CAN WE HEAR **DIRECTIONALITY** IN SPEAKER WIRE?

THREE: 1998

US $7.00
CANADA $10.00

Speaker Builder®

THE LOUDSPEAKER JOURNAL

BUILDING A 3-WAY PYRAMID

SNAIL 2: FOLDED HORNS REDEFINED

AR-3a: THE FINAL SOLUTION

DRIVE REPORT: SCAN-SPEAK 7" MID/WOOFER

Dick Pierce Reviews CLIO s Little Brother


THE ART OF CONNECTION
WBT-0150
WBT-0108
WBT-0101
In 1985 WBT introduced its first RCA type connector...machined from a solid block of material and equipped with the adjustable WBT collet chucking device. Today WBT offers a full range of connectors, designed and manufactured to be the highest quality, best sounding, connectors on the market.
Top line connectors feature the highest tolerances (< 2/100 mm!). Made of the best materials (68% 5N pure copper) with unbeatable, 5-layer supra-gold plated, surface technology. The midline range ensures solid connection technology at a competitive price.
WBT banana plugs feature a one piece signal carrying plug element and set screw "crimp" termination technique. The maximum pressure expansion tip "locks" the banana and greatly reduces contact resistance.
WBT binding posts feature a one piece signal carrying element and set screw "crimp" termination. Machined pressure rings keep contact resistance to an absolute minimum.
WBT-0208
WBT-0201
WBT-0147
WBT-0144
WBT-0600
WBT-0644
WBT-0645
WBT®
The art of connection
WBT-USA - 2752 South 1900 West - Ogden Utah 84401 - 801-621-1500 - Fax 801-627-6980
www.wbtusa.com
Pat. NO.PCT-W091/10270 Pat. NO.DBGM8527598 Pat. NO.DE4100600
Reader Service #65

New! LEAP *Version 4.5*

LEAP

Precision Development Tools for Precision Loudspeaker Designs

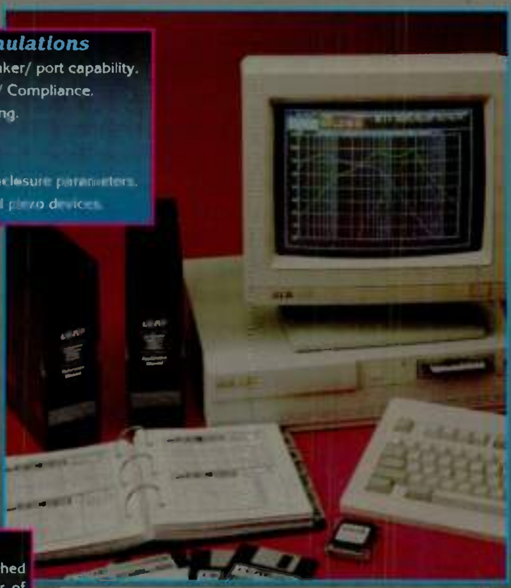
The Art and Science... of loudspeaker system development today has become more complex than ever before. Competition is tough, and to compete each design must perform to the best of its ability, and make the most out of every dollar's worth of transducer cost. The simple approach of choosing a combination 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) 612-9565

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. 9500 SW Tualatin-Sherwood Road Tualatin, Or 97062 USA Tel: (503) 612-9565 Fax: (503) 612-9344 Web: www.linearx.com

International Dealers **Agentina** Interface SRL (54-1)741-1389/ **Australia** ME Technologies 61(0)65-50 2200/ **Austria** Audiomax 49(0)71-31-162225/ **Belgium** Belram 32(0)2-736-50-00/ **Canada** Gerraudio 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 Audio 62(0)21-639-5806/ **Italy** Outline snc 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** Dai-Ichi 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** Gestion Taiwan 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

Reader Service #36

Good News

INVISIBLE SPEAKERS

Miller & Kreisel's (M & K's) SW-85 and SW-95 in-wall speakers appear frameless because the grille fastens to the steel baffle with six custom-magnetized seven-pole magnets. By simply painting the grille the same color as the surrounding wall, you can create a perfect match and blend, resulting in an "invisible" speaker. You may use the SW-85 and SW-95 as either main or surround-channel speakers, and kits are available for both models. Miller & Kreisel Sound Corp., 10391 Jefferson Blvd., Culver City, CA 90232, (310) 204-2854, FAX (310) 202-8782.

Reader Service #136

AMP PROTECTION CORRECTION

SB 1/98 included an announcement about Parasound's S/PS-140 loudspeaker selector. A resistor was incorrectly described as 4W, 60Ω. It should read 4Ω, 60W. We apologize for any inconvenience.

EXPERIENCE MAXXBASS

NXT has been granted exclusive rights to license the MaxxBass® technology of Waves Ltd. to users of its flat-panel loudspeaker technology. Using patented algorithms that process any audio signal, MaxxBass analyzes the fundamental frequencies of music that fall below a speaker's frequency range. The technology then adds precisely calculated harmonics of these fundamentals to the signal, producing realistic low-bass sound and enhancing the speaker's ability to reproduce music. NXT New Transducers Ltd., Stonehill, Huntingdon, PE18 6ED, UK England, (+44) 1480-451777, FAX (+44) 1480-437177.

Reader Service #134

BACK TO YOUR CORNER

MB Quart's Octa QL A40 is a subcompact speaker within an eighth-sphere molded enclosure, which fits in corners and wall-ceiling junctures. Spanning 5″ in each direction, the unit produces 100Hz–18kHz while employing a 4″ driver with dual-range cone and a long-throw motor system. Available in black or paintable white, the Octa comes complete with wall/corner-mounting hardware. MB Quart Electronics USA, Inc., 25 Walpole Park South, Walpole, MA 02081-2532, (508) 668-8973, FAX (508) 668-8979.

