. Consider these points of interest: at about 4.7kHz, the curve crosses the line of zero displacement, indicating that the two drivers are exactly in phase with each other at this frequency when they're mounted on a common baffle.

From about 2.3–6.7kHz, the overall trend is quite uniform in direction, i.e., increasing with respect to frequency. Near the middle of this region, from around 3–3.5kHz, you find the elusive flat line—not as long as you might desire, but it's a "given" in this situation.

I would be inclined then, when designing a system using these drivers, to cross them over squarely in the center of that flat line, at about 3.25kHz. The displacement at this frequency is approximately 11mm, so the tweeter's mounting surface would be behind that of the midrange by this amount. This would place the drivers precisely in phase through the region closest to the crossover frequency. By using fairly sharp filters of 18 or 24dB per octave, you would minimize in importance the phase differences above and below the crossover point.

## MAKING THE BEST OF IT

Whether such an interface is "phase aligned" is a question of degree. Many design decisions are a matter of making the best of what you have to work with, and with these two drivers, I believe phase-test data has made it possible to use the units more effectively than might otherwise be the case.

Consider that using a common baffle would represent an offset of 11mm at 3.25kHz. This would be a phase shift of about 38°. Coincidentally, because this tweeter is horn-loaded, I estimate that this mounting would very nearly align the voice coils. In this case, it would seem that you can improve somewhat upon the configuration that your default assumption would yield.

There are, of course, other design considerations involved, such as the power handling and frequency response of the drivers, which might make such a straightforward, if hasty, approach impossible. What if, for example, the only flat spot on your curve was below the tweeter's resonant frequency? It's conceivable that two drivers you had considered for use together might not be a good match in terms of phase characteristics.

With some combinations of drivers, it's entirely possible that you could achieve excellent phase-alignment using a common baffle. Others could work best with the voice coils aligned, or at some other point. To find a combination of drivers yielding a curve closer to the desired flat line would make design easier and capable of more correct phase alignment. Testing large numbers of speakers in this way can be time-consuming, though, and a perfect combination is an ambitious goal.

I never said that phase-alignment data would make crossover design any easier, only that it is necessary before you can accomplish any truly corrected design. In terms of expediency, it's much easier to keep the blinders on and rely on the assumptions we've used for years!

## CAVEATS

I must also emphasize that filter design is just as important to a system's phase behavior as anything offered here. While this article is intended to provide a means of measuring physical time-alignment data, both active and passive crossovers introduce phase effects unrelated to anything I've discussed herein.

To make things worse, if the (default)

resistor model of a moving coil's loudspeaker's impedance is used for passive filter design, any carefully measured alignment data is compromised in applicability anyway. Anyone having doubts about the inadequacy of this resistor model would do well to review Victor Staggs' excellent "Exploring Speaker Impedance" (*SB 5/94*).

Another area of concern is the question of sine-wave vs. transient reproduction. It's all well and good to define a phase difference when simple sine waves are tested, but what does it tell us about the music reproduction? My best response to this legitimate concern is that you are at the mercy of your drivers.

Some manufacturers publish relevant information, such as tone-burst pictures that show a remarkable ability to track a signal accurately under transient conditions. It stands to reason that the better your driver can accurately follow transient signals, the more valid the phase information from sine-wave tests will be. Even in worst cases, however, any information is better than none at all.

## DAMPING EFFECTS

What about installing insulation or other damping material inside the phase-testing jigs? When I first used my prototypes, I lined the tunnels with 1″ fiberglass insulation, partly because using damping materials tends to be second nature to a speaker builder. But I had concerns about internal reflections blurring the effect of cancellation at the point of minimum measured voltage, making the tester harder to read.

Later on, however, I tried making the same measurements in both an unlined setup and with the tunnels stuffed. Interestingly, the measured results were the same regardless of damping material. So don't worry about it. Also, significantly, because the speed of sound decreases in a stuffed enclosure, this demonstrates that the phase differences measured are characteristics of the drivers themselves, and are unrelated to the speed of sound in the medium into which they radiate.

The wooden tunnels illustrated in *Photo 5* are obviously not big enough to be used with large drivers. An 8″ speaker is the largest that will fit into these test jigs. In order to test a larger driver, it would be necessary to build some larger jigs. Although I haven't had a need to try this, it should work, with a simple recalibration.

## REFERENCES


1. Alexis Badmaieff and Don Davis, *How to Build Speaker Enclosures*, Howard W. Sams and Company, 1966, p. 27–28.

2. Hank Zumbahlen, "Zobels and All That," *Audio*, June 1995, p. 36.


## OTHER THINGS TO CONSIDER

If you assemble your own phase tester and want to spend some time playing with it, there are some other areas to consider. I will offer these without elaboration, as ways in which you can investigate wave activity on your own.

1. What if you were to connect the two drivers in-phase electrically instead of out-of-phase as in the tests I've shown? Could you still make accurate phase measurements? Under this different condition, of what would the point of maximum cancellation be indicative, and could its location be predicted at a given frequency from the measurements already made in the out-of-phase configuration? And how about the point of maximum reinforcement?
2. In addition to measuring displacement differences between drivers, could the phase tester be configured to determine the actual acoustic center of a driver, and if so, how?
3. Could the phase tester be used to measure the speed of sound?
4. These test results would seem to indicate a change in acoustic center of one or both of the drivers as frequency changes. What would be the cause(s) of the fluctuations in acoustic center of a drive unit with respect to frequency?

# AN EIGHT-INCH SUBWOOFER TEST BOX

By Bill Fitzmaurice

This article is somewhat of a departure, for rather than presenting a finished project, it is the story of how I devised a prototype for an alignment I have not seen described before.

My main focus has always been speakers for live performance, with my next major project a PA subwoofer. In keeping with my personal requirements, it must be very small but very loud. The main stumbling blocks in achieving this are the pro-sound drivers, which, though very efficient, tend to have $Q_{ts}$ values that are often 2.0 or lower. Optimally tuned boxes with low-$Q_{ts}$ drivers usually end up with $f_3$s anywhere from 60–100Hz—hardly adequate for subwoofer usage. Although you can lower $f_3$s through oversized boxes or horn-loading, both routes result in large cabinets. I thought there must be a better way.

**PHOTO 1:** The completed reflex box.

## SERIES-VENTED ALIGNMENT

Deciding to concentrate on a bandpass design, I examined both sealed/vented and vented/vented approaches, but neither seemed suitable, both exhibiting rather narrow passbands, and the vented/vented presenting potential patent hassles with Bose. I wondered what would happen if both the front wave (cone radiation) and rear wave (port radiation) were directed into a second chamber that was itself then vented through a duct.

I searched all my back issues of *Speaker Builder*, but found no reference to this scheme except in an advertisement from a software company, SpeakEasy, from which I got the term "series-vented." Since I don't even own a computer, the only way to check out this alignment was to build one.

Rather than use a pro driver, I found an 8″ woofer that shares pro-driver characteristics. The Pioneer model BU20FU20-52D—available as #290-067 from Parts Express (800-338-0531)—has a low $Q_{ts}$ of .22, low $V_{as}$ of 1.84, and an $F_s$ of 32Hz. By designing around this small and inexpensive driver, I could test my alignment and then transfer the results to larger versions for stage use.

My first step was to build a standard vented box to serve as a control for the experiment (*Photo 1*). I constructed a 981in³ box with a port area of 8in² and a duct 10″ long; the relatively large port area would allow for lots of leeway in tuning, without cutting it too small for proper breathing of the box. I built the port as three separate tubes of various sizes, so that I could easily seal off each one to tune the box (*Photo 2*).

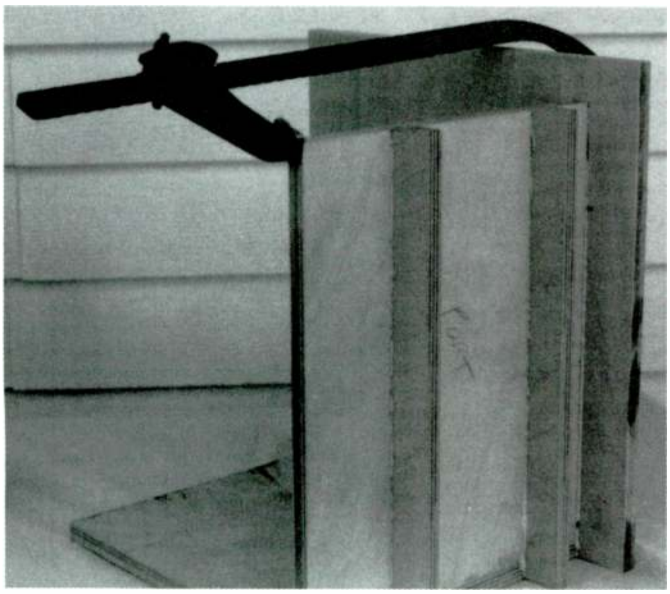


**PHOTO 2:** Assembly; note the partitions running the full length of the port, dividing it into three separate sections.

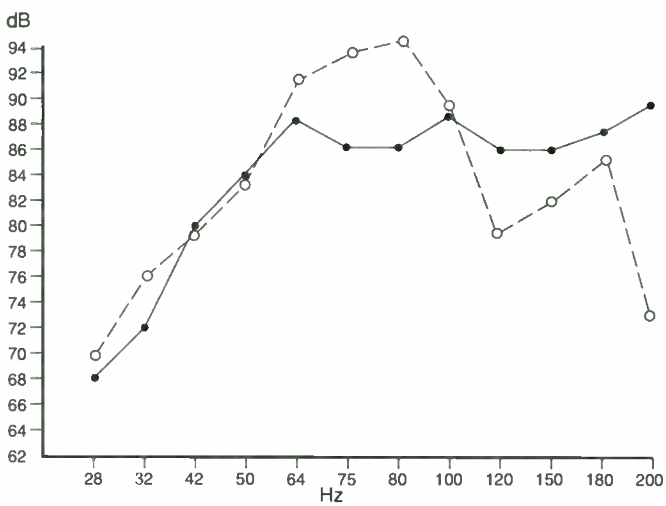



**FIGURE 1:** Preliminary test results. •—•—• = reflex box, 981in³, port 10″ deep × 8in²; o—o—o = bandpass box, double chamber, double port—front chamber, 672in³, port 10″ deep × 18in²; rear chamber, 981in³, port 10″ deep × 8in².

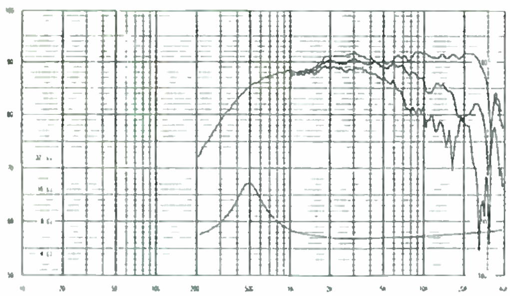
## scan-speak

### D2905/9900

**Revelator Dome Tweeter**

The D2905/9900 is our new state of the art tweeter. This "revelation" is a 1" textile dome tweeter that will reach new borders within high-end loudspeaker drive units. The new magnet system with SD caps and rings that eliminate the electrical phase shift. The new chamber design reduces air noises and compression. The 130mm machined aluminum front plate has more controlled directivity (down to 2Khz). The textile dome is hand coated and a special device is placed behind it to reduce dynamic compression.

| | | | |
|---|---|---|---|
| Sensitivity 1W/1m | 91dB | Lin. & max. excursion | ±0.5 / ±1.5 mm |
| Free air resonance fs | 500 Hz | Air gap flux density | - |
| DC resistance | 4.7 Ω | BL | 4.6 Tm |
| V.C. inductance | 0.009 mH | Moving mass incl. air | 0.35 g |
| Power | 225W | Net weight | 0.8 kg |
| Effective cone area | 8.5 $cm^2$ | Vas | - |
| V.C. diameter | 28 mm | Qms | - |
| V.C. height | 3.5 mm | Qes | - |
| Air gap height | 2.5 mm | Qts | - |



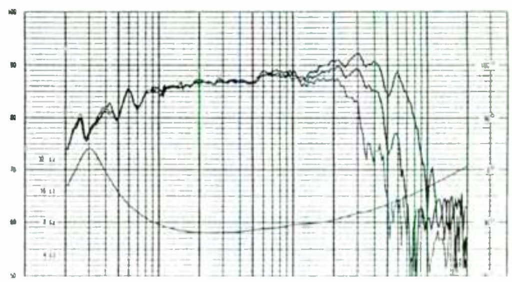
## scan-speak

### 18W/8545

**7" Carbonfibre Woofer**

This 7" features the NEW heavily damped and carbonfibre impregnated paper cone that dampens resonance's normally associated with stiff cones. The magnet system is the new SD-1 system which eliminates modulation and dynamic distortion, as well as clipping distortion created as it exceeds its maximum linear distortion. These designs all together make a drive unit with a very "open" sound with excellent detailing combined with low coloration and very precise imaging. Cast frame, rubber surround. The 18W/8545 will get down to 65Hz in a 12 ltr sealed enclosure and 44Hz in a 19 ltr vented enclosure.

| | | | |
|---|---|---|---|
| Sensitivity 1W/1m | 89dB | Lin. & max. excursion | ±6.5 / ±10 mm |
| Free air resonance fs | 29 Hz | Air gap flux density | 1.1T |
| DC resistance | 5.5 Ω | BL | 7.6 Tm |
| V.C. inductance | 0.1 mH | Moving mass incl. air | 14.7 g |
| Power | 70W | Net weight | 2.05 kg |
| Effective cone area | 143 $cm^2$ | Vas | 60 ltr |
| V.C. diameter | 42.5 mm | Qms | 2.04 |
| V.C. height | 19 mm | Qes | 0.25 |
| Air gap height | 6 mm | Qts | 0.23 |



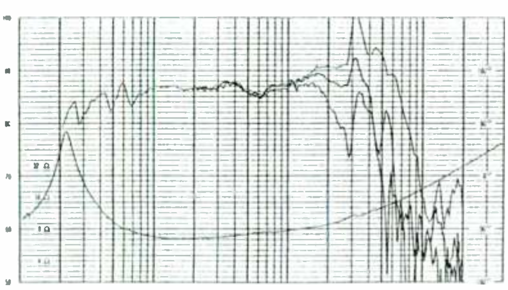
## scan-speak

### 21W/8555 & 21W/8555-01

**8" Paper Woofer / Subwoofer**

This 8" features a very stiff paper cone, heavily impregnated to reduce resonance's normally associated with stiff cones. The magnet system is the new SD-1 system which eliminates modulation and dynamic distortion, as well as clipping distortion created as it exceeds its maximum linear distortion. The low-loss rubber surround is designed for better dynamic capability, detailing and less compression. Both the 21W/8555 and 21W/8555-01 will perform well in either sealed or vented systems of the highest quality. The 21W/8555 has an F3 of 45Hz in 34 ltrs sealed and F3 of 35Hz in 50 ltrs vented. The 21W/8555-01; F3 of 50Hz in 24 ltrs sealed; F3 of 35Hz in 34 ltrs vented.

| | | | |
|---|---|---|---|
| Sensitivity 1W/1m | 87 / 87.5 dB | Lin. & max. excursion | ±6.5 & ±12 mm |
| Free air resonance fs | 20 / 19 Hz | Air gap flux density | 1.16T |
| DC resistance | 5.5 Ω | BL | 8.3 / 9.3Tm |
| V.C. inductance | 0.6 mH | Moving mass incl. air | 33 / 37.5 g |
| Power | 100W | Net weight | 2.20 kg |
| Effective cone area | 232 $cm^2$ | Vas | 145 ltr |
| V.C. diameter | 42 mm | Qms | 4.61 / 4.97 |
| V.C. height | 19 mm | Qes | 0.33 / 0.28 |
| Air gap height | 6 mm | Qts | 0.31 / 0.27 |



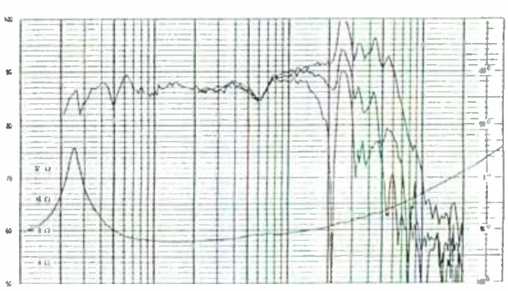
## scan-speak

### 25W/8565 & 25W/8565-01

**10" Paper Woofer / Subwoofer**

This 10" features a very stiff paper cone, heavily impregnated to reduce resonance's normally associated with stiff cones. The magnet system is the new SD-1 system which eliminates modulation and dynamic distortion, as well as clipping distortion created as it exceeds its maximum linear distortion. The low-loss rubber surround is designed for better dynamic capability, detailing and less compression. Both the 21W/8555 and 21W/8555-01 will perform well in either sealed or vented systems of the highest quality. The 25W/8565 has an F3 of 34Hz in 100 ltrs sealed and the 25W/8565-01 has an F3 of 38Hz in 76 liters sealed. The -01 could also be used vented in 100 ltrs.

| | | | |
|---|---|---|---|
| Sensitivity 1W/1m | 87.5 / 88 dB | Lin. & max. excursion | ±6.5 / ±12 mm |
| Free air resonance fs | 20 / 19 Hz | Air gap flux density | 1.16T |
| DC resistance | 5.5 Ω | BL | 8.3 / 9.3 Tm |
| V.C. inductance | 0.4 / 0.6 mH | Moving mass incl. air | 45 / 49.5 g |
| Power | 100W | Net weight | 2.2 kg |
| Effective cone area | 333 $cm^2$ | Vas | 222 ltr |
| V.C. diameter | 42 mm | Qms | 5.65 / 5.91 |
| V.C. height | 19 mm | Qes | 0.45 / 0.38 |
| Air gap height | 6 mm | Qts | 0.42 / 0.35 |



**MADISOUND SPEAKER COMPONENTS; P.O. BOX 44283, MADISON WI 53744; TEL: 608-831-3433 FAX: 608-831-3771**

*Reader Service #1*

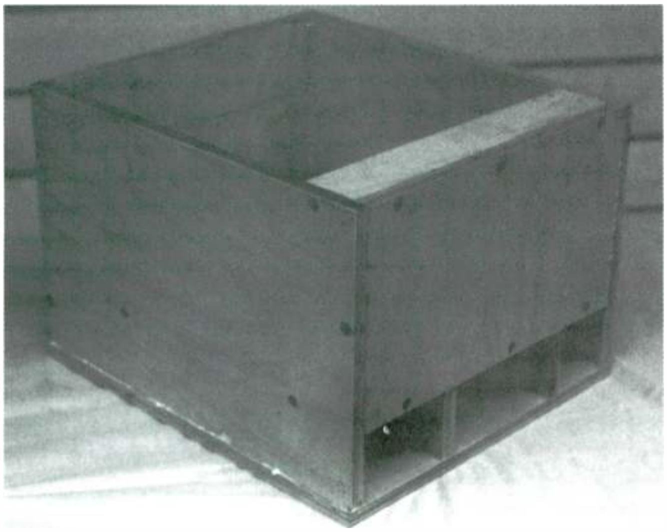


**PHOTO 3:** The completed front-chamber box.

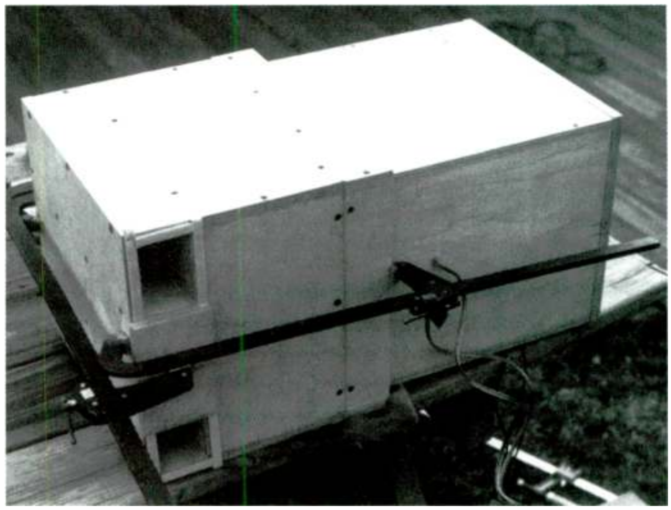


**PHOTO 4:** The two box halves clamped together and showing a port section blocked off.

In keeping with standard T/S theory, I was trying for a 50Hz tuned box, which should have given me an $f_3$ of 69Hz. Test results, however, showed $f_3$ to come in at 50Hz (*Fig. 1*), probably due to incorrect driver specs. All things considered, a box with less than $1ft^3$ total displacement and an 8″ driver going to an $f_3$ of 50Hz was not that bad, though certainly not subwoofer material.