Reader Service #141

HEAD FOR THE ROCKIES

Rockustics introduces two outdoor speakers, the Rocquette and Pavarocci. The 70W Rocquette is powered by a 6.5″ coaxial Vifa driver and measures 16.5″ W × 11″ D × 9″ H. The Pavarocci, 30% larger than the Rocquette, is powered by a 70W, 8″ coaxial Vifa driver and measures 16″ W × 13.5″ D × 12.5″ H. Both models are constructed with crushed stone and weatherproof, environmentally safe resins that can withstand harsh weather elements in all climates, including ultraviolet rays, heat, rain, snow, and wind. Rockustics, Inc., 15400 E. Batavia Dr., Aurora, CO 80011, (303) 363-6161, FAX (303) 363-0011.

Reader Service #137

TOTALLY TUBULAR

The RS series of speakers from SoundTube Entertainment incorporates the company's Zero-Reflection™ enclosures with wave-flow technology. With curved and fluted side walls, these cabinets provide 360° coverage while reducing standing waves, reflections, and panel resonances. SoundSleeves are interchangeable outer coverings that come in a variety of colors and patterns and are available for all RS models. SoundTube Entertainment, Inc., PO Box 1120, 505 Main St., Park City, UT 84060, (435) 647-9555, FAX (435) 647-9666.

Reader Service # 140

ANTENNA INSTRUCTION

The Right Antenna (second edition), by Alvis J. Evans, provides information on a wide variety of antennas. The book explains how they work and devotes a chapter to interference and antennas used by hams for antenna-band operation. Also discussed are the basic concepts of cellular telephone system operation and the most popular antennas, as well as chapters on DSS and other satellite TV antennas. Available as BKS58 from Old Colony Sound Lab, PO Box 576, Peterborough, NH 03458, (603) 924-9464, FAX (603) 924-9467, E-mail custserv@audioxpress.com.

Reader Service #135

Reader Service #22 →

Speaker Builder®

The Staff

Editor and Publisher
Edward T. Dell, Jr.

Regular Contributors

Joseph D'Appolito **Robert Bullock**
Richard Campbell **John Cockroft**
David Davenport **Vance Dickason**
Bruce Edgar **Bill Fitzmaurice**
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 L. Hampsey Editorial Assistant
Tina Hoppock Graphics Director
Diane Luopa Assistant Graphics Director
Joan Ahern Production Assistant
Joannie Berriman Production Assistant
Laurel Humphrey Marketing Director
Robyn Lasanen Circulation Manager
Kelly Bennett Customer Service
Peter B. Wostrel National Advertising Director
Lisa DiRusso Advertising Sales
Ann Avery Advertising Coordinator

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/CUSTOMER SERVICE 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: custserv@audioxpress.com.

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: editorial@audioxpress.com.** No responsibility is assumed for unsolicited manuscripts. Include a self-addressed envelope with return postage. The staff ***will not*** answer technical queries by telephone.

ADVERTISING RATES & SCHEDULES

Contact Advertising Department, Speaker Builder, PO Box 494, Peterborough, NH 03458, 603-924-7292, FAX 603-924-9467, E-mail advertising@audioxpress.com.

About This Issue

Our lead article in this issue is an excellent example of combining the art and science of speaker building. **Rüdiger Geppinger** has designed a showcase pair of low-cost pyramid speakers, which you'd be pleased to place in your living room. But more importantly in this case, aesthetics supports function, as this design greatly benefits performance. Check out these quality speakers ("The Pyramids," p. 8).

Adhering to the concept that bigger must be better, **Bill Fitzmaurice** has packaged his Snail folded-horn design (from *SB* 6/97) in a larger unit. The result is a PA enclosure with plenty of power to reach your desired audience ("Snail II: Redefining the Folded Horn," p. 20).

The question of directionality in speaker cables has been widely debated in the audio community. In an attempt to investigate this issue, ***Speaker Builder*** participated with Belden Wire & Cable Company to explore the question, "Does Wire Directionality Exist?" The answer begins on p. 30.

Tom Yeago has provided us with a unique DIY perspective on overhauling a speaker system. In this final installment ("Rebuilding the AR-3*a*, Part 6," p. 32), after a few tweaks, adjustments, and finishing touches, he's prepared to kick back and sample the fruits of his labor.

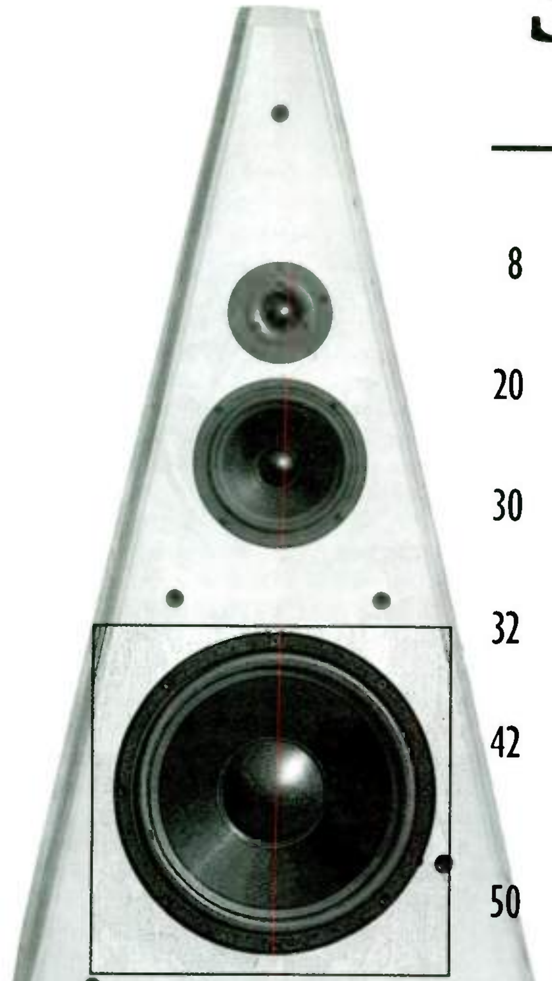
In the product spotlight in this issue is Audiomatica's latest version of its loudspeaker-measuring software, entitled CLIOLite. **Dick Pierce** examines this scaled-down version of its big brother, CLIO ("Product Review," p. 42).