## KEEPING IT SMALL

I next constructed a second box (*Photo 3*) to be mated to the first, transforming it into a bandpass box. Since my aim was to keep the box small, I arbitrarily set the volume of the second version at 2/3 that of the first. On the other hand, I made the port area over twice as large—$18in^2$—figuring that since the output of both sides of the cone would have to exit this single port, I didn't want port noise to become a problem.

I again set the length of the duct at 10″, and again built in three separate tubes for easy tuning. This box also incorporated a mounting flange that would allow me to mate it to the other box to produce either a single port outlet or a conventional (Bose style) dual-exit box.

I joined the boxes together with long clamps, sealing the joint between them with foam gasketing (*Photo 4*). Test results in the double-vented mode were as anticipated (*Fig. 1*), with efficiency increasing between 64 and 100Hz, and a steep drop-off in response outside the passband. Tweaking the port sizes of both boxes made no improvement. At this point I concluded that subwoofer performance from this driver was not likely, for I still couldn't get decent power below 50Hz.

## EUREKA!

Finally came the moment of truth. I unclamped the two boxes and reset them so there was only one port radiating—the series-vented alignment. I tightened the clamps and began testing. The value of $f_3$ immediately dropped to about 40Hz, while response remained flat to over 120Hz, and then rolled off gradually (*Fig. 2*). Efficiency remained the same.

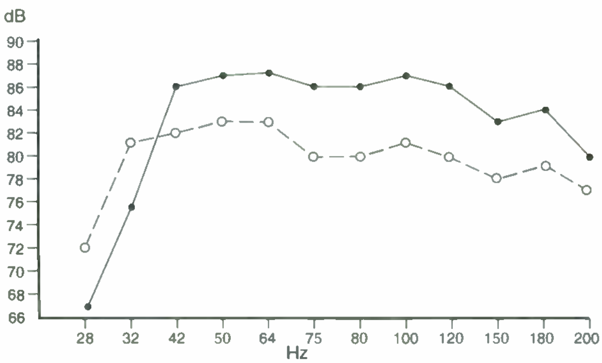



**FIGURE 2:** Dual-chamber, dual-port, single-exit box (series ports). ●—●—● = front chamber, $672in^3$, port 10″ deep × $18in^2$ exit port; rear chamber, $981in^3$, connector port 10″ deep × $8in^2$. o—o—o = exit port reduced to 10″ deep × $10in^2$.

I obtained the smoothest response by lining the rear wall of each box with $40in^2$ of 1″ "eggcrate" foam. (I found that stuffing either or both chambers with polyfill or fiberglass hurt performance.) The rolloff below $f_3$ was at a normal 24dB/octave rate. Without any alterations, I had already achieved my goal. However, I now set about tweaking operations to see what this box could really do.

First, I cut the size of the output port. With an area of $10in^2$, response at 32Hz ($f_s$) increased by 5dB, while the rest of the passband dropped by 5dB, resulting in flat (±2dB) response from 32–180Hz, a range of over 2½ octaves (*Fig. 2*).

I next reduced the size of the rear chamber by one-half. After also reducing the rear chamber's port area, I was able to regain a response close to that of the original configuration, but it was not as smooth (*Fig. 3*). By cutting the size of the rear chamber and its port area in half and shrinking the exit port to $6in^2$, I achieved a reasonably flat response from 32–120Hz with 80dB efficiency.

Doubling the size of the front chamber gave some peaking at 64Hz, but little else. Reducing the front chamber's volume by one-half and cutting the output-port area to $6in^2$ gave a response very similar to the unaltered cabinet, with a slightly steeper rolloff above 120Hz.

Decreasing the volume of both chambers with no alterations in port sizes resulted in a more typical bandpass curve, with a severe hump in the 50–64Hz range, and a second hump at 100Hz.

ORCA Design & Mfg Corp.
1531 Lookout Drive
Agoura, CA 91301 - USA
tel: (818) 707 1629
Fax: (818) 991 3072

by FOCAL.

ORCA is bringing to you from France a whole new and exclusive line of fine drive units specifically designed by Kimon Bellas, ORCA, and by Gilles Brun, FOCAL SA. Why ACCESS ?

Well think of ACCESS as "entry level", "first step". In clear, these drive units have been designed in such a way that any beginner using no other measuring instrument than a set of good ears should have 100% success designing his first system. Indeed most of these units will do great without any X-over part, or at the most with a single inductor. Now don't be fooled, nothing is more difficult to engineer than a drive unit that is easy to use. Experts do know that. And expert designers will be the first ones to dive into the ACCESS catalog !

Also, think of ACCESS as "affordable". That maybe was the toughest challenge for us: to bring you this degree of performance and ease of use at the cost of ordinary paper cone units. We did not cut corners, we cut cost through good engineering. All units feature the finest hand coated paper cones (still an art at FOCAL), alloy cast frame and, needless to say, the legendary quality of FOCAL craftsmanship. The same hands who are making the world renown FOCAL drive units are making your ACCESS drive units.

Makes sense to you ? Call ORCA for your catalog. It includes full description of each unit, large scale curves and graphs, all parameters, and two computer simulated bass response for each ACCESS unit.

| | |
|---|---|
| ACCESS 4A | Quick, high definition 4" midrange. Wide bandwidth (up to 12 KHz !). A natural and easy match for a highly transparent tweeter. . You pick the frequency and you pick the slope ! |
| ACCESS 4B | Potent & detailed 4" midbass. Clean up to 7 KHz. Very robust low end. Ideal for mini audio-video systems and very small size high quality speakers. |
| ACCESS 5A | Efficient 5" midrange. Smooth. Superb definition. It needs a good 91-92 dB tweeter for an effective match. Great for surround systems and for high quality high output 3-way designs. |
| ACCESS 5B | Solid 5" midbass, in the FOCAL tradition. Gentle roll-off around 4 KHz. Like most other ACCESS units, it can be used both in sealed and in vented cabinet designs. |
| ACCESS 6A | Efficient (92 dB +) and transparent 6" midrange. A single inductor might be all you need to get the quintessence of this beautiful drive unit. |
| ACCESS 6B | Surprising weight in the low end, which is powerful and well defined. This little woofer does not seem to be much embarrassed by any signal. |
| ACCESS 7A | Extremely smooth 7" midrange/midbass. Excellent prospect for a simple efficient 2-way bass reflex , It can also be used in surround systems main speakers, with or without a subwoofer. |
| ACCESS 7DB | Outstanding 7" dual voice coil midbass. Powerful, crisp and efficient, this drive unit will play anything your amplifier will throw with panache and relentless enthusiasm. |
| ACCESS 8A | Very efficient (93 dB +) 8" midrange/midbass. One of the truly rare 8" that can be used in 2-way designs. You will need a very good and efficient tweeter to match this unit (at least 92 dB/W/m) |
| ACCESS 8DB | Outstanding 8" dual voice coil midbass. Efficient, smooth and crisp sounding it is also capable of handling large dynamics and true low frequencies with the authority of a much larger woofer. |
| ACCESS 10A | Impact & dynamics (94 dB/W/m). If a 10" midbass can make it to the tweeter range, this is the one. Its nearly perfect roll-off will allow direct wiring without filtering. Rare unit for 2-way 10" designs ! |
| ACCESS 10B | Deep and musical 10" woofer. Ideal for medium size 3-way systems , with one of the 4", 5" or 6" ACCESS midranges. A classic. |

*Reader Service #62*

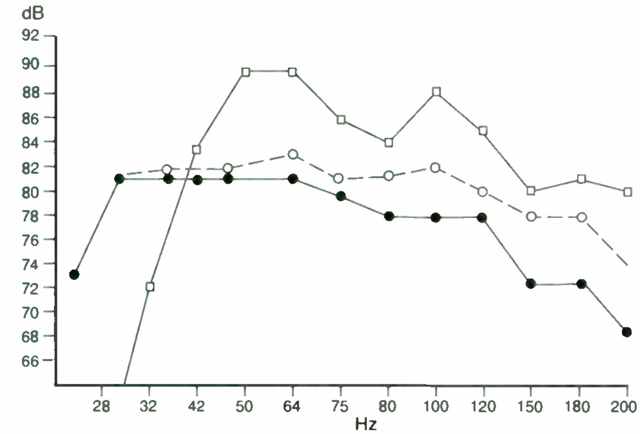



**FIGURE 3:** Reduced box and port volumes. •—•—• = front chamber, 672in$^3$, port 10″ long × 6in$^2$; rear chamber, 500in$^3$, port 10″ long × 4in$^2$. o—o—o = front chamber, 350in$^3$, port 10″ long × 6in$^2$; rear chamber, 982in$^3$, port 10″ long × 8in$^2$. □—□—□ = front chamber, 350in$^3$, port 10″ long × 18in$^2$; rear chamber, 500in$^3$, port 10″ long × 8in$^2$.

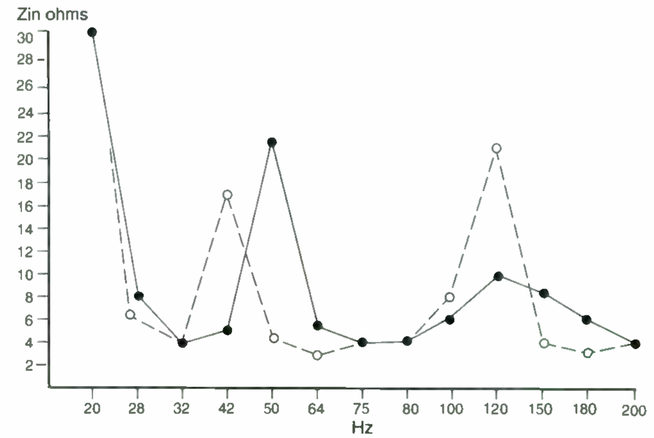



**FIGURE 4:** 8″ test-box impedance plot—series port alignment. •—•—• = exit port, 18in$^2$; o—o—o = exit port, 10in$^2$. Note the three impedance peaks, which resemble a double-vented box. Reducing exit-port size does not affect the frequency of the upper and lower peaks, but does shift the middle peak to a lower frequency, which in turn lowers the $f_3$ of the box.

## CONCLUSIONS

Several conclusions can be drawn from these test results. Obviously this alignment works quite differently than standard designs, both reflex and bandpass. Using low-$Q_{ts}$ drivers, neither of those designs can achieve flat response from $f_s$ with such a small box. Even without a loss in efficiency, my design is able to achieve an $f_3$-to-$f_s$ ratio of only 1.25; according to standard T/S theory, you cannot obtain this in drivers with $Q_{ts}$ of less than .325. Even more impressive is the fact that you can significantly reduce box sizes without major loss of response, as long as the desired output level does not result in port noise.

Overall, I am quite satisfied with my attempt to obtain low $f_3$ from a low-$Q_{ts}$ driver. Whether or not this can be translated successfully to a high-power system will be the subject of my next round of experiments.

As for my 8″ test box, it's not destined for the scrap heap. My wife's new car needs a good sub, and I think this box will work.

# A MODEST-COST THREE-WAY SPEAKER SYSTEM, PART 3

**By G.R. Koonce and R.O. Wright**

Parts 1 and 2 (*SB* 5 and 6/96) covered the design and construction of a three-way system. This part will cover some additional testing, listening results, and follow-up work after construction of the first pair of systems.

## HOW THEY SOUND

I am not up to fancy descriptions of sound quality and will leave this to others. I liked these speakers with either CO installed. A summary of my listening notes starting with the third-order CO and SEAS Tweeter are as follows:

1. Narrow "sweet spot" (typical of this CO).
2. Smooth, well-integrated transition between drivers.
3. Clear, good detail in sound and image.
4. Good overall sound, bass is "fast."
5. Image behind plane of speakers (again typical of this CO).
6. With Audax tweeter—same as above, but highs are smoother.

The first-order CO did not test as accurate as the third-order, but it is very musical, and for some music I preferred it. My listening notes with the first-order CO and Audax tweeter read:

1. Smooth, very musical.
2. Wider "sweet spot" than third-order.
3. Image is good; better than I expected from baffle tests of CO.
4. Standing/sitting sound quite equal; I had worried about this.
5. Image is more forward, extending ahead of speaker plane.
6. Image resolution not as precise as third-order.
7. I can't resolve quite as much detail in the music as with the third-order.

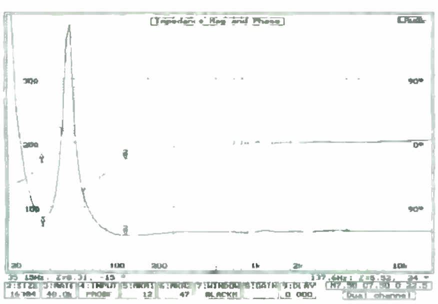


**FIGURE 40:** Enclosure B (Audax tweeter) input impedance with first-order crossover.

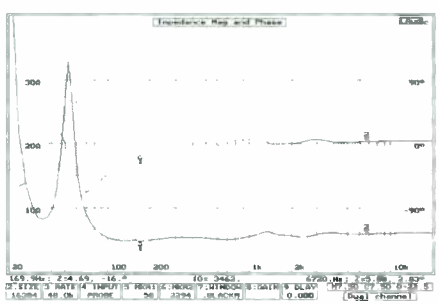


**FIGURE 41:** Enclosure B (Audax tweeter) input impedance with third-order crossover.

## FINAL TESTING

*Figure 40* shows the input impedance for enclosure B (Audax tweeter with the first-order CO). Once above the region controlled by the woofer motional impedance, the system is nearly a fixed 6Ω resistive load. The first-order CO is "constant-resistance," so this is the expected result, aided, I'm sure, by all the tricks that were needed to make the midrange impedance the same as that of the tweeter and to make the CO work with two different tweeters.

As *Fig. 41* shows, with the third-order CO, the impedance is also very consistent, but not quite as flat as with the first-order. The curves for enclosure A were nearly identical. It is clear that these are nominal 6Ω systems, with a minimum input impedance of 4.7Ω. This system might thus be a good candidate for giving those who use single-ended, tubed, or feedbackless amplifiers a smooth response in the mid- to high-frequency range.

As noted earlier, I have no facilities for testing a complete enclosure in an anechoic environment. The room where the computer is located will only support up to about a 60″ test distance, which is not sufficient for valid far-field testing of structures as big as these. I tried some 60″ tests on enclosure B to see if I could identify the problem with the third-order CO packing technique.

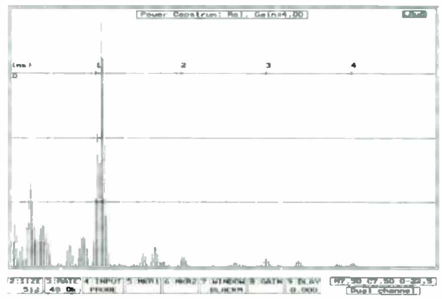


**FIGURE 42:** Acoustic response of enclosure B at 60″ with third-order crossover and Audax tweeter.

*Figure 42* shows the response of enclosure B with the third-order CO and the Audax tweeter at three microphone heights in the region of the midrange and tweeter height. The box was set up on an 18″-high chair to avoid floor echoes. I did not note whether the grille cloth was on; I suspect it was, but the grille frame was surely there. No major anomaly appeared in the 4kHz range, which is not surprising, as the sonic damage from packing this CO is subtle. These curves do verify that the relative levels of the three drivers are well matched.

## POWER QUESTION

I expect you will want to know the power capability of these systems—a hard question to answer. As best I can establish, the DJ840 woofer has a 100W power rating, which seems reasonable with a 2″ voice coil. Since it is being used to 40Hz in a vented box, the woofer is probably displacement limited, but I don't have a maximum linear-excursion value, so I can't estimate a displacement limited power.