Then, loudspeaker guru **Vance Dickason** offers his standard driver report on a new woofer release (18W/8546) from Scan-Speak (p. 50).

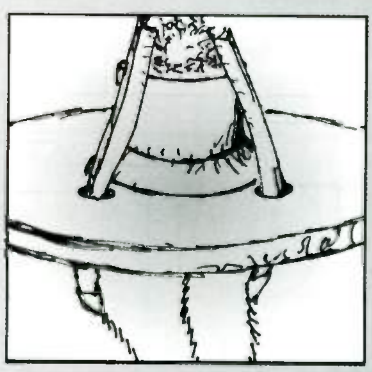
Speaker Builder (US USSN 0199-7920) is published every six weeks (eight times a year), at $32 per year, $58 for two years; Canada add $8 per year; overseas rates $50 one year, $90 two years; by Audio Amateur Corporation, Edward T. Dell, Jr., President, at 305 Union Street, PO Box 494, Peterborough, NH 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 19 NUMBER 3 MAY 1998



8



32

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: editorial@audioxpress.com.

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: custserv@audioxpress.com

ADVERTISING — Address advertising inquiries and information requests to the Advertising Department, Audio Amateur Corporation, PO Box 494, Peterborough, NH 03458-0494, voice (603) 924-7292, FAX (603) 924-9467, E-mail: advertising@audioxpress.com.

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, E-mail: custserv@audioxpress.com.

THE PYRAMIDS

By Rüdiger Geppinger

Pyramids have some distinct advantages over box-type speaker cabinets. For example, the nonparallel walls minimize standing-wave effects and the slanted front improves the time adjustment of the drivers (*Photo 1*). Furthermore, the front is wide enough at the base to accommodate the woofer, and narrow at the top, where the tweeter is located. This minimizes diffraction effects and helps to improve sound dispersion. The panel width also varies from bottom to top, which distributes panel resonances. The only disadvantages of which I am aware are that a pyramid is more complicated to build and, for a given height and volume, it requires more floor space than, for example, a tower speaker.

THE DRIVERS

The tweeter I used for this design is a Vifa D27TG-45-06. This 1″ driver, manufactured in Denmark, features a coated diaphragm of fabric, ferrofluid damping, and a replaceable voice coil. It costs $23, and is probably one of the best choices for less than $50 per pair.

The midrange is a Vifa P17WJ-00-08, actually a 6½″ mid/woofer. It comes with a magnesium basket, mineral-filled polycone, and rubber surround, and costs about $35.

With the pyramid's restricted volume, I needed to search for a decent woofer suitable for a closed design of approximately 50 ltr, and close to my budget figure of $60. With a 6½″ driver used as a midrange, I could choose a very low crossover point—in other words, a fairly large woofer.

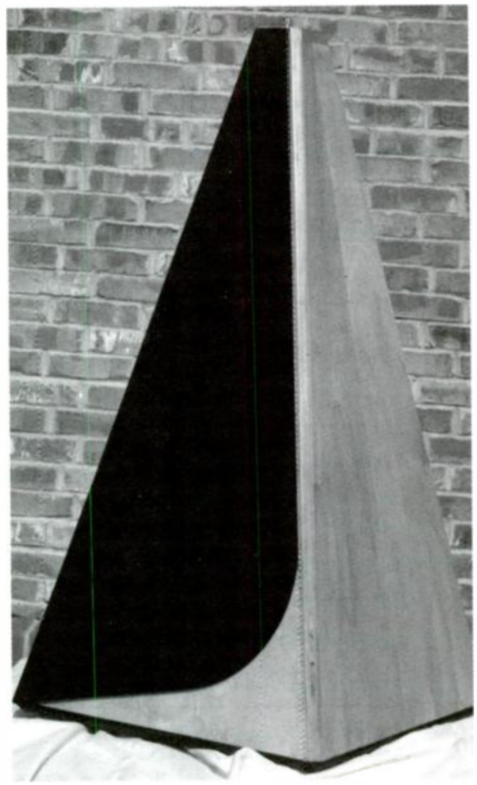


PHOTO 1: Completed speaker with grille.

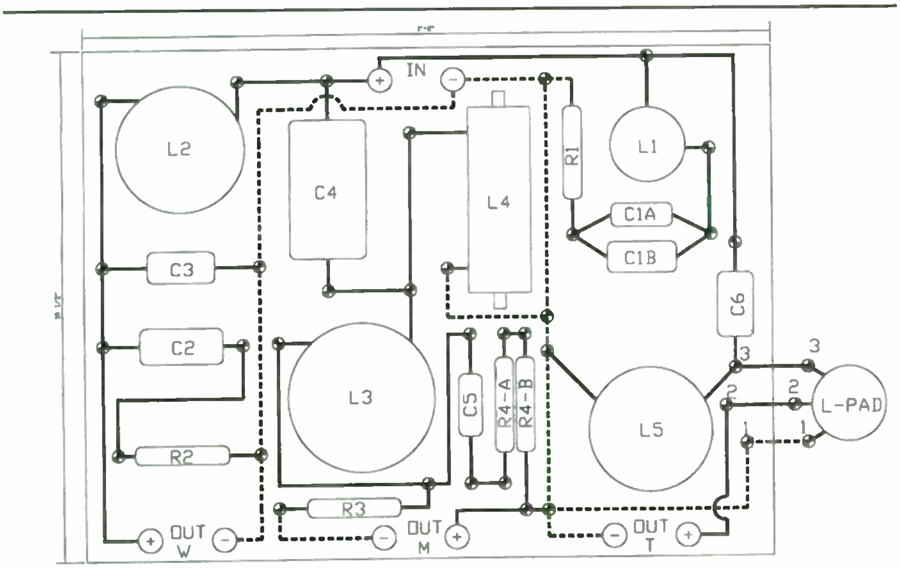


FIGURE 1: Crossover layout.