With a lower CO frequency of 600Hz, over half the average power will go into the midrange driver. If I understand the rating for the SEAS midrange correctly, it can take a continuous *system* power input of 110W, providing the midrange is protected with at least a first-order CO at 800Hz. We would meet this requirement with the third-order CO, but not with the first-order, since the

CO frequency is 600Hz. I would be more cautious with the first-order CO installed, for the sake of protecting both the midrange and tweeter.

The systems have a sensitivity of about 89dB/2.83V/m. The highest sustained listening level I used was about 13W (into 6Ω) *average* input (average SPL = 100dB @ 1m), which was handled without distress, and I had no desire to go any louder. With music containing very heavy bass content, even this level might mean trouble. This is an 8″ woofer system designed for good sound quality and not for high-level playing. Again, it's better to show more restraint when using the first-order CO. All the resistors on the Zobel board are sized for a system-input power of under 20W. If you intend to play at a higher average level, you should increase their power ratings.

## USING THE SYSTEMS

For playing, I generally located the systems several feet from the rear wall (about 4′ to the cabinet back) and facing straight out. My spacing between the inside faces of the boxes was only about 6′; for wider spacing, toeing them in somewhat toward the listener might sound best. If your L-pads are the same as mine, then about 100° counterclockwise (CCW) rotation back from full clockwise (CW) is the anechoic flat level with the Audax tweeter. About 20° more CCW rotation should be flat for the SEAS tweeter. These tweeter levels apply to either CO type.

If you use the same construction I did, some of what I learned about changing the tweeters and CO boards might be useful. Here is the best way I have found to change the tweeter without destroying the dome (the SEAS is protected, but not the Audax). First, remove three of the four tweeter mounting screws, but only loosen the fourth. Then, when you have enough leeway to work your fingers down into the fiberglass and get a firm hold on the edge of the tweeter, remove the fourth screw and set the tweeter on top of the cabinet. Loosen, but don't remove, the screws in the barrier terminal strip and remove the tweeter pigtail.

If you do pack the COs in the area behind the tweeter, you will find CO changes are a bit twitchy. The third-order CO is very heavy and hard to handle while disconnecting the pigtails from the Zobel board. I did not want to make these pigtails any longer than necessary, but they must be long enough so you can turn the third-order CO board over to get at the terminal strips on the bottom.

## CONCLUSION

We have tried to make this more than a straight cookbook construction article by showing how the system was developed and including what techniques 60+ combined years of speaker building experience have shown to work. Unfortunately, we also had to document our failure to develop a CO packing technique free of sonic degradation. We plan to continue investigating this area.

We would be interested in hearing through *Speaker Builder* from anyone building this project. Did you try both tweeter types, and if so, which did you prefer, and why? Did you try both CO types, and if so, how did you package them, which did you prefer, and why? Did you try an alternative box construction, and if so, what was it and how did it work out?

## SOURCES

**1. Liberty Instruments, Inc.**
PO Box 1454, West Chester, OH 45071
(513) 755-0252

**2. Kim Girardin**
Homer Rd., Winona, MN 55987

**3. Madisound Speaker Components**
University Green, Madison, WI 53744-4283
(607) 831-3433

**4. Martin Sound Products, Inc.**
Alpha Park, Cleveland, OH 44143-2297
(216) 442-2286

## ACKNOWLEDGMENTS

We would like to thank the people at Martin Sound Products (Source 4) and Brian Kane at Madisound Speaker Components (Source 3) for their aid in identifying candidate drivers for this project. Without Liberty Audiosuite (Source 1), this project would not have been possible, and thanks are due to Kim Girardin (Source 2) for his fine calibrated microphones. Also thanks are due to Ed Dell and others at *Speaker Builder* for encouraging the project and evaluation of the sonics of the result. GRK would like to thank ROW for his participation and the purchase of numerous driver types evaluated for this project.

## CORRECTION

An incorrect figure was printed in "A Modest-Cost Three-Way Speaker System, Part 1" (*SB* 6/96, p. 24); the correct Figure 25 should appear as follows.

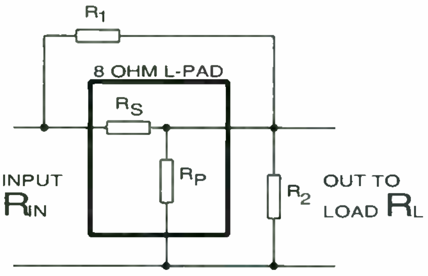



**FIGURE 25:** Schematic for L-pad modification.

## DESIGNING YOUR OWN BOX

Once you start changing things, you are on your own. Please make sure the woofer box is stiff enough to maintain the fast bass of which this woofer is capable. The following concerns are critical if you want to get sounds similar to those this project produced:

1. Don't make much change in the spacing of the drivers on the front panel, as all the crossover development work is based on this spacing. Sliding the midrange driver and/or the tweeter slightly off cabinet center line probably would not much change the summation response.
2. If you greatly change the woofer height or overall box width, you will change the "diffraction rise" (woofer $4\pi$ to $2\pi$ radiation transition) frequency range and thus the lower midrange performance of the system.
3. Design the front-panel slant angle and midrange height so that when you're seated, your ears are on a line to the midrange center that is about 5° below the on-axis midrange line.
4. Do not decrease the volume of the midrange chamber very much, or you will move the midrange system resonance (now 141Hz) up too high and hurt the performance of the first-order CO.
5. Either omit the grille cloth and frame, or put the damping material on the front panel.
6. Any change in the type of CO used defines a whole new system!

An alternative layout with a pedestal below the diffuser port is a candidate for consideration. It may be tough to get both COs packaged in this pedestal area if it is the same width as the box. Making a removable pedestal with a larger footprint would probably be best. I have packaged the CO in such pedestals many times in the past without trouble.

There is no reason you could not add a pedestal about 3″ high under the box we used, since the resulting woofer height would still be below what we used in the breadboard listening tests. Moreover, the listening angle would be better (down 5.3° rather than 3.9°). Since the port duct fires against the pedestal, it should be very stiff to avoid vibration. And remember that the box must stand in the correct position on the pedestal when you tune the woofer. You could still design the Zobel board to mount behind the tweeter for easy L-pad access. — *GRK*

# KITS AND MORE

*from*

OLD COLONY SOUND LAB

## Woofer Wizard-Assembled Subwoofer Filter

**KF-7A $99.00**
***By Auto Sound Lab***

This mathematically-correct bass compensation device has been researched and tested for more than eight years in virtually every kind of vehicle—and it's been used successfully in the home! Its unique tuning capabilities allow it to work equally well with closed box, ported box, or trunk-mounted free-air applications. Because the filter extends low frequency cutoff, smaller systems can be made to reproduce frequencies much lower than normally expected.

Fully assembled and made in the USA from high-quality components, the unit measures 1 1/4″ H × 4 3/8″ L × 2 1/4″ D. Four phono jacks for input. Two small L-bracket clips for side mounting included. Instruction and application manual. Designed by Daniel L. Ferguson, author of *Killer Car Stereo on a Budget* and the newly updated edition, *Ultimate Auto Sound*. Shipping weight: 2 lbs.

## Muller Pink Noise Generator Kit

**KSBK-E4 $49.00**
***By Bernhard Muller***

This unique kit features a stereo/mono/reverse-polarity switch that distinguishes it from other generators. CMOS digital circuits form a pseudo-random bit stream generator switchable between mono, stereo, and stereo reverse, and another switch selects pink or (optional) white noise output. Pink noise rolls off between 16Hz and 20kHz at 3dB/octave and at 6dB/octave above 20kHz, while white noise is constant through the 16Hz-20kHz range.

The unassembled kit comes with a 4 1/8″ × 2 3/16″ PC board, IC, precision resistors and capacitors, and switches. Case not included. White noise option requires additional .0022 microfarad cap and 1.8k resistor (not supplied). The unit is powered by a 9V battery (not included). An article reprint is included. Shipping weight: 1lb.

## Assembled Muller Pink Noise Generator

**KSBK-E4A $79.00**

Assembled unit, case is not included. White noise option requires additional materials (not supplied).
Shipping weight: 2 lbs.

## Warbler Oscillator Kit

**KK-3 $119.95**
***By Dick Crawford***

This popular unit will produce a swept signal covering any 1/3 octave between 16Hz and 20kHz. The total harmonic distortion at the output is less than 1.5%, and the output voltage is adjustable from 0–1V. When used with a microphone, the Warbler is more effective than a pink noise source in evaluating speaker system performance. It also reveals the listening environment's effect on sound through reflection and absorption. The sweep rate is set at about 5Hz.

The unassembled kit includes the 3 1/4″ × 3 3/8″ PC board, transformer, all parts and article reprint. Case is not included. Shipping weight: 3 lbs.

**Assembled Warbler Oscillator KK-3A $159.95**

The Assembled Warbler includes the assembled PC board, case not included. Shipping weight: 3 lbs.

---

OLD COLONY SOUND LABORATORY PO Box 243, Dept. B96 • Peterborough NH 03458 USA Tels. 603-924-6371, 603-924-6526 Fax 603-924-9467

❑ Yes! Please send me

| Qty. | Part # | Description | Price Ea. | Total Price |
|---|---|---|---|---|
| | | | | $ |
| | | | | |
| | | | | |
| | | | *Shipping | |
| | | | Handling | $ 2.00 |
| | | | Total Order | $ |

• Mastercard • Visa • American Express • Discover • Check or Money Order in US Funds Drawn on US Bank •

CARD # ____ Expiration Date ____

TEL/FAX ____ Today's Date ____

Name ____

Street ____

City ____ State ____ Zip Code ____

**SHIPPING BY WEIGHT:**

| Weight in Lbs. | Domestic (UPS) | Canada (Air) | Rest of World Surface | Rest of World Air |
|---|---|---|---|---|
| 1-3 | $ 5.00 | $ 8.50 | $11.00 | $23.00 |
| 4-6 | $ 5.50 | $12.50 | $17.00 | $39.00 |
| 7-9 | $ 6.00 | $16.00 | $23.00 | $56.00 |

## EFFECTS OF GRILLE FRAME AND CLOTH ON TWEETER PERFORMANCE

It has been my belief that one of the major effects of adding a grille (frame and cloth) to a tweeter is to cause delayed reradiated highs that time-smear the high frequencies and adversely affect their clarity. In the past, I had no way to measure this effect, but the latest versions of Liberty Audiosuite (Source 1) provide cepstral analysis, which reports delayed echoes.

I will not describe this technique; for that, see "Round the Horn," by Philip Newell (*SB* 8/94, p. 24), and "Reflecting on Echoes and the Cepstrum," by Bill Waslo (*SB* 5/96, p. 20). Basically, what you would like to see on the power cepstrum plots I will present here is nothing. Any spikes that appear on these plots indicate delayed echoes, which appear on the plots when they are delayed from the original signal.

For example, I measured the on-axis response of a tweeter with a side reflector placed so as to produce a path from tweeter to reflector to microphone that was about 1ms longer than the direct path. *Figure 43*

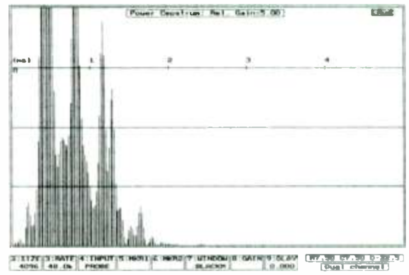


**FIGURE 47:** Power cepstrum results for planar tweeter, case 2.

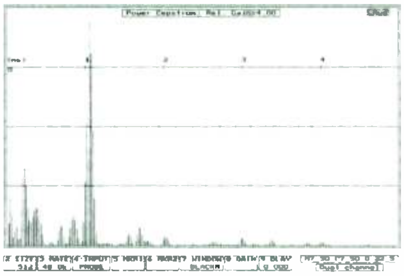


**FIGURE 43:** MG Ribbon tweeter on-axis response, with 1mS echo back.

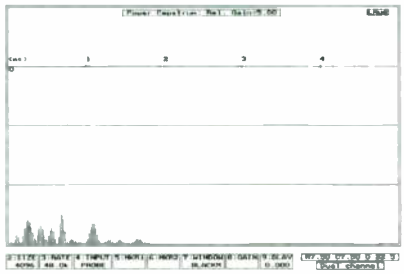


**FIGURE 45:** Power cepstrum results for planar tweeter, case 0.

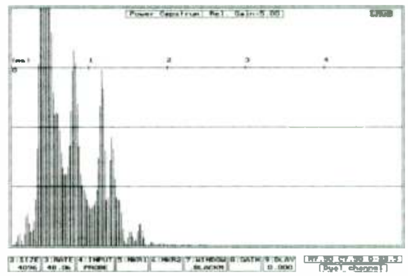


**FIGURE 48:** Power cepstrum results for planar tweeter, case 3.

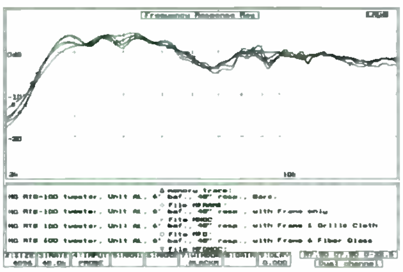


**FIGURE 44:** On-axis response for planar tweeter for cases 1 to 5.

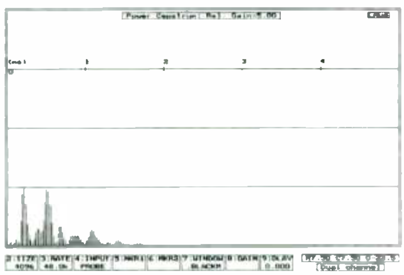


**FIGURE 46:** Power cepstrum results for planar tweeter, case 1.

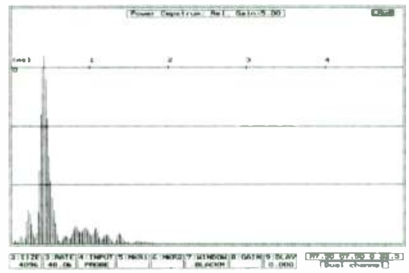


**FIGURE 49:** Power cepstrum results for planar tweeter, case 4.

shows the power cepstrum results: an echo group centered just past 1ms, which indicates I slightly missed my reflector placement.

### TESTING SETUP

For this testing, I kept all Audiosuite processing gains constant, so you can directly compare the plots. I did the testing with a grille frame that set the grille cloth out 1″ from the front panel, an excessive amount, but selected so that delay effects would be clearly visible. Assuming the tweeter radiates from a point flush with the front panel, any energy that bounces off the grille cloth and reradiates from the front panel would be late by about 0.15ms and multiples thereof.

For the tests, I selected the planar MG RTB-100 tweeter because when "bare" it is cleaner than most dome tweeters and quite flat to past 20kHz. I tested it under the following conditions:

Case 0: Standing free on a column smaller than the tweeter. This case shows delayed echoes due to the tweeter's own structure.

Case 1: Mounted in a bare 6″ test baffle.

Case 2: A 1″-deep grille frame made of 5/8″ particleboard was taped to the baffle. The inside dimensions of the frame were 10.5″ wide by 14″ high, and it was positioned with its inside top edge about 4.5″ above the center of the tweeter, which is typical of a small two-way system.

Case 3: The same frame, covered with one layer of thin, black Radio Shack grille cloth (part # 40-1935).

Case 4: The grille cloth was removed and the front-panel area inside the grille frame (but not over the tweeter structure) covered with 1″-thick fiberglass.

Case 5: As in case 4, but with the grille cloth reinstalled.

### TEST RESULTS

*Figure 44* shows the measured on-axis frequency response of the tweeter for cases 1 to 5. The initial reaction is that the grille has little effect; in terms of frequency response, this is true. Once familiar with cepstral analysis, you learn to look for a periodic ripple on the frequency-response plot, which is very evident in the 3–5kHz range on several of these curves. As explained in Bill Waslo's article, this is what a delayed echo produces.

*Figure 45* is the power cepstrum for case 0, which is quite clean. I was not able to correlate the delay time of any of the echo groups to the path-length difference from the edges of the tweeter. *Figure 46* shows the results for case 1, which is slightly worse than case 0, but still quite clean. Again, I can't account for the two major echo group delays, or why they are different from case 0, except that the test distance changed from 18″ to 48″.

When the frame is added (case 2), *Fig. 47* is the result. Now you surely see delayed echoes. The first two large echo groups correspond well in time with echoes occurring from the symmetrically spaced sides of the grille frame and the bottom frame edge. The top frame-edge echoes are probably buried in the first large echo group. It is clear that the bare grille frame alone can be very destructive to the clarity of the highs.

Case 3 adds the grille cloth, and, as *Fig. 48* shows, you can't really distinguish the effect from that of the bare frame; (it is slightly better for echoes from the frame bottom). There is a slight increase in very early echoes, but compared to the frame echoes, this can probably be ignored.

Case 4 (*Fig. 49*) adds the fiberglass cover without the grille cloth, and the improvement is evident. The frame-side echoes dominate, clearly indicating the merit of offsetting the tweeter from the front-panel center line. Finally, case 5 (*Fig. 50*) reinstalls the grille cloth, somewhat increasing early echoes.

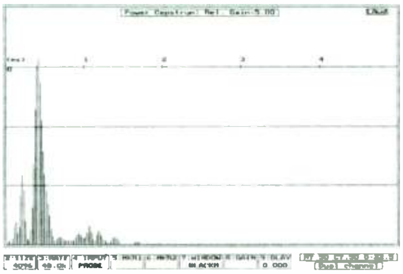


**FIGURE 50:** Power cepstrum results for planar tweeter, case 5.

## WITH THE AUDAX

The Audax 1″ dome tweeter behaved much the same as the planar tweeter, so I'll show only three plots to make two points. *Figure 51* shows the case 0 results, where the Audax displays higher echoes in its structure than the planar tweeter. *Figure 52* shows that the results for case 5, fiberglass and cloth, are not too bad except for the echo group at about 0.18ms. This seems to be an exaggeration of some echo shown in the basic tweeter structure.