I finally decided the Swan 305 was a good choice. This driver is 12″ in diameter, has a polypropylene diaphragm with foam surround, and requires a volume of about 50 ltr for a Q_{tc} of 0.7 in a sealed cabinet. Last, but not least, it costs $58, fitting my budget perfectly.

THE CROSSOVER

The crossover is a three-way design with 12dB/octave slope. Vifa recommends crossing over the tweeter at 3.5kHz, a relatively high crossover point for the 6½″ midwoofer. However, the frequency-response and dispersion curves for the P17WJ-00-08 show that the driver rolls off at 5kHz on-axis and is only 2–3dB down at 3.5kHz, measured under 30°. Also, I was not yet willing to trade the power-handling capabilities of the tweeter for a better dispersion at a lower crossover frequency.

The beauty of the large midrange is that it can easily be crossed over below 500Hz. This moves the crossover points out of the most sensitive audible spectrum. I finally chose a crossover point of 350Hz between woofer and midrange.

I started the design by measuring the impedance curves of the woofer and midrange drivers and compensating the impedance rise. I calculated the required values for coils, capacitors, and resistors manually. The crossover is constructed with parts of excellent quality in the signal path, and parts of acceptable quality elsewhere (*Table 1*).

This "no-compromise" crossover is relatively expensive, using parts of excellent quality even in some less critical places. Savings of about $30 per crossover are possible by substituting less costly alternatives for components not in the signal path. The crossover layout (*Fig. 1*) is based on the physical dimensions of the high-quality components.

Typically, components of lesser quality are smaller (coils with thinner wire, or electrolytic instead of foil caps). By constructing the crossover based on the layout for the larger components, you can easily exchange parts to upgrade. The 50µF capacitor in the

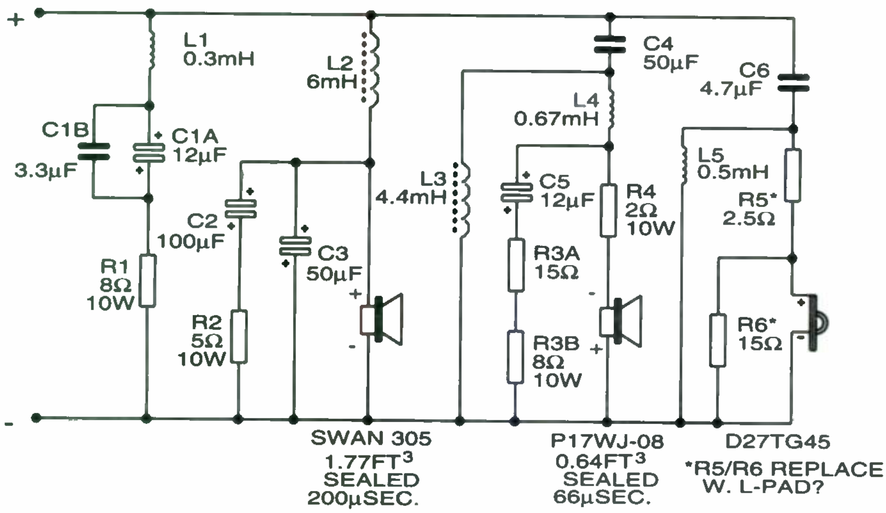


FIGURE 2: Crossover schematic.

midrange bandpass would be my first choice for an upgrade.

LISTENING TEST

After completion of the woodwork and crossovers, I assembled the speakers for a first listening test. The results showed that the speakers seemed to overemphasize the upper midrange, approximately at the crossover frequency between midrange and tweeter.

I do not yet possess the tools for measuring frequency response, and I was not willing to spend more time with trial and error to correct the problem. I finally sent my crossover design to Madisound, which offers design services and simulation on LEAP software. I asked them to simulate the response based on my design, and then to improve this design to achieve a flat response. I paid $40 for this service, and after the few required modifications and additions to the existing crossover, the sound improved markedly. *Figure 2* shows the crossover schematic.

Note that I replaced R5 and R6 with an L-Pad to allow for adjustment of the treble. *Figure 3* shows the simulated on-axis response of the system. Except for the 2dB hump at 70Hz and the tweeter rolloff at 15kHz, the simulation is within ±1.5dB from 45Hz to 20kHz.

Figure 4 shows the impedance magnitude and phase. Most importantly, the impedance does not drop below 4.5Ω, which means the speaker is actually amplifier friendly. *Figure 5* shows the simulated response of each speaker. The actual crossover frequencies are at 300Hz and 3.25kHz—from my point of view, close enough.

I constructed the crossover on a 3/8″-thick plywood panel. I mounted the components with tie-wraps, fastened all cabling with hot glue, and made the cable connections to the terminals and speakers with solder lugs and posts using machine screws with washers and nuts. I prefer this method, since it allows you to exchange components easily and to make all connections inside the cabinet without soldering. *Figure 6* shows more details of the crossover's mechanical construction.

THE CABINET

The cabinet is a double-layer construction. The inner cabinet is fabricated from ¾″ particleboard, and the outer shell from ¾″ birch plywood (*Fig.7*). Start by cutting the front, back, sides, and the divider between the woofer and midrange chambers of the inner cabinet. Note that the top and bottom ends of these pieces, as well as the divider, must be cut at an angle.

Assemble these parts with plenty of particleboard screws and wood glue, except for the front panel, which you attach only with screws,

PHOTO 2: Front view of completed speaker with grille removed.

since you'll need to remove it at a later stage of the project. The dimensions (metric) are shown in *Figs. 8* and *9*. Cut the holes for the drivers after you get them. Manufacturers do change technical data without notice, and it is difficult to alter the size of one of these holes, especially if you decide to flush-mount the drivers.