*Figure 53* shows what happens in case 5 if a far more dense grille cloth is substituted. It

*to page 43*

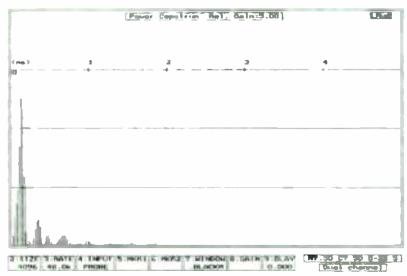


**FIGURE 51:** Power cepstrum results for Audax tweeter, case 0.

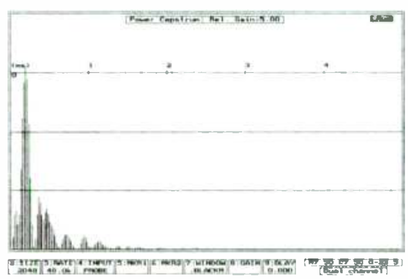


**FIGURE 52:** Power cepstrum results for Audax tweeter, case 5.

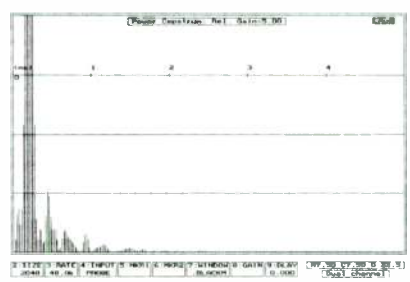


**FIGURE 53:** Power cepstrum results for Audax tweeter, case 5 with dense grille cloth.

## LISTENING TO THE K/W SYSTEM

**By Edward T. Dell, Jr.**

Two very large, heavy packages, along with a smaller one, arrived one snowy morning almost a year ago via UPS. I began to open the larger ones in my kitchen, only to discover they were boxed twice, with lots of plastic peanuts between the outer box and the inner one. When I finally managed to unpack the two large parcels, I had before me the results of at least two years' work by the Koonce/Wright team.

The things would have won no beauty contests, being made of heavy particleboard and looking more like short-legged tilted-back giant bookends, since no driver of any kind was visible on what I assumed were the fronts. The backs had very large slots in the top section. On opening the smaller box, I found not two but four crossover modules mounted on inverted T-shaped pieces of the same heavy particleboard stock, plus the two alternative tweeters.

Finally, discovering the copious instructions from G.R. Koonce, I learned that I must remove two heavy particleboard covers from the sloping fronts of the two boxes, which protected the drivers in transit. Having set these aside, I successfully wrestled the two units into place without suffering a rupture or other ill-effects.

The four complex crossover networks (including a remarkable body count of parts in each) turned out to be one more indication of the kind of thorough exploration G.R. is willing to undertake for any project.

My system consists of Audio Concepts Sapphire IIIs with subwoofers. These are driven by four amplifier units, two of them stereo and two monoblocks. These are wired directly to each of the three drivers in the ACI units. The monoblocks are Adcom GFA 565s rated at 300W each. The stereo pair are Adcom GFA 585s, Limited Edition, rated at 250W/channel, each of which drives one side of the system. In this way the only common connection between the left and right channels is in the Adcom GFP 565 preamp.

I disconnected my usual system, carefully shorting the terminals of the ACI drivers to avoid interaction. However, since the Koonce/Wright pair was not wired for tri-amping, I connected them to the two monoblocks, installing crossover 1 first. My listening room is ideal, measuring 13w x 7h x 32 feet with a cement floor, and covered with wall-to-wall carpet.

I am quite familiar with the sound of my regular system, having a series of "demo" disks which I use to show it off to friends.

I kept the K/W system in place for almost a month, listening to all sorts of material. But I went back time after time to my standard disks. Halfway into the month I changed the tweeters and crossovers. I left these in place for only three days, since to my ear the top end was tipped up with an edge not present with the original set.

From the beginning of my listening sessions, I was constantly surprised at the very small differences between the Koonce/Wright pair and my own system. I noted a slight difference in definition and soundstage, especially in the midrange. I heard no difference of any significance in the bottom two octaves—both in frequency range or in level. I'd consider the bass genuinely impressive, especially since the bass driver is so inexpensive.

The system sounded quite well integrated, with a smooth response across the spectrum. The stage depth was not quite as good as with my comparison system, however. This could be the result of single amp vs. tri-amp configuration. In long-term listening, I did not notice any fatigue.

All in all, the system Koonce and Wright have crafted is an excellent example of a carefully structured system matching the drivers to the box and to the compensation and filter networks. Those who build the system carefully, following the parts lists and schematics, plus the physical layout of the box, will have a very satisfying system at an amazingly low cost.—E.T.D.

# Audiophile Sweepstakes

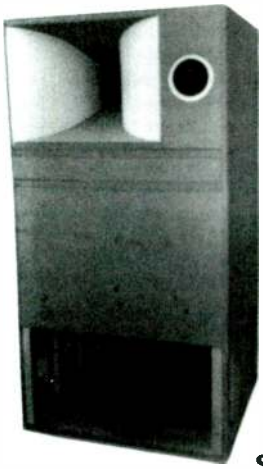
## Enter and win one of these exciting prizes!

Simply complete and mail the reader service card in this issue or the coupon below and you will be automatically entered in our third and biggest yet, Audiophile Sweepstakes:

## GRAND PRIZE

Our grand prize winner will receive a pair of **Electra-Print Audio 130EP Single-Ended Monoblocks** to drive his new **Edgarhorn System 80 horn system!**

Each monoblock uses a matched pair of Svetlana 911-3's and an exclusive dual tuned choke power supply to deliver 30 Watts of clean, reference-quality power. The design is reminiscent of the old McIntosh 75s.



A breakthrough in horn folding technology has allowed the utilization of a JBL 5″ monitor woofer on a 5′ long 80Hz bass horn. This high performance horn system is ideal for use with low power single ended triode amps. Unlike most other horn systems it can be used in small listening rooms.

## FIRST PRIZE

**The Audio Alchemy DDS Pro CD Transport**

This new dual-chassis transport has the advanced new Pioneer "stable platter" CD transport system and offers both I²S & SPDIF digital output. This unit comes complete with full-function remote and detachable AC mains cord with integrated line filtering.


## SECOND PRIZE

**The Davidson-Whitehall Storadisc™ Library Series LS-360 CD storage unit**

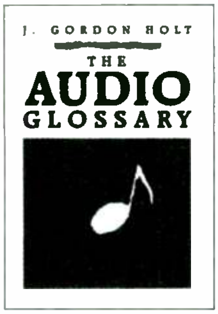
This unit, given an A+ rating in the December 1995 issue of *Audio* and chosen as *CD Review's* top choice in a 60 product comprehensive comparison, stores 360 CDs with a non-slip surface that holds even a single CD upright. This fine furniture-quality storage unit is a perfect balance of function and elegance. From Davidson-Whitehall of Atlanta.

## 3 THIRD PRIZES

Three of our readers will receive a $100 gift certificate from **International Audio Group** towards the purchase of the renowned **Sowter transformers**. Choose from a large selection of standard design push-pull or single-ended output, power, electrostatic loudspeaker, moving coil, or line transformers or custom design your own!

## 25 FOURTH PRIZES

**The Audio Glossary by J. Gordon Holt**




This sweepstakes is void where prohibited by law. All entries must be postmarked by December 31, 1996. Multiple entries are allowed and encouraged. Employees and relatives of employees of Audio Amateur Publications are ineligible for this sweepstakes. One entry per envelope please.

Name:

Address:

City: State: Zip:

[ ] Please enter my name in the Third Audiophile Sweepstakes
[ ] I'd like information from the advertisers in the following magazine(s):

O **Speaker Builder** **Issue # O#4 O#5 O#6 O#7 O#8**

O **Glass Audio** **Issue # O#4 O#5 O#6**

Reader: Please circle the reader service number as seen at the bottom of an advertisement in the magazine(s) about which you want information. For more, please see card in the magazine.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
| 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
| 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |

# *Speaker Builder* BACK ISSUES

**1981** A Testing Unit for Speaker Parameters • Variable-Volume Enclosure • Thiele/Small Theory, Pt 1-3 • Easy to Make Enclosure Using Concrete Blocks • The Tractrix Horn: Good Dispersion From an Old Design • Diffuser Port for Small Boxes • Mini-Speaker Made From PVC Tubes • Closed vs. Vented Box Efficiency • Interview with P.G.A.H. Voigt • Dual 8" Symmetrical Air Friction Enclosure • Thiele/Small Calculator Computation • Thiele/Small Parameters for Passive Radiators •

**1982** Transmission Line Theory • Thiele/Small Sixth-Order Alignments • The Quad 63 • Table Saw Basics • AR-1 Mods • Active Crossover and Phase • Three Transmission Line Speakers • A Beginner's First Speaker • How Passive Networks Interact with Drivers • Horn Loaded Heil • Phase Correcting Active Crossover • Wind Your Own Inductors • Series and Parallel Networks • High Performance Corner Speaker • Using Zobels to Compensate for Driver Characteristics •

**1983** Building the Two-Way Dynaudio • A Crossover That Offsets Speaker Impedance • Using a Calculator for Box Design • Choosing a Calculator • A Simple Peak Power Indicator • A Small Horn Speaker •Audio Pulse Generator • How to Use Speaker Pads and Level Controls • An Easy-to-Build Voltmeter for Speaker Measuring • Nomograms for Easy Design Calculations • Interview with KEF's Raymond Cooke • Build a Simple Wattmeter • A New Type of Speaker Driver •

**1984** Build an Aligned Satellite/Woofer System • BOXRESPONSE: A Program to Calculate Thiele/Small Parameters • Casting with Resins • A Phase Meter • An Interview with Ted Jordan • Building the Jordan-5 System • Self-Powered Peak Power Indicator • Closed Box Design Trade-offs • How to Build Ribbon Tweeters • Build a Dual Measurement Impedance Meter • A High-Power Satellite Speaker Sys-tem • Build and Use a White/Pink Generator • Sound Pressure Level Nomographs •

**1985** OUT OF PRINT, some single issues still available at $7 each •

**1986** The Edgar Midrange Horn • Sand-Filled Stands • Crossover Networks: Passive and Active • 5-sided Boxes • A 2 x 4 Transmission Line • The Free-Volume Subwoofer • Notch Filters • By-Wiring the LS3/5A • A Push/Pull Constant Pressure System • Current and Power in Crossover Components • The Unbox (Egg) • Upgrade Speakerlab's S-6 Crossover • Measure Speakers with Step Response • A Gold Ribbon System • A Visit with Ken Kantor • A Tractrix Horn Design Program • Reviews: Audio Concepts "G"; Seven TL Midranges; Focal's Model 280; the Audio Source RTA-ONE.

**1987** A Compact TL Woofer • Frequency Response and Loudspeaker Modeling, Pt 1-3 • A Manual Coil Winder • The Model-One Speaker • Designing a Listening Room • A Sixth-Order Vented Woofer • Tapered Pipe Experiments • Visiting Boston Acoustics • A Vented Compound System • The Octaline • Spreadsheets for Speaker Design • In Memoriam: Richard Heyser, Pt 1-2 • Using Non-Optimum Vented Boxes • Building Speaker Stands • Evaluating Driver Impedance Compensation • Tuning Bass Reflex • Six Woofers Compared • Bullock on Passive Crossovers: Alternate Bandpass Types • Fast, Easy Filter Calculations • A Mobile Speaker • Polk 10 Mod •

**1988** Electronic Turns Counter • Two-Way Design • Minimus-7 Mod • Dome/Midrange/Tweeter Array • Plotting Complex Impedances • A Driver Design Primer • A Cabinet Primer • Tuning Up Old Systems • Low-Cost AR-3 Upgrade • Electronic Time Delay • Enclosures Shapes and Volumes • Minimum-Phase Crossovers • Spot Sound Absorbers • How to Add a Subwoofer • The Swan IV System • Sub-Bass Power Boosting • The Unline: A Short TL • Active Filter Computer Design Program • Low-Cost Two-Way Ribbon • Amp-Speaker Interface Tester and Construction Plans • The $QB_3$ Vented Box is Best • A Pentagonal Box System • Keith Johnson Profile • Sheathed Conductor ESL • A Symmetrically Loaded System, Pt 1 • Ceramic Enclosure • Inductance Measuring Technique • Polk 10 Mods •

**1989** (4 Issue Set: VERY LOW STOCK) The Audio Laboratory Speaker System • A Passively Assisted Woofer • Digital Filter Tutorial • The Listening Arc Alignment • Small IC Power Amp & Crossover • Easy Surround Sound • Building Speaker Spikes • An Isobarik in a Thunderbird • Sheetrock Cabinetry • A [illegible] Speaker • Servo Controlling [illegible] R-1 • [illegible]ent, Safe Muting System • Equalizing the Klipsch Cornwall • A Test Switcher • Visiting the Klipsch Kingdom • Rehab for Kitchen Music • Spreadsheet Design • A Subwoofer/Satellite System • Impedance Measurement as a Tool • Practical Passive Radiators • A Symmetrical Dual Transmission Line, Pt 1 • The Microline • A Voice Coil Wheatstone Bridge • Tweeter Q Problems •

SOLD OUT

**1990** Acceleration Feedback System • Cylindrical Symmetrical Guitar TLs • Compact Integrated Electrostatic TL, Pt 1-3 • Minimus-7 Super Mod • The Show (Bass Horn) • A Small Two-Way System • Helmholtz Spreadsheet • Heresy Upon a (Klipsch) Heresy • Beer Budget Window Rattler • Contact Basics • MDT Mini-Monitor Speaker System • Titanium + TPX + Polypropylene = Fidelity • Tom Holman, Skywalker, and THX, Pt 1-2 • Bud Box Enclosure • Klipschorn Throat Riddle • Modular Three-Way Active Speaker • CD Speaker System • SPEAKER DESIGNER Software • Symmetrical Isobarik • Novice Crossovers • Triamplified Modular System • Magnetic Crosstalk in Passive Crossovers • Mitey Mike Loudspeaker Tester • Symmetrical Loading for Auto Subwoofers • Improved Vented Box with Low $Q_{TS}$ Drivers • BOXMODEL Woofer System Design Software • Four Eight By Twos • Dynaco A-25 Mod • Klipschorn Throat Revisited •

**1991** Students Building Systems • Servo Subwoofers • An Apartment TL • L-R Crossover for the Swan IV • More or Less Power • New Guidelines for Vented Boxes • The Pipes • Macintosh's Wave and Sound Programs • Creating Professional Looking Grilles • Octaline Meets D'Appolito • Using Radar to Measure Drivers • Deep Bass for GMC • PSpice LF Response Calculating • Pipe and Ribbon Odyssey • The Delac S-10 • Infrared Remote Volume Control • Backloaded Wall Horn Speaker • Mod for the Minimus 7 • Simplifying Cabinet Assembly • Fibrous Effects on TLs • The DOALs • Loudspeaker Cable • Speaker to Ear Interface • Speaker Sensitivity to Errors in T/S Parameters • TL Speaker Evaluation • Cable and Sound • Kit Reports: Little V; Audio Concepts' Sub-1 •

**1992** Rumreich on Box Design & Woofer Selection • MLSSA • Double-Chambered Reflex by Weems • Active Crossover and Delay • Electrical Circuit Bandpass Enclosure • A Dreadnaught System (satellite swivels) • Designing Real-World Two-Way Crossovers • 20-foot Ribbon Dipole Speaker • Biamping the Sapphire II • Capping Passive Crossovers • A High Quality Speaker Cabinet • 1/3-Octave Noise Source • Disappearing Loudspeaker • The A&S Soundoff Winner, Pt 1-2 • Alignment Jamming • Marc Bacon's "Danielle", Pt 1-2 • Double-Chambered Isobarik Bass • Ferguson's Pickup Installation • Electronic Counter for Coil Winding • Oakley on Speaker Placement • Making Your Room Hi-Fi, Pt 1 • More on Dust Caps • Spreadsheet for Nonoptimum Vented Box Design • Acoustic Resistance Tuned Enclosure •

**1993** Waslo's IMP, Pt 1-3 • Quasi-Monotonic Vented Alignments • Making Your Room Hi-Fi, Pt 2-3 • A&S Soundoff Winner, Pt 3 • Flexible Dipole Woofer • The Simpline • Stalking $F_3$ • A Bi-Structural Enclosure • A Sixth-Order T/S Subwoofer Design • Speaker Enclosure Screws • Electric Bass Tri-Horn • Prism V Satellite/JBL Subwoofer, Pt 1-2 • Fitduct: Program for Designing Duct Software • Compact Coincidental Point Source Speaker • IMP: Measuring T/S Parameters • KIT REPORT: Rockford's Beginner Software/Driver Paks • SOFTWARE REPORT: Low Frequency Designer 3.01 • Three Affordable Measurement Microphones • Two Ways to Realize a Dream • Matching Driver Efficiencies • Two-Woofer Box System • Designing a Dual Voice Coil Subwoofer • SOFTWARE REPORT: Blaubox 1.2 • Tale of Three Speaker Projects • A&S Sound-off 1992 • Monolith Horn • Orbiting Satellites • Real-World Three-Way Crossovers • The Simplex • Living with a Speaker Builder • The IMP Goes MLS •

There's More ☞

Please send me the following back issues of Speaker Builder

❑ 1995 $32 ❑ 1994 $32 ❑ 1993 $25 ❑ 1992 $25
❑ 1991 $25 ❑ 1990 $25 ❑ 1988 $23 ❑ 1987 $20
❑ 1986 $20 ❑ 1984 $18 ❑ 1983 $18 ❑ 1982 $18
❑ 1981 $18

**SHIPPING BACK ISSUES**

| | | |
|---|---|---|
| UPS: | Domestic ground service by value of order: | |
| | Less than $60.00 - $4.50 | $131.00-220.00 - $8.50 |
| | $61.00-130.00 - $6.50 | $221.00+ - $10.50 |
| Canada: | Add $6.00 per year. | |
| Foreign Air: | Europe add additional 40% of total order. | **Total Magazines** ______ |
| | Other destinations: 50% of total order. | **Postage** ______ |
| Foreign Surface: | Add additional 20% of total order. | **TOTAL ENCLOSED** ______ |

Rates subject to change without notice. All remittance in US $ only drawn on a US bank.
Make checks payable to Audio Amateur Corp.

❑ Check or Money Order ❑ Discover ❑ MC ❑ VISA

DISCOVER/MC/VISA NO. ______ EXP. DATE ______

NAME ______ ACCOUNT NO. ______

STREET & NO. ______

CITY ______ STATE ______ ZIP ______

*Speaker Builder*

Post Office Box 494, Dept. B96, Peterborough, NH 03458-0494
(603) 924-9464 FAX (603) 924-9467

Answering machine for credit card orders only–before 9:00 a.m., after 4:00 p.m. and weekends
Please have all information plus MC/VISA available.

*from page 40*
is clear that with the Audax, the grille-cloth density has a major effect, and the echoes here may be grille-cloth reflections that reecho from the tweeter face plate, which is not covered with damping material, but perhaps should be.

The SEAS tweeter is a bit of an anomaly. It is quite clean by itself (it has a rather "flat" dome) and, for some reason, was not bothered as much by the frame. The very worst case with this tweeter was with the grille cloth and fiberglass covering (case 5), a result I can't fully explain, but suspect the following. This tweeter is constructed with the dome located rather deep behind the mounting plate, and I believe the tweeter output thus does not "see" the grille frame. However, when the fiberglass is installed right up to the mounting plate, the output will "see" this and cause the delayed echoes.

You would expect twice the transmission loss through the fiberglass, but you get nowhere near this value, since the fiberglass directly reflects a large percentage of the sound striking it. In view of this, making the layer thicker does not necessarily reduce reflections, and I believe the SEAS tweeter would have tested better with a thinner fiberglass layer. I suspect there are better materials for this application.

The test results do not fully agree with what I hear, i.e., the undamped front panel does not sound bad until the grille cloth is installed. The results clearly indicate that a grille frame (with or without cloth) may be destructive to the clarity of the highs. They also show that covering the front panel with damping material up to the frame edges is helpful in correcting the problem.

In summary, I believe my tests show that if you have a grille frame, you want the damping material on the front panel (probably thin material in the case of the SEAS tweeter). If you go without a grille, you may still need damping material unless asymmetrical tweeter placement and careful rounding of the cabinet edges are sufficient to prevent audible delayed-echo effects.—*GRK*

## FOLLOWING UP

Now that I am in the process (a year later) of completing my second set of boxes, it is no longer clear to me that the problem with the third-order CO sonics was due to packaging. In *Fig. 16* of Part 1, you see that there is an excess of energy on the listening axis in the 4kHz range. I believe the sibilance that caused me to want to turn down the tweeter level was the result of this excess, plus the facts that this type of CO has slight increases in total output power at the CO frequencies and that the dome tweeter has a wide radiation pattern around 4kHz.

It also appears that I made matters worse by using a value for C7 that was about 4.94µF, instead of the correct value of 4.74µF. Testing with the drivers for the second set of boxes shows even more peaking around 4kHz on the listening axis.

I kept the LP and BP sections of the CO fixed and started to move the HP design frequency up to correct the listening-axis response. The smoothest response turned out to be with the HP moved all the way up to 5.1kHz, a value you would expect to yield a large dip. This is the value I started listening with on the second set of boxes. I much preferred the sound and will pack the CO with these values. At this point, no sibilance problem exists, and I'm running the tweeter at full anechoic level. *Table 6* shows the values for the HP CO components for various values of CO frequency. I definitely recommend that you experiment here before freezing the CO design.

To package the COs in the area provided



# *Speaker Builder* BACK ISSUES *Continued*

**1994** Sanctuary Sonics • Modular Active Crossovers • A Full-Range Open-Baffle System • An Evolving Magnepan MG-1 • Low-Frequency AC-To-DC Converter • A Compact Bass Guitar Speaker • Measuring Speaker Impedance Without a Bridge • The Dynapleat • The Danielle II • The Birdhouse: A Sound-Reinforcement Subwoofer • The Linear-Array Sound System • A Revised Two-Way Minimonitor • Exploring the BUF 124 with Pspice • Signet's SL280B/U • Time Response of Crossover Filters • Converting Radio Shack's SLM To Millivolt Use • Acoustic Distortion and Balanced Speakers • Microphone Response Correction with IMP • More About the Birdhouse Bandpass • A 16Hz Subwoofer • D.H. Labs Silver Sonic Cables • The System III Loudspeaker • Exploring Loudspeaker Impedance • IMPcycling • The Linear-Array Chronicles • Book Report: Loudspeaker Recipes, Book One • The Woofer Test • A Large Ribbon You Can Build • Loudspeakers, A Short History, Pt 1-2 • Absolute SPL Sensitivity Measuring with IMP • The Damping Factor: One More Time • Cliffnotes for Loudspeaker University • Software Report: The Listening Room for Macintosh • Book Report: The Theory and Design of Loudspeaker Enclosures • A 15" Transmission Line Woofer • Inductor Coil Cross Talk • Quick Home Theater on a Budget • Silk Purses: A Two-Way Salvage Design • Audio Phase Inductor •

**1995** The T-Rex Minisubwoofer • High Quality Use of Motorola's Piezo Driver, Pt 1 • The Achilles: A Two-Way Automotive Transmission Line • Driver-Offset-Related Phase Shifts in Crossover Design, Pt 1-2 • The Linear-Array Chronicles, Pt 3 • From Sad to Sparkle: A SAAB Story, Pt 1-2 • A Compact Two-Way PA, Pt 1-2 • The Baekgaard Crossover Technique • Rebuilding the KLH-9 Power Supply • KIT REPORT: Audax of America A652 • Satellites For a New System • Box Models: Benson Versus Small • PRODUCT REVIEW: Sapphire III Reference Monitor • The Simpline Sidewinder Woofer • Focused Arrays: Minimizing Room Effects • A Flexible Four-Way System • Extending IMP: A Program Set • CD REVIEW: *My Disc* From Sheffield Lab • The Freeline: An Open-Pipe Transmission Line • Computer-Aided Bass Horn Design • A Mike/Probe Preamp For Sound-Card Measurements • Four-Poster Speaker Stands • Mining For Gold On the Madisound BBS • SOFTWARE REVIEW: CLIO Test System • The Waveguide Path to Deep Bass, Pt 1-3 • Stereo Bass: True or False? • A Morning Glory Midrange Horn • Testing a Simple Focused Array • PRODUCT REVIEW: LinearX's pcRTA • A Self-Powered Subwoofer for Audio/Video • Your Car's (and Living Room's) Bass Boost • Driver Temp and T/S • SOFTWARE REPORT: SoundBlaster 16 • A Push-Pull Planer Speaker Quest • PC Sound Overview • Design a Three-Way TL with PC AudioLab, Pt 1 • PRODUCT REVIEW: Audio Control C-101 • SOFTWARE REVIEW: Electronics Workbench •

**TABLE 6**

**HIGH-PASS COMPONENT VALUES VERSUS DESIGN FREQUENCY**

| $F_{CO}$ | C7 | L8 | C8 |
|---|---|---|---|
| 4kHz (Orig.) | 4.74µF | 0.178mH | 12.4µF |
| 4.5kHz | 4.18µF | 0.159mH | 11.1µF |
| 4.8kHz | 3.90µF | 0.149mH | 10.4µF |
| 5.1kHz | 3.66µF | 0.140mH | 9.86µF |
| 5.5kHz | 3.38µF | 0.130mH | 9.18µF |

just about dictates the use of ferrite bobbin core coils, which received a bad review recently (*SB* 4/96, p. 22). However, I have found they provide good sonics if the proper size of core is used in each location. They also have the advantages of low resistance, reasonable cost, and ease of inductance adjusting.

We have been trying to get someone to offer a kit of coils for the project, but the cores are becoming difficult to obtain, and to date we have not tested satisfactory samples of all eight types. To aid you in selecting coils, *Table 7* shows the peak linear current requirements for each coil, along with the measured results for the coils I used. The requirements are based on the CO staying linear up to 400W peak to the woofer, 200W peak to the midrange, and 80W peak to the tweeter. — *GRK*

**TABLE 7**

**PEAK COIL REQUIREMENTS FOR CROSSOVERS**

| COIL | PEAK CURRENT —AMPS | COILS USED —AMPS |
|---|---|---|
| L1 | 8.4 | 9.5 |
| L2 | 5.9 | >16 |
| L3 | 8.9 | 10 |
| L4 | 8.2 | 10.5 |
| L5 | 5.8 | >16 |
| L6 | 7.4 | 9.5 |
| L7 | 5.8 | >16 |
| L8 | 3.9 | 10.5 |

Note: my tester goes only to 16A.

## R.O. WRIGHT COMMENTS:

The development of this system was dependent on others and most especially we wish to thank Design Engineer Tom James of Eminence Speaker. His application engineering based on design parameters established by us was essential. He chose one of Eminence's stock drivers and further found a distributor for us to buy the drivers from.

After receiving the speaker pair from G.R. Koonce, I proceeded to hook them up to my system. The listening tests were done in three groups:

1. My system and the 1st-order crossover.
2. My system and the 3rd-order crossover.
3. My normal preamp, a McIntosh MC2500, and an amplifier that I use for testing.

The normal system has a final output of 350W and the McIntosh a solid 500W/ channel, as I never want power to be a problem when I test other speakers. The speakers were tested with music ranging from pop rock to easy listening. The audience spanned college age (my sons and friends) to retirement age (myself).

When first played, one of the speakers lacked bass response. It was found that some of the fiberglass had fallen down over one of the ports, and it was replaced with Owens-Corning fiberglass mat #703 1″ thick. The response of the speaker remained the same. Some builders might like to use this material in lieu of the loose fiberglass blanket. I have used it for years, as it is solid and whole, can easily be cut with a bread-knife, and has good structural integrity with very few loose fines. Then the speaker was resealed with 3M strip-caulk, black #8578.

It was concluded by all who listened that the first-order gave the most musical sound for all of the forms of music played. It gave the tightest transient response on the pop rock and vocals, whereas the third-order crossover gave better accuracy with the classical music. The listeners still believed that the "trade-off" was in favor of the first-order crossover for overall sound quality. The younger listeners all were impressed with the amount of bass and the quickness of response on such a small speaker. Both tweeters were tried, but the listeners preferred the Audax. I agree with G.R. Koonce that the speakers can handle approximately 100–150W peak-to-peak. The younger set on several occasions checked out the "upper end" of the power spectrum on my amplifiers, and the speakers showed no signs of distress. Nothing will kill a set of speakers faster than an amplifier that "clips."

As for the future of the speakers, I have several choices in the way of finishes: cloth-rug, paint, and veneer. I will more than likely use the veneer method. The woodworking industry now markets a special thin-cut, fiber-backed self-adhering veneer that is easily cut with scissors and applied.

Deep into the project, Madisound agreed to stock the 8″ speaker, and we obtained samples of the current speakers that G.R. Koonce tested. These samples were found to be almost exactly the same as those that we had obtained two years earlier. This speaks very well of Eminence's quality control.

# Software Review

## TOPBOX

*Reviewed by Mark E. Florian*

**TopBox 1.0** by Joseph D'Appolito, Ralph Gonzalez, and Ron Warren. Available in PC and Mac versions for $99 from ORCA Manufacturing & Design, 1531 Lookout Dr., Agoura, CA 91301, (818) 707-1629, FAX (818) 991-3072.

**System requirements**: Any Macintosh computer with at least 512K RAM.

It is certainly true that the ability to model a loudspeaker in the initial design phase using a computer is a significant milestone in audio. In the past five years, the software has become more accurate, provides more features, and is less expensive, enabling more and more hobbyists to take advantage of these programs. Though many IBM-platform software reviews have appeared in the pages of *Speaker Builder*, reviews of Macintosh packages have been rare. In this article, I'll review the Mac program, TopBox.

### INTRODUCTION

No doubt many of you are familiar with Joe D'Appolito's designs, articles, and responses to letters in the pages of *Speaker Builder*. Ralph Gonzalez has also contributed numerous articles over the years on crossover design and theory. Now it is possible to have their assistance in designing your own systems using TopBox, an easy-to-use program that calculates and graphs the predicted responses of closed-box, vented-box, and bandpass designs.

In addition, TopBox will design passive and active equalizers for use with these designs. For example, it can couple a second-order active filter with a vented box in order to produce a sixth-order alignment. Frequency, impedance, maximum SPL, and maximum input data can be included on the same graph, all together or in any combination by merely selecting the graphs you want.

The program also provides vent lengths when given the diameter of the pipe you wish to use, and plots up to six multiple alignments in color on one graph, allowing you easily to see which one would be most suitable. This program is based on modified Thiele/Small equations and the authors' many years of experience, ensuring that the designs are accurate and buildable.

TopBox is equipped with a library of drivers from 15 manufacturers. If your favorite driver is not included, you can easily add it to the list. The program itself occupies 278K bytes and requires at least 512K of memory. For those of you with a 68020, 030, or 040 and a 68881 math coprocessor installed, a special version of TopBox (TopBox-881) is included that takes advantage of these. This version runs significantly faster than the regular one on a Mac IIci or later.

Also included on the disk is a demo version of Gonzalez's loudspeaker modeling program, LMP-Pro, which assists you in designing a crossover for your speaker system. The working version is available for $39.95.

The 14-page manual provided with TopBox is broken down into three sections: Getting Started, Interface Features, and Design Options. The second section explains each of the menus, their commands, and the Design and Calculate windows. The third section is the longest, providing detailed information on closed, vented, and bandpass enclosures, on each of which you can implement a mix of active and passive filters. I'll start by describing the equalizer designs available with the closed boxes.

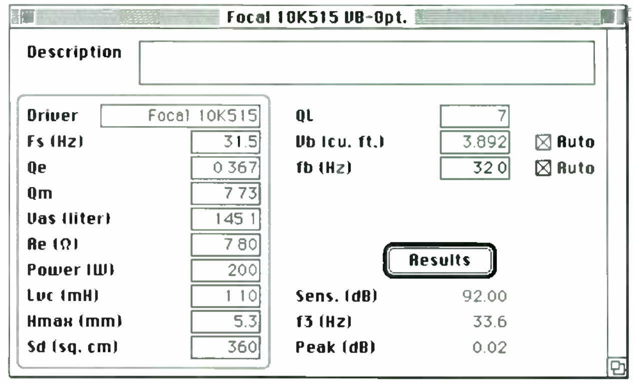



**FIGURE 1:** TopBox data window for vented box alignment. Contents of description field are printed out at the top of the reports.

## EQUALIZER/LOUDSPEAKER COMBINATIONS

Closed EQ1 consists of a passive, first-order, high-pass filter inserted between the preamp and power amp, implemented here by a single capacitor that you can use to reduce the amount of low-frequency information reaching the loudspeaker. For example, it controls excessive cone motion caused by record warps. This corner frequency is then used to find the value of the capacitor. TopBox will figure a maximally flat (third-order Butterworth) combined response of the equalizer/speaker combination.

Closed EQ2 is an active, second-order, high-pass filter that gives a steeper cutoff (12dB/octave) and allows you to add boost and extend the low-frequency response, if you wish. TopBox will figure the amount of boost and the corner frequency this active filter needs to produce a maximally flat response. The manual provides the necessary equations to calculate the component values for the Salen & Key filter.

Vented EQ1 is similar to Closed EQ1 in that you can use a first-order high-pass filter (capacitor). The program, however, will not provide an optimum design, because very high Q drivers and large enclosures are required. These drivers are best utilized in a Closed EQ1 system.

Vented EQ2 employs the same active filter as above for the Closed EQ2 design. This results in the popular sixth-order alignment discussed in Bullock's articles.[1] TopBox will calculate the box volume, EQ frequency, and boost necessary to provide good low-frequency extension and cone control in a reasonable box size.

Regarding bandpass designs, TopBox is capable of producing optimum fourth- and sixth-order systems, given the upper and lower –3db points and driver parameters. Note that in a fourth-order bandpass design, the upper and lower slopes are second-order. Similarly, in a sixth-order bandpass, the upper and lower slopes are third-order.

Also, unlike the active second-order filter used in the Closed EQ2 and Vented EQ2 designs, the Bandpass EQ2 filter is a passive second-order, composed of an inductor and capacitor in series between the power amplifier and the loudspeaker. Given the driver parameters, upper and lower –3dB points, and estimated inductor resistance, TopBox will provide the front and rear volumes, vent length for a given diameter, and the inductance and capacitance values.

## TOPBOX IN DETAIL

TopBox lets you import the driver parameters directly from the driver files or enter them by hand. For closed-box design click on the Auto box, and TopBox will figure out the optimum volume for your driver and display it along with the sensitivity, $f_3$, and peak (if any). The frequency response will then be displayed on the graph in the background.

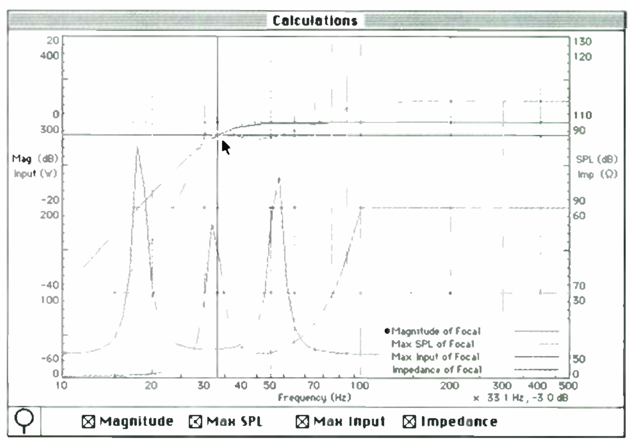



**FIGURE 2:** Graph of Focal 10K515 driver in vented box. Note –3dB point highlighted by cursor.

You may also select Max SPL, Max Input, and Impedance and display all of them on the graph at once.

*Figure 1* shows the window for designing a vented box. Click on Auto to find the optimum values for $V_B$ and $f_3$. Clicking on Results will fill in values for sensitivity, $f_3$, and peak, and plot the response curves you have selected. By canceling the Auto selection, you can override TopBox's choices and see how varying these values affects overall response. Finally, you can select either $V_B$ or $f_3$, and TopBox will select the optimum value for the other.

*Figure 2* shows all four of the curves for the Focal 10K515 driver. Notice that the crosshairs have selected the –3dB point on the magnitude curve and that the values of this point appear in the bottom right-hand corner, just under the graph. I'll discuss the cursor and graph details later in the review.

## DESIGN EXAMPLES

For the first example I selected the North Creek Celeste design, having recently finished one. This speaker uses a Vifa P13WH 5″ woofer and a Vifa D25AG 1″ aluminum dome tweeter in a 3.3 ltr closed box.

The advertised $f_3$ for the Celeste is 123Hz; for the TopBox design, it is 122Hz. The only difference between the two is the box volume. The volume TopBox chose was 2.9 ltr, compared to 3.3 ltr for the Celeste. I moved the cursor to the –3dB point on the graph, and it shows 122.9Hz. The small black dot next to the title in the legend tells you which curve the cursor is on, and the data at this point is displayed just above the legend. This makes it easy to read numbers right off the graph.