I found it to be extremely difficult to cut the bottom and top pieces to the exact size and

TABLE 1

CROSSOVER PARTS LIST

Item	Description	Cost (1 ea.)
L1	Air-core inductor, 0.3mH, MB, 19 gauge wire, 0.3DCR, 100W	$ 1.90
L2	Sledgehammer ferrite bobbin inductor, 6.0mH, 0.31DCR	$12.20
L3	Sledgehammer steel laminate inductor, 4.5mH, 0.231DCR	$11.75
L4	Perfect-lay winding air-core inductor, 0.68mH, 0.17DCR	$ 9.50
L5	Perfect-lay winding air-core inductor, 0.47mH, 0.13DCR	$ 8.00
C1A	Bennic bipolar electrolytic capacitor, 12µF, 100WV	$ .80
C1B	Bennic metalized polypropylene capacitor, 3.3µF, 160V AC	$ 2.40
C2	Bennic bipolar electrolytic capacitor, 100µF, 100WV	$ 2.70
C3	Bennic bipolar electrolytic capacitor, 50µF, 100WV	$ 2.00
C4	Polypropylene Solen fast capacitor, 50µF, 250V DC	$15.85
C5	Bennic bipolar electrolytic capacitor, 12µF, 100WV	$ .80
C6	Polypropylene Solen fast capacitor, 4.7µF, 250V DC	$ 3.05
R1	Lynk noninductive wirewound resistor, 8Ω, 10W	$ 1.80
R2	Lynk noninductive wirewound resistor, 5Ω, 10W	$ 1.80
R3A	Lynk noninductive wirewound resistor, 15Ω, 10W	$ 1.80
R3B	Lynk noninductive wirewound resistor, 8Ω, 10W	$ 1.80
R4	Lynk noninductive wirewound resistor, 2Ω, 10W	$ 1.80
LP	15W 8Ω, L-pad for tweeters	$ 2.75
	Total for one crossover:	$82.70

angle at the same time. My first attempt ended with another scrap piece. I found the following method to be a lot easier and more successful. Cut the bottom and top pieces about 2″ larger than required and mount them to the assembly, making sure they extend evenly around the speaker. Attach with screws and wood glue, again except for the front panel.

I used a belt sander to carry out the final alignment between the cabinet and the top and bottom pieces. Start with 50-grit belts and finish with 100-grit. The whole procedure should not take more than 15 minutes, and it provides an exact fit, even if the cabinet is not exactly rectangular.

The first time I tried this, I was a little bit too enthusiastic with the sander and ran it into the cabinet walls. This is not really a serious problem, since you'll cover the inner cabinet with the birch layer, but if you have had little experience with handling a belt sander, attach a piece of sheet metal as wide as the base of the cabinet with duct tape. This protects the cabinet and leaves an edge as thick as the sheet metal. To sand away the last 1/32″ of material, remove the sheet metal and use a fine-grit sanding belt.

Remove the front panel and attach it with screws (no glue) to a 2′×4′ birch plywood panel. Mark the centers of the driver cutouts, and drill small pilot holes through both panels. Mark the plywood panel around the perimeter of the particleboard. Separate the two panels and cut out the holes for the drivers on each panel separately with a jigsaw or router.

To flush-mount the speakers, you must use a router. Rout the outer circumference of the driver first, then set the template for the cutout diameter and rout all the way through the material. The centerpiece needs to be attached to the bench with two screws and the front panel with two clamps; otherwise, the center will move and the router will run into the front panel.

INSTALLING CABLES

It is easiest to install the cables for the midrange and tweeter at this stage. You can later locate the crossover at the bottom of the woofer chamber. Drill a 3/8″ hole through the center of the internal divider. Cut the cables at least a foot longer than you think they need to be.

Solder lugs to the ends that will be located in the woofer chamber, and run the other ends through the hole in the internal divider. Mark the cables as tweeter/midrange, +/– on both ends, and make sure the markings match (use an ohmmeter or battery and flashlight bulb if you are in doubt). Fasten the cables and seal the hole with hot glue and silicone.

You can now permanently attach the particleboard front to the inner cabinet. For this connection, I used silicone as well as wood glue to make sure the cabinet is really airtight. The most important joint is actually between the internal divider and the surrounding walls. If this joint leaks, the woofer will pressurize the midrange chamber, which will have a devastating effect on the performance of the midrange. Once the wood glue is dry, apply plenty of silicone to all inner edges and corners of the cabinet.

The next step is to cut and mount the birch front panel. Cut the panel about ¼″ wider and 2″ longer than required. Make sure the driver cutouts match, and attach the panel using wood glue and the screws for fastening the drivers so as to apply pressure in the center of the panel. Use clamps to apply pressure at the edges of the panel. I used a router with a piloted straight bit to remove the excess material at the sides, and the belt sander again to align the top and bottom of the birch panel to the cabinet.

THE BACK PANEL

Now you can cut and attach the plywood back panel. First locate and cut the hole for the terminals and tweeter controls. This hole is required, since the lengths of the terminal and potentiometer shaft are not sufficient for a 1½″ wall thickness. As described for the front panel, I also cut this one larger than required.

It is awkward to use clamps on a pyramid, because the opposite walls are not parallel, so instead of clamps, I used 1¼″ particleboard screws driven from the inside of the cabinet when attaching the plywood panels. Drill about

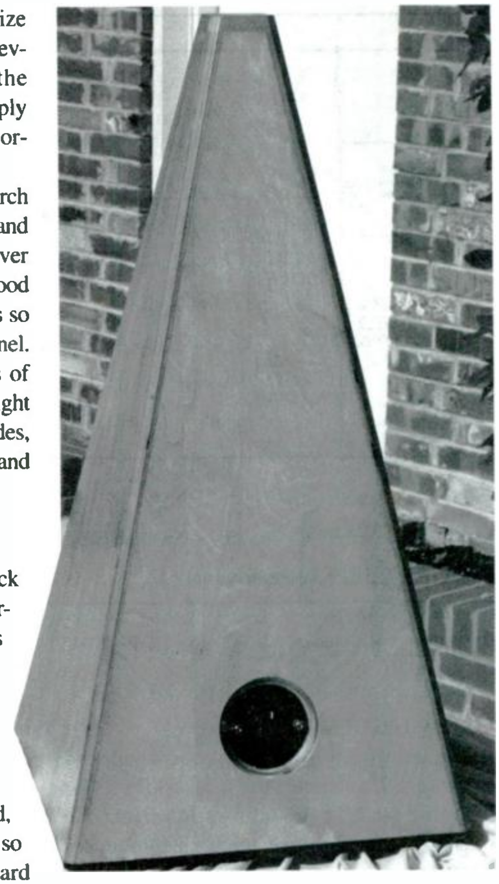


PHOTO 3: Back of speaker, showing recessed treble control and terminals.