## THE SWAN BASS

My second design example uses the Swan Symmetrical Bass Units. Each of these contains a pair of Swan 305 woofers in a 100 ltr vented box utilizing a sixth-order Butterworth alignment. Modeling this speaker with TopBox is easy and straightforward.

## MULTIPLE CURVES

You can display up to six curves on one graph, which is useful for trying out "what if" alignments. And, of course, you can use different drivers for each curve to determine the best box/driver alignment. One excellent feature of TopBox is the moving cursor. The value (Magnitude, Max. SPL, Max. Input, or Impedance) is displayed along with the frequency in the lower right-hand corner of the window. When you are close to a curve, the cursor will snap to it and display the value against the frequency.

### THE MANUAL

The only problem I found with the manual is that the font size is rather small, and thus a bit hard to read. Otherwise, it is clearly laid out and easy to follow, even for beginners. It does not provide any of the equations used by the software beyond those described above regarding the active and passive filters. It mentions that design results may differ from those obtained using standard calculations, partly because the program takes into account the additional mass reactance loading on the driver when it is installed in a box.

### PRINTING COMMANDS

The print command is implemented differently in TopBox. In order to print the T/S parameters and alignment-information window, you find the print command in its usual place under the File menu, but no Page Setup command precedes it. Instead, it is incorporated into the print command, thus saving an extra step.

By contrast, to print the graph or data table, you find the print command under the Calculate menu. It will toggle between Print Table and Print Graph, depending upon which window is currently active.

I also discovered that if you select Gray Scale in the print window, your graph may take more than three minutes to print, depending on its complexity. However, if you specify black and white, it will be finished within 30 seconds. The large time difference is due to the increased resolution of grayscale mode. In some programs, graphs must be printed in hi-res mode so that the various shades of gray will distinguish between curves. Fortunately, TopBox will print all of the curves in the quicker black and white mode.

I use this method and then highlight each curve with colored markers, which makes them stand out better than just different shades of gray—and it saves lots of time.

Those of you with a LaserWriter probably won't notice much time difference.

### STRANGE BEHAVIOR

During this evaluation, I encountered some strange software behavior. First, when you have selected either Closed EQ1 or EQ2 designs and then use the tab key to advance to the next field beyond the piston diameter (Sd) in the main window, an error message appears stating, "Error trying to personalize locked or read-only copy of TopBox." Worse yet, the program will then quit and trash any and all data relating to your design(s)! For some reason, this occurs only with the closed-box designs. The others will advance to the next field, which is box volume ($V_B$), and then wrap around back to the description field as the tab key is repeatedly pressed.

Second, when you're using the Port Design window, the value typed into the Diameter of Width field quickly disappears when the Tab key is pressed to advance to the next field. Instead, after entering the port diameter, you must click the Calc button to obtain a vent length. In addition, if values for the diameter and length are displayed and then you press Tab to try another port diameter or to use a different number of ports, all of the information just produced will also disappear! Tab does cause the cursor to wrap around to the beginning, but in doing so, all of the information is cleared. Both of these quirks are rather annoying, to say the least.

### SUGGESTIONS

I have a couple of suggestions regarding improvements. First, a legend does appear at the lower right-hand corner of the graph, but not much room is left for the plot title after "Magnitude of" is printed each time. Perhaps "Magnitude" could be abbreviated to allow for more space. Fortunately, the notes from each description field are printed at the top of the graph for easy reference.

Second, it would be very convenient to incorporate the use of the cursor keys when entering numbers from the keypad. This way, you could enter data right down the list without having to reach all the way over to the Tab key. The arrow-down key (easily reachable) could be made equivalent to Tab, and arrow-up equivalent to Shift-Tab—which, by the way, is not implemented here as on most Mac software to move in the direction opposite to Tab.

Finally, perhaps the Calculations window that instead displays the plots could be renamed Plots or Graphs. I was staring at a list of designs just created, looking for the "graph" window to see the results, when I realized it was the calculations window I wanted.

TopBox does have its share of gremlins, especially concerning the fault that occurs in the closed-box modes, but Joe D'Appolito informs me that an updated version is on the way, hopefully correcting these faults. TopBox was designed to do just what the name says and nothing else, and it does it quite well despite the minor cracks in the sidewalk.

*Manufacturer's Response:*

*TopBox MAC can run on any Macintosh computer. In fact, TopBox MAC comes with two programs on the disk. The user will install the program best adapted to the specific Mac model he is using. At ORCA we have been using TopBox with the following units: IIX, IIFX, Performa 6300, and my own 8500.*

*The kinks mentioned by Mark Florian came as a surprise to me. I use TopBox on my Mac just about every day, and I never encountered these problems. Furthermore, I don't remember having ever heard of them from any actual user, and we have quite a few. After reading the review, I could not wait to open TopBox, and, sure enough, Mark Florian is correct: I get the same error message. So what does that mean? Well, simply, that if you use the mouse to do just about everything, as most Mac users do, you may not even notice the problems. Now that we know about it, I asked Ralph Gonzalez to fix it, just for the sake of it, and it will be done promptly.*

*Mark Florian does not mention the possibility of printing landscape graphs. I personally use that feature a lot, as it allows a larger graph, therefore a higher resolution when needed.*

*The very important point I would like to express here is that TopBox is deceptively simple, and that is the way it naturally*


### Acknowledgements

Thanks to Kimon Bellas at ORCA for his assistance with this review. Also thanks to Joe D'Appolito and to George Short at North Creek Music for their assistance.


### REFERENCES


1. Robert M. Bullock III, "Thiele, Small & Vented Loudspeaker Design, Part V: Sixth Order Alignments," *SB* 1/82, pp. 20–25.

2. Joseph A. D'Appolito and James W. Bock, "The Swan IV Speaker System," *SB* 4/88, pp. 9–20.

*appears in the review. In reality, it is certainly the most sophisticated and most powerful cabinet-simulation software available to amateurs. Most cabinet-design software is nothing else but a graphic implementation and representation of the well-known equations extracted from the work of Thiele, Small, and others. Clearly, anybody with a working knowledge of basic mathematics and a good scientific calculator should be able to do the same.*

*TopBox, much to the contrary, hides a much more complete and sophisticated set of equations devised by Joe D'Appolito to create a model that is closer to the real-life functioning of a drive unit. Joe, for example, takes into account the actual mass of moving air in the TopBox system designs. He also takes into account the fact that we are not always dealing here with small signals (as you know, Thiele/Small parameters are based on small-signal measurements).*

*Working with TopBox will never give you a hint of that sophistication, but the results will. The simulations it makes are amazingly accurate. You can effectively build cabinets based on calculations, and get the very results it predicts. This is the true goal targeted by Joe D'Appolito, and it is attained beautifully.*

*Kimon Bellas*
*ORCA*

*Regarding the "strange behavior" you observed:*

*(1) The crash you encountered when pressing the Tab key to advance in a Closed EQ1 or Closed EQ2 design is a bug of which I was not aware. Until this is corrected, the workaround is to use the mouse to select the desired field in the circumstance.*

*(2) The quirks in the Port Design window are, as we say, "features, not faults." Since Diameter and Area are exclusive, entering one field causes TopBox to automatically clear the other—the Diameter field will be cleared when you Tab to the Area field. Again, use the mouse instead of the Tab key to avoid this. Likewise, since TopBox automatically computes Length for you, the Length is cleared when you enter (by Tab or mouse click) the Diameter or Area field.*

*Let me credit Joe D'Appolito, who developed TopBox's highly customized formulas over years of professional speaker-design work. His analysis of bandpass designs has been published by the Audio Engineering Society. Because of its carefully selected range of options, its in-depth modeling of moving-coil loudspeaker systems, and its rapid "what-if?" interface, I believe that TopBox is unsurpassed in meeting the requirements of real-world speaker designs.*

*Ralph Gonzalez*
*Bermuda*

## SOURCES

**LMP and LMP-Pro**
Ralph Gonzalez, Landview, 7 McGalls Hill Ct., Smith's Parish, Bermuda FL05
$39.95

(Also available from Old Colony Sound Laboratory, PO Box 243, Peterborough, NH 03458, (603) 924-6371, FAX (603) 924-9467.)

**TopBox 1.0**
By Joseph D'Appolito, Ralph Gonzalez, & Ron Warren
ORCA Manufacturing & Design
1531 Lookout Dr., Agoura, CA 91301
(818) 707-1629, FAX (818) 991-3072
$99.00

## RESISTOR REASONING

I recently built some stage monitors for live-music use. While designing the crossover networks, I pored over my *Speaker Builder* back issues for relevant information. An article by G. R. Koonce on crossover design (*SB* 5/90, p. 26) was particularly useful. There is one matter, however, which still bothers me despite the fact that my monitors seem to be holding up well in high-power performance situations.

When resistors are necessary in the crossover design, how do you determine what values to use in regard to power handling? The wire-wound resistors I used are rated 5W, 10W, 20W, and so on, but my JBL E140 woofer is rated at 200W and my high-frequency driver at 50W. I combined small-value resistors in series to increase power handling, but no solid rationale motivated me. Can you provide some guidelines for resistor selection?

Ed McEowen
Jerico Springs, MO

*G. R. Koonce responds:*

*I am glad Mr. McEowen found my crossover article useful, and would like to remind readers that the article contains a mini-index of the numerous works on crossovers published in earlier issues of* Speaker Builder. *Mr. McEowen raises a valid point. Articles have appeared on establishing the stress on reactive components in passive crossovers (*SB *3/86 and 4/86), while ways of calculating the stress on resistors have generally been ignored.*

*I see three areas where resistors are used in crossovers:*

*1. Padding—resistors are used for series padding drivers and to implement L-pads. I'll address padding placed between the crossover output and the driver load.*
*2. Zobels—I'll discuss the series resistor-capacitor impedance compensating network, which I call a simple Zobel.*
*3. Special networks, such as impedance-changing or passive-response contouring networks are cases that must be individually addressed, so I will not cover them here.*

### *ESTABLISHING DRIVER POWER LEVELS*

*Mr. McEowen would like to relate the resistor power requirements to those of his drivers, and I believe that is a good approach. Speaker systems are normally voltage-dri-*

*ven, and finding the actual power delivered to a driver is a difficult problem, due to the complex impedance of the driver. I will make the standard assumptions that over its operating-frequency range, the driver has been impedance corrected to an approximate resistance ($R_L$) and that the power ($P_L$) delivered to the driver is given by the square of the driver voltage ($V_L$) divided by $R_L$.*

*I know that part of the actual power is going to the Zobel resistor, but when examining padding I will assume the pad terminates in a resistor $R_L$ that absorbs power $P_L$. Since the input resistance of a driver/Zobel combination is very close to the voice-coil resistance value, my $P_L$ is effectively the same as the reference power used by Small.*

*You can start by establishing a $P_L$ value for each driver. If you are working at high power, as in Mr. McEowen's application, and want the resistors to reach their thermal limit at the same time as the drivers, then you would set $P_L$ for each driver at its rated thermal limit. As Mr. McEowen states, this is 200W for his woofer and 50W for his tweeter. I normally do not run drivers near their rated power limit, and in many cases you do not have this rating with surplus drivers.*

*I normally select a maximum power to deliver to the system—say, 20W average power of music. With a normal system of about 90 dB/W/m sensitivity, this is reasonably loud (103dB at 1m average). For a two-way system or bottom end of a three-way system, with a crossover frequency in the neighborhood of 800Hz, about half the power will appear on either side of this frequency.*

*For more detail on how power divides in a crossover, see* SB *3/86, p. 14. Typically, in a three-way system with the upper crossover frequency in the neighborhood of 4kHz, the tweeter will see only about 5–10% of the input power. Thus, with a three-way system taking in a total of 20W average music power, I might set $P_L$ at 10W for the woofer, 8W for the midrange, and 2W for the tweeter.*

### *DISSIPATION IN THE ZOBEL RESISTOR*

*The simple Zobel consists of a series resistor and capacitor right across the driver terminals. This partially corrects the rising driver impedance with rising frequency so as to make a passive crossover perform closer to the ideal. Calculating the actual power to the resistor in a Zobel is nearly as complicated as computing the true power into a driver, since it involves details of the crossover type and actual driver-input impedance.*

*If driven with a fixed-frequency sinusoid, warble tone, or other narrow-band signal, it is possible in theory for the Zobel resistor to dissipate more power than the driver. Generally, the Zobel resistor is about the same value as the driver voice-coil resistance, so its dissipation is limited to the total power ($P_L$) you think you are delivering to the driver/Zobel combination.*

*The Zobel resistor will see its maximum power at the highest frequency at which the driver is operated, due to the capacitor in series with it. If you plan the very dangerous game of testing with narrow-band signals to the thermal power limit of the driver, I would recommend that the Zobel resistor wattage rating match that of the driver.*

*When driven by music signals, the Zobel resistor has a reduced power dissipation, as it sees much less power at the low end of the driver passband. I did a study of this many years ago, which unfortunately I can't locate, but I remember the conclusion was that it was safe to size the Zobel resistor at one-half the wattage ($P_L$) you anticipate delivering to the driver/Zobel combination. I have used this approach for years without a problem. If anyone has information that this is not a safe approach, I would love to hear it.*

*Thus, for a three-way system intended to drive with 20W average of music—10W to the woofer, 8W to the midrange, and 2W to the tweeter—I would size the Zobel resistors to a wattage that's at least half of the expect-*

*ed driver power. To drive Mr. McEowen's high-powered system to maximum driver power with music, I would want 100W capability in the woofer Zobel resistor, and if a Zobel is used on the tweeter, I would want it to have a 25W resistor.*

### DISSIPATION IN PADDING RESISTORS

Figure 1a *shows series padding via a single resistor ($R_S$) placed after the crossover output and in series with the driver/Zobel combination load ($R_L$). The power delivered to the load is taken as the $P_L$ developed earlier. The power delivered to $R_S$ can be easily found:*

$$\text{Power to resistor } R_S = P_L \times R_S/R_L$$

*An L-pad following the crossover* (Fig. 1b) *consists of a series resistor ($R_S$) and a second resistor ($R_P$) in parallel right across the load ($R_L$). If the network is a true L-pad, then the input resistance looking into $R_S$ is the same as $R_L$. Given the power delivered to the load ($P_L$), the power delivered to the two resistors is as follows:*

$$\text{Power to resistor } R_P = P_L \times R_L/R_P$$
$$\text{Power to resistor } R_S = P_L \times R_S\,(1 + R_L/R_P)^2/R_L$$

*These equations are valid even if $R_S$ and $R_P$ are not the proper values to make the input resistance equal to $R_L$, i.e., it is not a true L-pad.*

*Using Mr. McEowen's tweeter L-pad as an example, assuming 50W delivered to the 8Ω tweeter, the parallel 8Ω resistor would also be seeing 50W, and the series 4Ω resistor would be seeing 100W.*

*Any reader who is designing padding using my PadComp program (on Distribution Disk #3, available from Old Colony; see* SB 2/94) *will know that this program reports the percentage of the input power that goes to each resistor and to the load. This makes it very easy to size the padding resistors according either to the input power or to the power delivered to the load.*

### COMBINING POWER RESISTORS

*Mr. McEowen created high-power resistors by using multiple lower-wattage units, which is a good approach. I have seen this done incorrectly, however, and offer the following caution. When multiple power resistors are used in series or parallel, they share the power uniformly only if they are of the same resistance.*

Figure 2a *shows four resistors in series, three 2Ω at 25W and one 6Ω at 15W. The belief that this is the equivalent of a 12Ω resistor at 90W is incorrect. When resistors are in series, they all pass the same current (I), so you must look for the "weak link" in terms of current capability. Remembering that the power to a resistor is given by $P = I^2R$, the 2Ω resistors can take 3.54A, while the 6Ω can take only 1.58A, so the current through the string must be limited to the 1.58A value. The string is thus equivalent to a 12Ω resistor at 30W. With series resistors, the units with the highest resistance take the highest dissipation.*

*A similar thing occurs with multiple resistors in parallel.* Figure 2b *shows three 12Ω resistors at 20W and one 4Ω at 10W,*

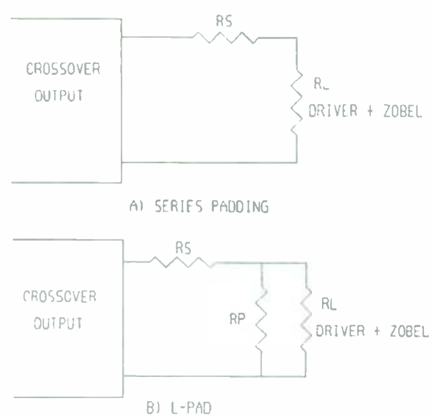



**FIGURE 1:** Resistors used in a) series padding and b) an L-pad.

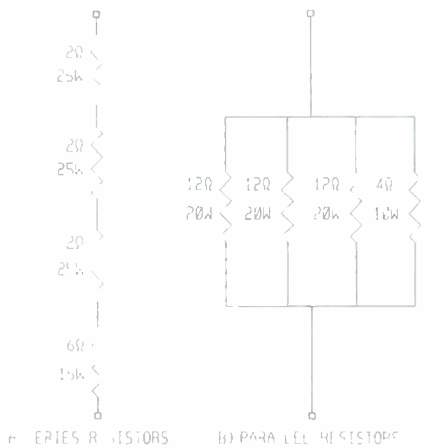



**FIGURE 2:** Power resistors connected in a) series and b) parallel.

*all in parallel. They are not equivalent to a 2Ω at 70W resistor. Parallel resistors all see the same voltage, so you must find the voltage "weak link." Power to a resistor is given by $P = V^2/R$; the 12Ω resistors can take 15.49V, while the 4Ω can take only 6.32V, so the group must be limited to the 6.32V value. Thus the resistor group is equivalent to a 2Ω at 20W resistor. With resistors in parallel, the lowest ohmage units take the highest dissipation.*

## HORN-CABINET QUESTIONS

I was looking through some boxes the other day and found some old issues of *Speaker Builder*. I have now resubscribed and started some serious inquiries in the speaker-building world to find Macintosh software for designing bass boxes. This is indeed a difficult task: everyone makes software for IBMs, but no one seems to be interested in Macs; truly unfortunate.