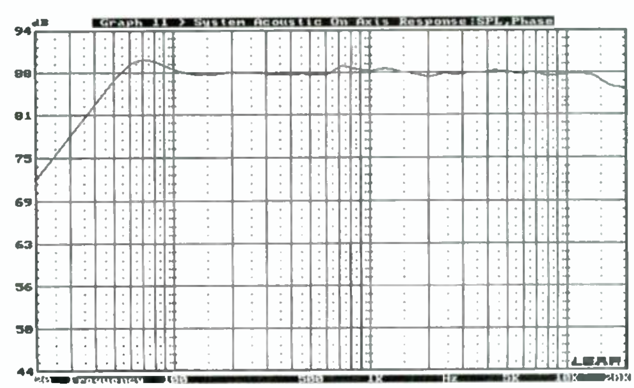


FIGURE 3: Simulated on-axis response.

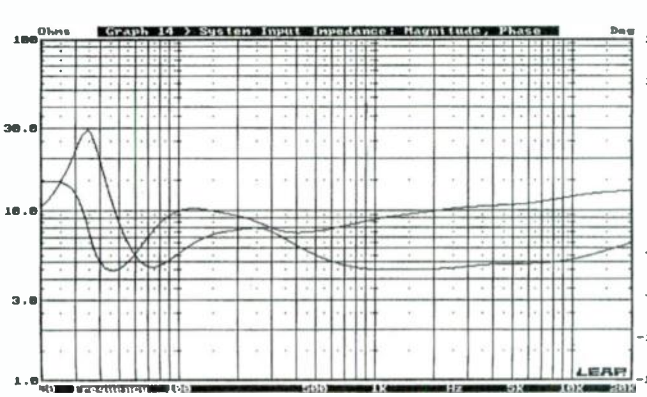


FIGURE 4: Impedance magnitude and phase.

Swans *M2* kit

The Swans M2 is a floorstanding model that features several technological achievements and sound quality distinctions.
The speaker system is a two-way bass-reflex design with MTM driver configuration. The front baffle is very narrow with rounded edges to reduce cabinet diffraction for better clarity and imaging. The internal panels and corner reinforcement bars substantially suppress unwanted cabinet vibrations. The bottom part of the cabinet is sealed and can be filled with sand or lead shot for better stability and further performance improvement. A port is mounted on the rear panel.
The drivers used in the Swans M2 represent a new high performance design from Hi-Vi Research. The 5-inch paper/Kevlar cone bass-midrange has a rubber surround, cast aluminum frame and a magnetically shielded motor system. This driver utilizes a central phase plug to avoid air compression, improving frequency response and dispersion. The extremely rigid cone is hand coated with a special dampening compound to further maximize its performance. The cone is coupled to a selected grade rubber surround, this provides break-up free operation and very low distortion even at high power levels. These key features greatly contribute to the Swans M2's clear transparent sound and effortless dynamic performance. Swans M2 delivers amazing bass without runing in "doubling" or Doppler distortion problems.
The tweeter is a high-tech planar isodynamic design that employs Neodymium magnets and extremely light Kapton® film, with flat aluminum conductors.
The vibrating element of the tweeter is almost weightless in comparison to a conventional dome driver. This unit provides an immediate and precise response to any transients in original signal, and gives the Swans M2 an exceptional ability to reveal the true dynamics of instruments with a complex high frequency spectrum.
The crossover is a second order Linkwitz-Riley type resulting in an in-phase connection of the drive units. The crossover frequency between the two drivers is 3.3 kHz and only high quality polypropylene capacitors are used. Each filter has it's own dedicated board mounted on a special rubber interface to reduce vibrations and microphonic phenomenon. The filter boards are spaced inside the loudspeaker with the inductors positioned at right angles to minimize the interaction.
Swans M2 provide very even acoustic power dispersion. The important horizontal early reflections that create spatial impression and add to the overall presentation have the same even spectral balance as the direct sound, these are crucial features of a good loudspeaker.
On the contrary, the vertical dispersion is well controlled in the midrange and high frequency domain in a 15° arc symmetrically to the reference axis. While 15° create adequate room for adjusting a listening position, the floor and ceiling reflections are well down in amplitude. This feature greatly contributes to the clarity of sound and imaging of the system.
Swans M2 kit includes:
- 4x F5 paper/Kevlar bass-midrange drivers,
- 2x RT1C isodynamic tweeters with sealing gaskets,
- 2x dedicated tweeter crossovers,
- 2x dedicated bass-midrange crossovers,
- two ports and two Swans logos,
- two pairs of heavy-duty gold plated terminals.

For those who are interested in a home theater set up, the instructions and parts for correspondent central channel speaker are available.
The drawings of the cabinet shown here represent general dimensions required for optimum bass performance. Rounded corners are advisable as they improve imaging and clarity. Actual finish and appearance is a matter of personal taste. The system should be installed on adjustable spikes and slightly tilted back to aim tweeter axis at listening position.
Retail price: $ 530.00 (including everything)
Delivery in US within 4-6 days.
Warranty 3 years, 30 days money back guarantee.

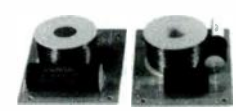
High sonic resolution Loudspeaker with room friendly performance

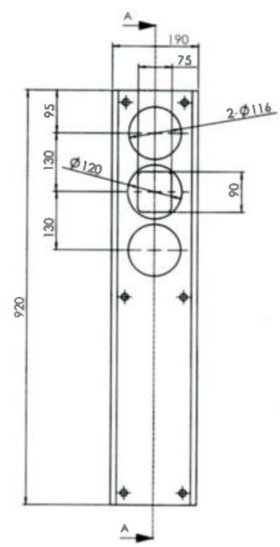
SWANS
SPEAKER SYSTEMS

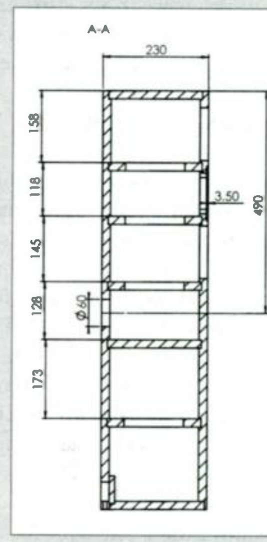
The step beyond the limits

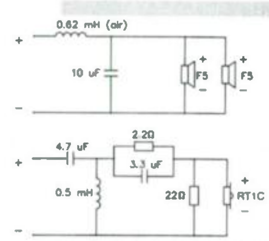

RT1C Tweeter

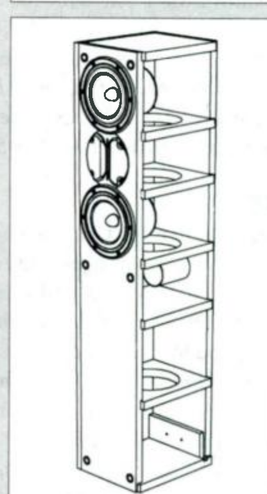

F5 Bass-midrange


Filter









SPECIFICATIONS	
Frequency response (1m,half space)	53Hz-20kHz,±2.5dB
Sensitivity,1W/1m (100Hz-8kHz averaged)	87.5 dB
Nominal impedance	4 ohms
Harmonic distortion At 90dB SPL, 100Hz-10kHz, 1m	THD less than 1%
Power handling	80W nominal, 150W program
Dimensions,HxWxD (without spikes)	920x190x230 mm; 36 1/4x7 1/2x9 inches

Amplifier requirements:
30W recommended minimum.

ACOUSTIC TECHNOLOGY INTERNATIONAL INC.
15 WEST PEARCE STREET UNIT 2&3,
RICHMOND HILL
ONTARIO L4B 1H6 CANADA
Tel: (905)-889-7876 Fax: (905)-889-9296
www.dulcet.com

ten holes through the particleboard, located so they are accessible through the woofer and midrange cutouts.

Lay the back panel on the workbench, apply wood glue, and position the cabinet on top of the panel. Make sure the panel is aligned with the cabinet sides, and drive the screws from the inside through the particleboard into the panel. If the plywood is slightly warped, the top end of the cabinet will cause some trouble, since you cannot use screws in this area. In such cases, I have used duct tape wrapped a couple of times tightly around the top of the cabinet.

The side walls are the easiest part. You cut and attach them in the same way as the back panel. The top piece is made of solid poplar. Cut it slightly larger and attach it only with glue. Here you cannot use screws from the inside to apply pressure. Here again, I used duct tape to fix this piece in place (a weight of about 20 lbs works as well), and used the belt sander to grind it to size after the glue was set. Protect the side panels with a small piece of sheet metal as described above.

The bottom piece is also cut slightly larger and attached with glue and screws, this time driven through the plywood into the cabinet. I used the sander to align them to the cabinet. Be very careful not to sand into the side walls.

As a last finishing touch to this stage of construction, I chamfered all edges except for the top with a router and a 45° chamfer bit. I sanded the speakers, stained them golden oak, sanded again with 400 grit, and applied two coats of varnish. I decided to paint the bottom flat black, as well as the particleboard visible through the terminal cutout in the back panel. This completes the cabinet construction.

Photo 2 shows the front with the grille removed. *Photo 3* shows the rear of the speaker, with the treble control and terminals recessed. *Figures 10a, 10b, 11a,* and *11b* are printouts for the woofer and midrange, generated by the design program used (Bassbox 5.1).

THE GRILLE

The best grille is no grille. That is one of the few things most audiophiles agree on. However, most of us have to consider aesthetics and the curiosity of children and pets. A grille does not need to look boring. One possibility is shown in *Photo 1*. It is cut from 3/8″ plywood, all edges are rounded with a roundover bit, and it is painted flat black.

The fabric should be suitable for this application. Most speaker-component vendors carry an excellent stretch material that is easy to use. I attached it with an electric stapler, covering the staples with black tape. You can attach it to the cabinet with Velcro or ball-and-socket headlocks.

To make sure the balls and sockets match, place the grille frame on the cabinet and temporarily fasten it with tape. With a small drill bit, drill a pilot hole through the grille frame and into the cabinet. Remove the frame and drill a hole of the diameter required to accept the sockets and balls. I used a small amount of hot glue to secure the balls to the frame.

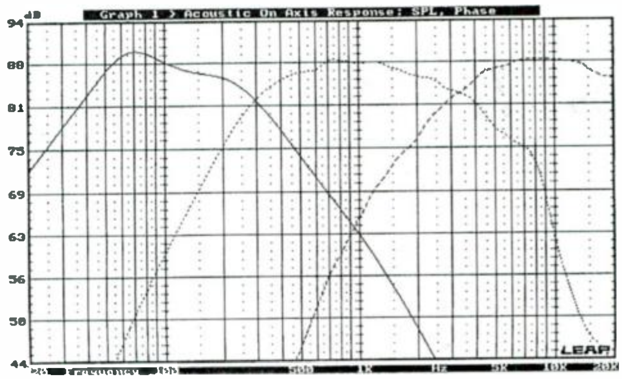


FIGURE 5: Simulated on-axis response of each driver.