At any rate, I found a response by Bruce Edgar to a letter in the "SB Mailbox" section titled, "Rear-loaded Horn Cabinets" (*SB* 2/86, p. 54). I had built a similar pair of single-driver units powered by Fane 15B monitors and found that no matter how thick I made the slides, they still tended to resonate at moderate-to-high volume levels. By chance, I tried stuffing the area directly under the slides with insulation, which immediately remedied the problem.

I found that the issue of damping was never addressed in the article. This raises the question of how much insulation should be placed in the cabinet, since the amount directly affects box volume. I have tried different setups, but years later, am still searching for the ultimate state of nirvana.

My second question concerns crossover networks, which were not mentioned by Mr. Edgar. Do you regard rear-loaded horns as bass drivers with natural rolloffs, i.e., no need for inductors? Does the nature of the cabinet design prevent the woofers from becoming energized by the high frequencies? The article states that since these are in fact rear-loaded horns, the fronts of the drivers radiate into free space and provide response up to several kHz. If this is the case, what is the formula to figure out exactly how high a response is provided? If I could determine that, maybe I could cross it over with some mid- and high-frequency drivers.

That leads to my next question. In the sketch of the double horns, there is no provision for any mid- or high-frequency drivers or arrays. In my case, I teamed them with 18½″ Fane midrange horns and 11″ Omega tweeter horns; for good measure, I also threw in a pair of 2″ × 6″ Motorola Piezo horns.

I mounted the arrays in separate boxes sitting on top of the horn cabinets, which now stand 72″ tall and frighten all who see them. Has there ever been any work on streamlining the design so that the mid- and high-frequency drivers could be integrated into the design without making them look as though they just came from a concert stage?

Edgar's article also mentions that he abandoned the design because of two basic problems: first, that at some frequency in the upper bass, some sound cancellation occurs because the sound coming out of the bass horn is 180° out of phase with the sound wave being radiated from the front of the driver; second, that to match the output from the front radiator with the horn output, the horn must be shortened. By doing so, however, some horrible resonant peaks are introduced into the bass response.

I have built several different speaker systems and have been a serious audiophile for years. In all that I have been exposed to, these rear-loaded horns may slightly lack in their reproductive fidelity of mid- and high-frequencies, but I have not yet heard a system with more "visceral horsepower."

John Danylewich
Laval, QC, Canada

*Mike Klasco responds:*

*First, the easy answers. With regard to box software for the Mac, you should check out TopBox and MacSpeakerz, and Old Colony Sound Lab also has a few Mac programs, such as LMP Professional, LDP, and MAC-SPEAKERBOX.*

*As for the enclosure walls of the rear-loaded horn cabinets resonating at higher sound levels, and your use of fiberglass insulation to damp it out, the answer is not to absorb the sound, but to increase the rigidity of the panels. Bracing is the answer; see* Figs. 1 *and* 2 *for one solution. Most PA applications of this woofer enclosure left out fiberglass, which was less than ideal.*

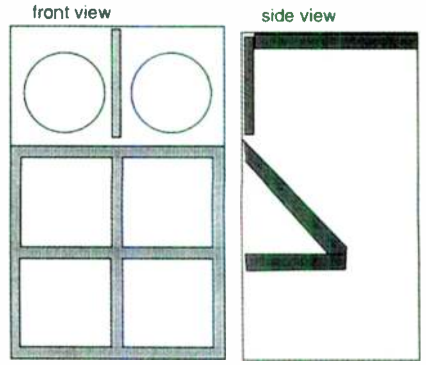



**FIGURE 1:** Bracing for large panel spans, front and side views.

*The reason for the direct-radiating woofers was so they could reach up to the compression driver horns, which typically came in around 800Hz or so. The rear horn loading does provide a bandpass effect on the output from the rear, but not on the drivers' front radiation; there is no chamber* *nor wave guide in front of the woofers. The higher (or midrange) frequencies are radiated (on the JBL E-140) by the dust cap, which is directly bonded to the voice-coil bobbin.*

*Some fiberglass directly on the enclosure wall behind the woofers reduces the bounce path from the back of the cone—which would otherwise hit the cabinet panel behind the woofer and come back out through the cone, causing a notch in the mid-range response near the crossover region. I would use 2″ medium-density fiberglass, not the wall thermal-insulation stuff, and definitely forget the stuff with paper or aluminum facing. If you want less reflected midrange energy, at the expense of 1–2dB loss of low end, then put a second 2″–4″ layer of fiberglass over the first, and then low-density fiberglass (1½ lb.) is all right.*

*As for crossover networks, especially with this scoop design, band-pass for both the upper and lower limits is critical. If you have the budget, a combination parametric/electronic crossover would be a good choice. Let us look at what this box is really doing.*

## BASS HORN—BOTTOM END

*The back wave of the woofer feeds into the throat of a folded horn. Near the cutoff frequency of the horn, the loading on the woofer disappears. Horn loading depends on the flare rate, the horn mouth size, and where the horn resides—hanging in the air is the worst case, on the floor is better, and in a corner on the floor provides the deepest loading for a given mouth size.*

*What happens to the woofer below the frequency where the horn loading drops off? Then the woofer thinks it is unbaffled, and the transducer will bottom out—just as a bass*

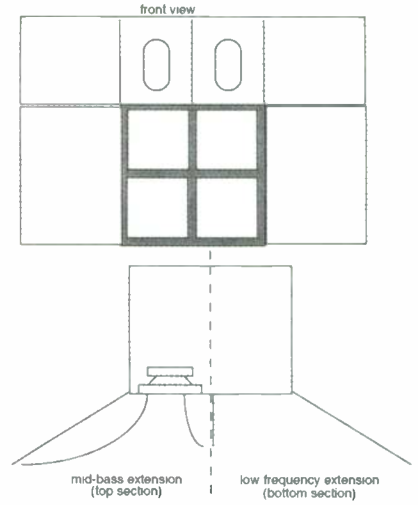



**FIGURE 2:** Front view of bracing, with top section of mid-bass extension and bottom section of low-frequency extension.

*reflex below the vent tuning—but the bottom drops out on horn-loaded (higher-order) designs much quicker than on the third- or fourth-order cutoffs of vented configurations.*

*You refer to the resonant peaks that are due to the horn being "too short." If it is too short, then the mouth size will be smaller. Less-than-adequate mouth size means that the lower frequencies have an impedance mismatch and cannot pass through; instead, much of the energy is reflected back into the horn. These standing waves cause progressively larger cancellations in the low-end response. This same phenomena can be seen in cassette decks when the tape-head wrap is too small, and it is similar to the midrange edge resonance of a surround on a cone speaker. One solution is to make the mouth larger with a bass horn extension.*

*When my old company (GLI) built a double scoop, we offered a combination extension flare that was the same height as the enclosure, but three times as wide. Not only was the low end smoothed out and extended downward, but the flare also included horn loading for the direct radiators. This brought up their output a few dB, and these very short horns provided a sharp cutoff below 200Hz, minimizing the cancellation around the notch area, which at least made us feel better.*

*Most bass horns use a sealed back chamber to load the woofers below horn cutoff. The air trapped behind the woofer in these designs acts like an air-suspension enclosure, i.e., an air spring. But in the scoop, the woofers are hanging in the breeze, with only the surround and spider to control cone motion—much like "free-air" woofers for car trunks when the trunk lid is open.*

*So, from my viewpoint, Bruce Edgar's advice of using the JBL E-140 is right on the money—a big-magnet electrically overdamped design with limited voice-coil overhang (not enough rope to hang yourself). But if there is a lot of low-frequency program material, you still had better have some sort of sub-sonic filter in front of your power amp—actually something that hits a little higher than where the horn unloads to avoid woofer overexcursion. Driving the woofers below the horn's loading will not only increase distortion (harmonic, intermodulation, and Doppler), but greatly decrease the life and dynamic range of the speakers.*

### BASS HORN—TOP END

*The upper end of the bass horn's response does rolloff sooner than the output from the front of the woofers. The mass of the air column, the lack of midrange contribution from the dust cap at the rear of the speaker, and the friction and folds in the horn all beat the response down at its upper end.*

*The front radiation of the woofers is basically just a direct radiator design, with some overlap between the rear-loaded horn contribution and the front direct radiation.*

### EVERYONE—ALL TOGETHER

*Bruce Edgar points out, sadly but correctly, that for the enclosure to be balanced, the front direct radiation must be comparable to the output of the horn. Since the rear radiation starts out at 180° out of phase with the front, the horn (with its folded path length) shifts the phase of the rear radiation, and the vector sum of the front and rear radiation ends up looking something less than your target "ultimate state of nirvana." Bruce mentions a notch in the response at 180Hz where the output of the horn is cancelled by the output of the direct radiation of the woofers.*

*You ask about a full-range design that is a streamlined two-way rather than a three-way. Why not consider a co-axial woofer, in which the compression driver is mounted to the rear of the woofer and shoots through the* *woofer's center? In this case, you must either accommodate the increased depth of the coax in your enclosure's back chamber or use a shallow coax.*

*So, by writing this up, I have talked myself into coming up with the plans for an improved (or at least revised) 4520. All I need is a volunteer to build this monster—are you interested?*

## ESL ECSTACY

I exalt and praise one of your advertising companies, David Lucas, for its electrostatic speaker products in general, and, in particular, Sales Manager Tim Kelly, whose dedication to customer satisfaction exceeds even that of the Saturn Car Company.

I encourage anyone who wants electrostatic loudspeakers (ESLs), but can't unload big bucks on commercial equipment, to consider building the Lucas ESLs. They use a proprietary method that eliminates plexiglass and other drawbacks of the Sanders-type ESL. The Lucas units are easy to build and have all the clarity and imaging of commercial models. In addition to having a wide frequency range and more than sufficient sensitivity, they sound fabulous.

Mr. Kelly returns phone calls the same day, and considers no question too trivial. He can offer knowledge and advice concerning the construction, operation, and theory of ESLs. If you have doubts about building Lucas ESLs, I highly recommend calling Mr. Kelly. This is the way to ESL Nirvana.

Bill Wallace
Stockton, NJ

## HELP WANTED

*[We encourage readers who may have information on the following topics to correspond directly with these letter-writers.—Eds.]*

Building Dick Olsher's Poly Natalia speakers has raised some questions for me about the time alignment of drivers. The Poly Natalia has two 8″ drivers in a vertical baffle and base enclosure. The mid driver is connected in reverse polarity, to accommodate the second-order electrical filters, and the crossover points are 600Hz and 4kHz.

Many three-way speaker designs incorporating twin bass drivers are built with a similar cabinet design. All four drivers do not time-align® with this layout; rather, the tweeter and mid are aligned, but not the bass drivers. I can get all four drivers to time-align by placing them in a straight baffle angled back approximately 12°; however, with the exception of Thiele's bass driver and passive radiator, no major speaker manufacturer incorporates twin drivers on a single angled baffle. When used in pairs, do bass drivers have different time-alignment parameters from those used for alignment with other driver units?

Is the time alignment of all drivers critical, or just one of many priorities that should be balanced? In other words, can and should I build a single angled baffle with four time-aligned drivers to conserve the internal volumes of the base and mid/tweeter cabinets? Or, should I dismiss the lack of time alignment between all drivers as part of Olsher's overall design and not worry about it?

Drew Harty
DrewHarty@aol.com

I'm using JBL 4345 speakers in a small 11′ × 9′ room. I am getting too much bass when playing CDs like Jennifer Warnes' "Hunter." I thought of modifying the speakers, or biamping them. Now, I am using a Marantz 7 preamp and Marantz 9 power amp that are homemade. I am currently constructing a 300B amp from a *Glass Audio* article. If you have any suggestions, please E-mail.

Paul Lim
paul.lim@cybernet.com.sg

Can you tell me anything about 18″ coaxials manufactured in Coventry, England, by British-Thompson Houston in 1956? They look like Tannoys, but have a metal plate behind the magnet with "BTH" inscribed.

Greg Akouris
grigor@inforamp.net

Please consider publishing a review of the 900MHz wireless RF speaker systems on the market and discussing the possibility of upgrading them. I considered using a pair as extension speakers, but had second thoughts after auditioning them. Let's face it: these items are designed for convenience, not quality.

The more expensive units sound better, yet I could never totally eliminate the RF tuning noise from any of them. Perhaps the speakers' close proximity to other AC-powered units caused the interference. The sound quality could be improved by replacing the drivers and, possibly, by tweaking the crossovers.

I've noticed that they all seem to have limited frequency response. Is this necessarily a result of the RF technology, or is it due to the use of low-quality drivers? Is it possible to remove the RF receiver electronics from each speaker so they could be installed in a home-built component speaker? If that's possible, I'd like to see a modification of MB Quart's new indoor/outdoor speaker for wireless use.

Scott Olson
Clearwater, FL 34616

## Musician's Speaker

*from page 14*

reduced, increasing the clarity of tapes. Most CDs lose all traces of zippy or grainy sound. Boosted low midrange and bass restores the impact of the music, lost when the speaker system is too bright.

Many solutions have been proposed for dealing with harsh sound: vacuum tubes, analog recordings, amplifiers with no feedback, and special cables. Rethinking speaker driver levels and using flat-response drivers is a relatively inexpensive solution.

I would like to thank Andrew Nittoli, Electronic Engineer for the Staller Center for the Arts, State University of New York at Stony Brook, for confirming the need to balance speakers by ear. His superb speaker systems are well regarded by musicians.

# Classifieds

# TRADE

**STATE-OF-THE-ART PASSIVE CROSSOVERS** featuring Hovland MusiCaps. Software available, free design guide. ***ALLPASS TECHNOLOGIES, INC.***, 2844 Charmont Dr., Apopka, FL 32703-5972, (407) 786-0623.

**ELECTROSTATIC**
**KITS PARTS TRADE SECRETS**
save $$$ building, repairing, modifying ESLs
CATALOG/START-UP MANUAL—$5.00
**DAVID LUCAS**
924 HULTON ST. OAKMONT, PA 15139

**THE BEST MUSIC YOU MAY NEVER HEAR.** Free catalog. ***CREATIVE MUSICIANS COALITION***, Dept. GBM, 1024 W. Wilcox Ave., Peoria, IL 61604, (800) 882-4262.

**ELECTROSTATIC** electronics, transformers, Mylar®, information. From author ***ROGER SANDERS***, (505) 759-3822.

**WE RE-CONE** all home, auto, pro, and vintage speakers. Re-foam kits, $10. ***TRI-STATE LOUDSPEAKER***, www.nauticom.net/www/speakers, (412) 375-9203.

**WELBORNE LABS**

**200 PAGE CATALOG and DESIGN MANUAL OF HIGH QUALITY AUDIO KITS and SUPPLIES!!!**
We've got Vacuum Tube and mosfet Amplifiers, Linestages Phonostages, Active Crossovers, Power Supplies, AC Line Conditioners and many other Audio Kits and Schematics.

**Parts and Supplies**
Hovland MusiCaps, Kimber Kaps, MIT MultiCaps, Solen WIMA and Wonder InfiniCaps; Caddock, Holco, Mills and Resista resistors; Golden Dragon, NOS RAM Labs, Sovtek and Svetlana tubes; Cardas, DH Labs, Kimber Kable Neutrik, Vampire and WBT connectors and wire; Alps, Noble and stepped volume controls, Enclosures, Books and other Supplies for DIY'ers. International Orders Welcome. For our Catalog and Manual, send $12 (US/Canada) $18 (International) or call (303) 470-6585, fax (303) 791-5783 or e-mail to: wlabs@ix.netcom.com with your Visa/Mastercard.

**WELBORNE LABS**
P.O. Box 260198, Littleton, CO 80126-0198
Visit our Website for more info: http://www.welbornelabs.com

**FINALLY! HIGH COMPLIANCE CLOTH SURROUNDS.** I will replace rotted foam with a lifetime guarantee. $30 for most woofers. ***LINEAR SURROUNDS***, (541) 488-5576.

**FANTASTIC THREE-DIMENSIONAL** stereo from two speakers! Free information! ***QUANTUM RESEARCH***, 17919 Seventy-Seventh Ave., Edmonton, AB T5T 2S1, CANADA.

# FOR SALE

Pair Shallco mono 32-position 10k ladder attenuator; pair Roederstein resistors, $85; pair Monarch Audio Digital Interface Processor, $75; pair 0.5M Have Digiflex Gold AES/EBU digital cable, never been used, $58 each, asking $35 each; pair Tango OPT ($1,200), asking $850. Ashby, (954) 723-5225.

VTL Stereo 90 tube amp, four years old, mint condition with like-new tubes (four each: 12AT7WA and 6550A military stock), $1,350 (45% of original cost). Renaissance Arts monitors: mini-monitors utilizing 5K013L, with TC120Tdx drivers by Focal, mounted in teak cabinets, new $2,200; asking $1,000; or, with subwoofer, bandpass design utilizing Focal 10C0121 driver, mounted in teak cabinets, new $1,500, asking $850. Studio monitors, four driver three-way design in exotic teak cabinets, two 8K415s, 5K413s, TC120Tdx Focal drivers, new $5,000; asking $2,650. Prices shown in Canadian funds. John, (604) 294-0155, until 11 p.m. (PST), CANADA.

Pair PAM 1s, one DSC-1 stereo control, one PS-1 dual power supply; all in walnut cabinet with single face plate, $125. Pair KLH 2s with Janszen 130 tweeters; woofer and tweeter in one cabinet; $400, plus packaging and shipping. Paul H. Leo, (718) 459-5443.

Pair SoundLab A1s oak/black, $3,600; pair SoundLab B-1 electrostatic subwoofers, $1,990 each. All in excellent condition and cannot ship. Bill Donnally, 44 Miller Dr., Boonton Twp., NJ 07005, (201) 334-9412, work (201) 724-2602.

Ampex 351-2; Apogee; BEL 2002; Bryston 10B; Berning OTL ZH270; Daniel; Day FM-1; Dynaco MKIII/VI; EV30W; Genelex KT-66; JAN 5751; Klipschom with acoustical wall; KSA 100S; Lexicon CP1/2.0; MC275MKII, C24, MR71, AA2; Nakamichi T-100; QUAD ESL, FM66; 2N5684/5686; Sony 850/852/854; Tannoy Monitor Gold; Teac 3340/X1000R/X2000R; Western Electric. Make offer. John Ng, (408) 737-2980, FAX (408) 735-1426.

Pair Focal K011DBL bass midrange drivers; used in Focal kits Compact B 400, Aria Z, 133, 233, 333; mint condition; $125, plus shipping. Cary SLA-70B Signature (oil caps) 60W/channel tube amp; $1,800 mint condition; asking $1,300 plus shipping. Bill Willes, (800) 227-6121, weekdays, 9 a.m.–5 p.m.

**Audio and industrial parts for the**
D-I-Y or equipment builder.
*Some of the brands Handmade stocks:*
RelCap MultiCap, Cardas, Kimber, Solo inductors, Solen, Golden Dragon, Nichicon Muse, Edison-Price, Hammond, Belden, Allen-Bradley, Caddock, low cost, very high qualty silver wire *and many others.*

*For a copy of catalog 1996-1997*, send $2.00 (US) or 5 IRC's (from your Post Office) to:
Handmade Electronics
P.O. Box 9114
Allentown, PA 18105-9114 USA

Pair Electro-Voice (Knight) SP12 12″ woofers; pair 12″ passive radiators, refoam by Speakerworks, $30; pair EPI 8″ woofers, $20; pair smaller Advent 9″ woofers, $40, new foam; pair Audax MHD12P25FSM 4″ mids, tested only, $30; pair Gauss 4582 15″ pro woofers, new recone, $150. All plus shipping. Andy, (303) 781-5573.

Audio Control Model SA3050 third-octave realtime spectrum analyzer, comes with mike, carrying case, and printer option. Excellent condition, asking $750, includes shipping. Niko Crosetti, (415) 578-1677, work (510) 264-1950 (PST).

Tannoy collection: pair Berkely 15s, walnut, mint condition, $1,750; pair Canadian Broadcasting Company Royal monitors, walnut, near mint condition, $1,500; pair DMT System 12, excellent condition, $1,500; pair SRM12B monitors, walnut, mint condition, $1,000; pair DMT 8 monitors, walnut, mint condition, $500; pair SRM15s, mahogany, mint condition, $1,000. Lowthers also available. Craig, (314) 579-0088.

Polk Audio 10a, $150; Koss-1A electrostats panels/parts, buy mine or sell yours; Hewlett Packard speaker test bench (will FAX list), $300; Electro-Voice CP-X variable crossover, $90; pair Electro-Voice XEQ-2 professional crossovers, $450; AR-4X cabinets, $75; Mark-V power amps (TA-802, TA-477). Ron, rlo@earthlink.net, (201) 543-2971, 7–10 p.m. (EST).

Dynaudio drivers: four 24W100, four D76AF. All new. Cost $1,200; asking $795 or best offer. Karl, (702) 884-3963.

Small Satellites Focal 90ti, Eaton 4203 (24dB, c.o. 1% matched parts, designed by Audio Concepts), $200. Pairs of original large Advent tweeters and woofers; Crown 1C150, $100; Crown OC150A, $150; Pioneer 1020L reel-to-reel tape deck, $250; or, take it all for $600 plus shipping. Bill Schulte, (513) 321-3175.

Use this convenient list to request the products and services that you need *fast*. Don't forget to mention *Speaker Builder!*

| COMPANY | PRODUCT | FAX |
|---|---|---|
| Acoustic Technology International | *Hi-End Drivers* | (905) 475-8226 |
| Allison Technology Corporation | *O-Scope II* | (713) 777-4746 |
| Antique Electronic Supply | *Tubes, Transformers, Books, & More!* | (602) 820-4643 |
| Audio Classics, Ltd. | *Audio Classics, Ltd.* | (607) 865-7222 |
| Gasoline Alley L.L.C. | *Acoustasheet* | (913) 827-9337 |
| Harris Technologies | *BassBox and X*over* | (616) 641-5738 |
| Kimber Kable | *Speaker cables, interconnects, etc.* | (801) 627-6980 |
| LinearX Systems, Inc. | *Leap* | (503) 598-9258 |
| Markertek Video Supply | *Unique & Hard-To-Find Accessories* | (914) 246-1757 |
| Morel Acoustics USA | *Loudspeaker Drivers, Car Speakers* | (617) 277-2415 |
| Newform Research, Inc. | *5″, 8″, 15″ & 30″ Ribbon Kits* | (705) 835-0081 |
| Parts Express Int'l, Inc | *Peak Instrument's Woofer Tester* | (937) 222-4644 |
| Speakers Etc. | *Specializing in Service* | (602) 272-8633 |
| The Speaker Works, Inc. | *Vifa* | (602) 230-8533 |
| True Image Audio | *WinSpeakerz & MacSpeakerz* | (619) 480-8961 |



Pair Bag End Infrasub 18″ subwoofer systems, each with integral crossover and 400W amp, $1,250 each. Pioneer LDS-2 laserdisc player; original owner, box, manual; cost $3,500, asking $1,250. Crown VFX-2A stereo electronic crossover, $225; Sherwood tuner, rackmount, solid state, $60. David, (914) 688-5024.

AES SE-1 power amp; Dual 1019 turntable; AR turntable XA model; Sony TC350 tape deck; Marchand XM16 electronic crossover, stereo two-way or pair of mono three-way available; Heathkit AR15 receiver amp, bad; Technics SB7070 speakers; Lafayette 8″ three-way coaxial speaker SK138; Solen Heptalitz coils and Sidereal caps. Chuck, (614) 787-1127.

Cash paid for damaged ribbon assemblies from

# AD INDEX



## WANTED

Magnepan or Carver speakers, prefer AL III units. Hal Morrison, (540) 459-5571, work (540) 459-2128, FAX (540) 459-3809.

KEF B139-B (SP1044) LF drivers in working condition. Call Doug H., (703) 243-2500.



Altec 838, 820; Laguna; Carmel; or other corner speaker; 604, 605, 601 coaxials. Tannoy Red or Gold monitors; Jensen CX-222, G-600, G-610; other corner and coaxial/triaxial speakers. Sonny, (405) 737-3312, FAX (405) 737-3355.

# CLUBS

## ARIZONA

**Arizona Audiophile Society**
PO Box 13058, Scottsdale, AZ 85267
Paul Christos, (602) 971-3979

## CALIFORNIA

**Tube Audio Enthusiasts**
65 Washington St. #137
Santa Clara, CA 95050
John Atwood, FAX (408) 985-2006

**Greater South Bay Audiophile Society**
Larry Fisher, (310) 599-6579
Dave Clark, (310) 427-4207

**San Diego Audio Artisans**
Wendell, (619) 538-6946 eves.

**Los Angeles Loudspeaker Designers Group**
Geoffrey, (213) 965-0449
Eduard, (310) 395-5196

**West Valley Audio Society**
Woodland Hills, CA
Barry Kohan, (818) 225-1341

**Bay Area Audiophile Society**
Dennis Davis, (415) 381-4228

**Westside Speaker Builders**
Cupertino, CA
Phil Terzian, (408) 446-1336
FAX (408) 446-4527

## COLORADO

**Colorado Audio Society**
1941 S. Grant St.
Denver, CO 80210
(303) 733-1613

## CONNECTICUT

James Addison
171 Hartford Rd., A-7
New Britain, CT 06053

**Connecticut Audio Society**
PO Box 116, E. Berlin, CT 06023
Charles King, (860) 665-2881

## FLORIDA

**Gulf Coast Audiophile Society**
5746 S. Lockwood Ridge Rd.
Sarasota, FL 34231
John R. Chait, (813) 925-1070

## GEORGIA

**Atlanta Audio Society, Inc.**
4266 Roswell Rd. N.E., K-4
Atlanta, GA 30342-3738
Chuck Bruce, (404) 876-5659
John Morrison, (404) 491-1553

## ILLINOIS

**Chicago Audio Society**
PO Box 313, Barrington, IL 60011
Brian Walsh, (708) 382-8433,
E-mail sysop@nybble.com

**Prairie State Audio Construction Society**
20 Wildwood Tr., Cary, IL 60013
Tom, (708) 248-3377 days,
(708) 516-0170 eves.

## INDIANA

**Tube Sound**
c/o William Schumacher
5417 Armstrong Ct.
Indianapolis, IN 46237-2318

## LOUISIANA

**New Orleans High End Audio Society**
PO Box 50231
New Orleans, LA 70150-0231

## MASSACHUSETTS

**The Boston Audio Society**
PO Box 211, Boston, MA 02126-0002
E. Brad Meyer, phone/FAX (617) 259-9684,
E-mail 72365.75@compuserve.com

## MICHIGAN

**Southeastern Michigan Woofer and Tweeter Marching Society**
PO Box 721464, Berkley, MI 48072-0464
(810) 544-8453,
E-mail aa259@detroit.freenet.org

## MINNESOTA

**Audio Society of Minnesota**
PO Box 32293, Fridley, MN 55432
(612) 825-6806

## MISSOURI

**Greater Osage Thermionic Warming Group**
7454 E. Fox Trot Ln.
Rogersville, MO 65742
James Guillebeau, (417) 889-3355

## NEW JERSEY

**New Jersey Audio Society**
209 Second St., Middlesex, NJ 08846
Frank J. Alles, (908) 424-0463
Valerie Kurlychek, (908) 206-0924

## NEW YORK

**The Audio Syndrome**
Nassau and Suffolk counties
Roy Harris, (516) 489-9576

**Catskill and Adirondack Audio Society**
PO Box 144, Hannacroix, NY 12087
(518) 756-9894

Daniel Phinney
29 Brian Dr., Rochester, NY 14624
(716) 594-8118, 5–9 p.m. EST

Long Island/Westchester County
Publio Morera, (516) 868-8863

**New York Audio Society**
136-69 71 Rd.
Flushing, NY 11367
Robert Kreisler, (718) 544-1222

**Western New York Audio Society**
PO Box 312, N. Tonawanda, NY 14150
Denny Fritz

**The Gotham City Audio Society**
c/o David Schwartz, President
375 11th St.
Brooklyn, New York 11215
(718) 788-0917

## NORTH CAROLINA

**Piedmont Audio Society**
1004 Olive Chapel Rd., Apex, NC 27502
Kevin Carter, (919) 387-0911

## TENNESSEE

**Memphis Area Audio Society**
8182 Wind Valley Cove
Memphis, TN 38125
J.J. McBride, (901) 756-6831

## TEXAS (Sweetwater)

Rick, (915) 676-7360

## UTAH (Salt Lake City)

**Wasatch Audio**
Edward Aho, (801) 364-4204

## WASHINGTON

**Pacificnorthwest Audio Society**
Box 435, Mercer Island, WA 98040
Ed Yang, (206) 232-6466
Gill Loring, (206) 937-4705

**Vintage Audio Listeners and Valve Enthusiasts**
1127 NW Brite Star Ln., Poulsbo, WA 98370
(360) 697-1936

## ARGENTINA

**Buenos Aires Audio Club**
Rincón 476
1081 Buenos Aires
Willy Pastrana, (011) 54-943-0007

**Figaro**
Esparta 1680 5000 Res.
Olivos Cordoba
Esteban Bikic, (011) 54-51-684251

## BELGIUM

**West Europe Lowther Club**
Avenue Plissart, 16
1040 Brussels
Victor Meurisse, FAX (011) 32-2-736-7394

## BRAZIL

**Audio Club de São Paulo**
c/o Mr. Valter Medina
Av. Ver. José Diniz 3135 cj 92
Campo Belo
São Paulo, SP 04603-020
(011) 530 1472, FAX (011) 530 8465
E-mail techmark@dialdata.com.br

## CANADA

**Montreal Speaker Builder Club**
4701 Jeanne Mance
Montreal, PQ H2V 4J5
Andrew McCrae, (514) 281-7954

**Toronto Area DIY Speaker Club**
Michael Mansor, (416) 626-9132
E-mail james.lcr@sympatico.ca

## CHILE

Christian Bargsted
Los Gomeros 1542, Vitacura, Santiago
(011) 562-538-0638

## FRANCE

**Sound Reinforcement Club of Paris**
11 rue de la fontaine du but
75018 Paris
Laurent Bonnet
Phone/FAX (011) 33-1-42-23-71-47

## GERMANY

**ESL Builders Group**
Gunter Roehricht
Bühlerstr.21, 71034 Böblingen

**Profi Club Visaton**
Visaton Lautsprecher
Ohligser Str. 29-31
42781 Haan
Bettina Schaaf, (011) 49-2129-522-0
FAX (011) 49-2129-522-10

## INDONESIA

**Silo Ultac Audio Society**
PO Box 6567 / SMS
Semarang 50065
FAX (011) 62-24-603595

**Tube Audio Enthusiasts**
Ignatius Chen, (011) 62-22-213277
FAX (011) 62-21-3868074,

## ISRAEL

**Audio Center**
c/o Kobi Cohen
11, Hayey Adam St.
Tel-Aviv 67499
FAX (011) 972-3-696-5054
E-mail audio_c@inter.net.il

## NETHERLANDS

**Audio Vereniging Midden Nederland**
Brinkersweg 16, 8071 GT Nunspeet
B. Doppenberg, (011) 31-3412-57848

## SOUTH AFRICA

**Hi-Fi Club of Cape Town**
PO Box 18262, Wynberg 7824
Chris Clarke, FAX (011) 27-21-7618862,
E-mail chrisc@iaccess.8a

## TURKEY

**Istanbul Hi Fi Club**
Adnan Arduman, (011) 90-216-310-44-70
FAX (011) 90-216-343-42-01

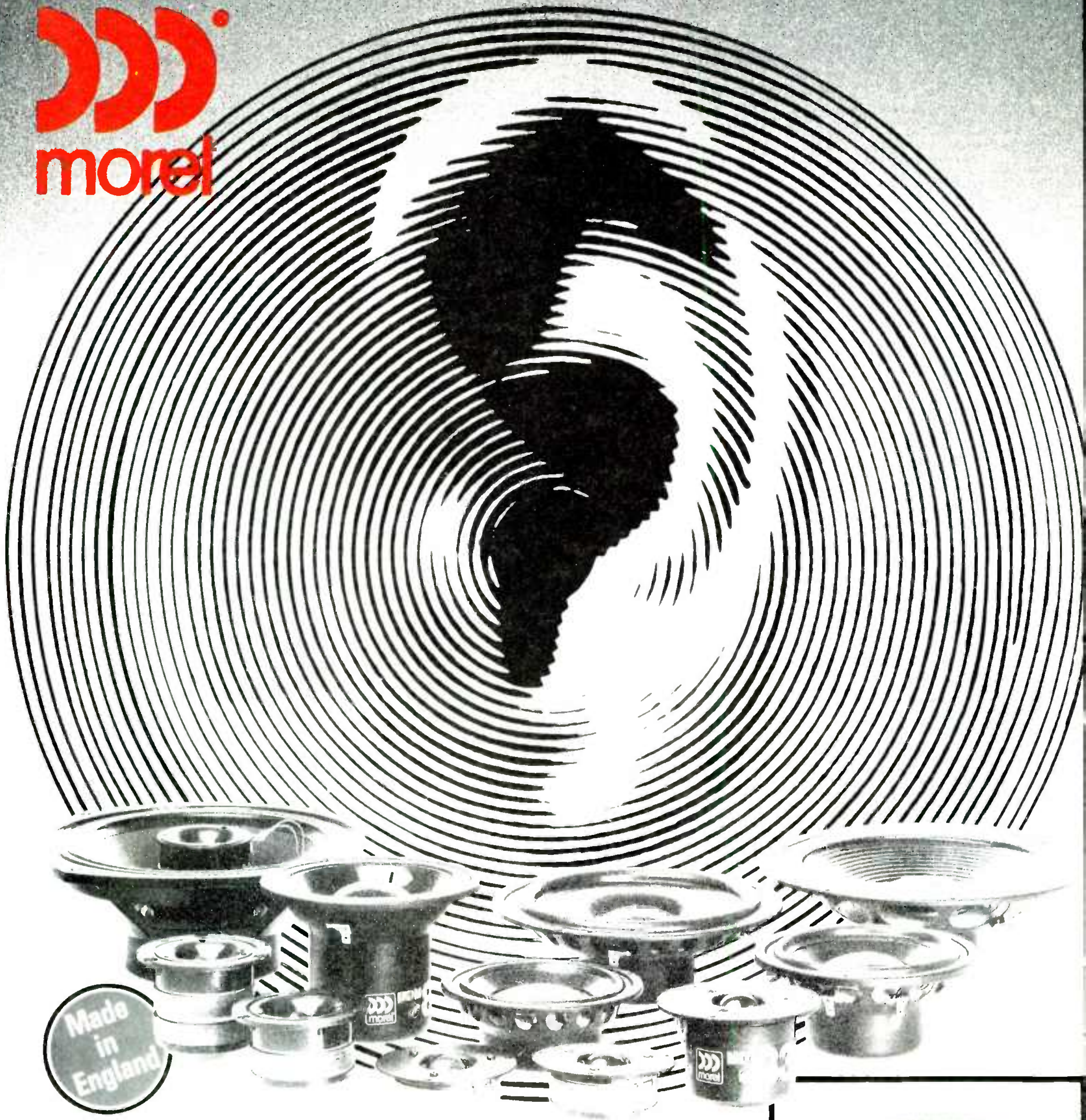
## UNITED KINGDOM

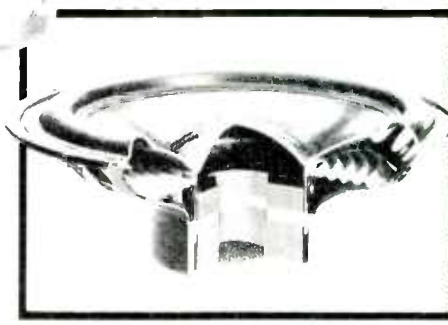
**London Live DIY Hi-Fi Circle**
Brian Stenning, (011) 44-181-748-7489

If your club is not represented or if you are interested in starting up a club, simply send the information (club name, contact person, address, and phone/FAX number) to:

**Audio Amateur Corporation, Clubs**
**PO Box 494, Peterborough, NH 03458**
**FAX (603) 924-9467**

morel



Typical Double Magnet Woofer Cross Section

# High-Tech Audiophile Loudspeakers

For Further Information Please Contact:

**morel acoustics USA**
414 Harvard Street
Brookline, MA 02146
Tel: (617) 277-6663
FAX: (617) 277-2415

Reader Service #15