FINAL ASSEMBLY

The first step of the final assembly is to drill the holes required for the terminals and treble controls. Vacuum all chips and dust from the cabinet interior, and inspect all joints to see they are properly caulked. You can use a small mirror to inspect the joints between the front panel and the cabinet side walls. Apply additional caulk wherever you doubt the seal is leakproof. As mentioned before, the cabinet needs to be absolutely airtight, especially the divider between woofer and midrange chamber.

Now prepare the crossover for final installation. Since it is very crowded inside the speaker, it is advisable to install as many connections as possible prior to crossover installation. Connect solder points 1, 2, and 3 on the crossover to the related points, also marked 1, 2, and 3, at the treble-control solder lugs. Prepare cables with lugs on both sides to connect the crossover input posts with the input terminals, and mount them to the input terminals at the crossover.

Prepare the connection cables between the crossover and the woofer. These cables have lugs on one end, and you solder them to the woofer terminals at the other end. Mount the lug end to the connection posts of the crossover. Attach weatherstripping with adhesive backing to the bottom of the crossover around the edges, and strips through the center

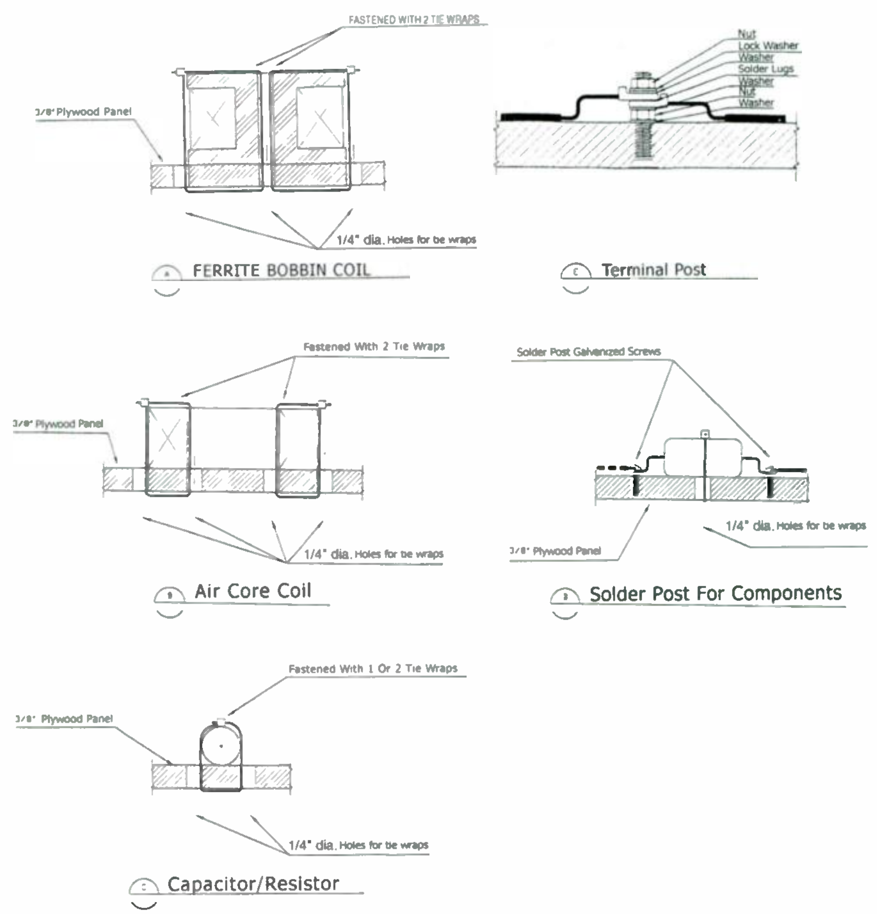


FIGURE 6: Crossover details.

of the crossover in both directions. Insert the crossover through the woofer opening, and place it approximately in the center of the bottom of the cabinet. Attach with eight 1¼″ particleboard screws.

Install the treble-control potentiometer. Unfortunately, the shaft of most such controls is only ¾″ long, so there is no space for the nut that comes with the controls. I attached the controls with hot glue. Run a bead of glue around the circumference of the control body to make sure it is installed airtight. Take care, however, that the glue does not spill into the potentiometer.

Now install the terminals. Make sure the cable hole is in position vertically to allow easy installation of the cables connecting the speakers with the amplifier. I used a small screwdriver to hold the terminals in position while tightening the nuts on the inside. Hook up the cables from the crossover input posts to the terminals. Make sure the polarity is correct. Install the second nut with a lock washer to make sure it will not come loose.

Attach the midrange and treble cables to the crossover connection posts. Use lock washers, tooth washers, or self-securing nuts to make sure the connections will not come loose.

DAMPING MATERIAL

Now it is time to fill the cabinet with damping material. A wide variety is available for this purpose, such as rockwool, polyester fiberfill or batting, and sheep wool or cotton (make sure the sheep wool is treated with moth repellent). Whatever you are using, it is most important not to overstuff the cabinet or compress the filling. Use the filling material to keep the cables away from the cabinet walls to avoid rattling noise.

To keep the filling away from the woofer cone, cut a piece of fabric with all sides approximately 2″ larger than the size of the woofer chamber. The material used for the front cover is a good choice. Poke a hole in the middle of the fabric, and run the cables for the woofer through the hole. Distribute the fabric evenly, so that the filling material is covered, and fasten the fabric with a few staples to the inside wall of the cabinet to keep it in place.

Proceed in the same way with the midrange chamber. Most likely, you will not be able to use the stapler in the midrange chamber. In this case it should be sufficient to push the fabric in between the filling and the cabinet walls. I tested the speaker for a couple of weeks before disassembling it to sand, stain, and varnish it. I found the fabric to be in the same position as originally installed.

Install the gaskets for all drivers using thin (1/8″) weatherstripping with self-adhesive backing. Do not overlap the ends, but make sure they butt against each other. Solder the cables to the drivers, making sure the polarity is correct, and position the drivers in the mounting holes. Be especially careful when soldering the tweeter. The voice coil uses very thin wire, and the terminals are very delicate. If you are not sure about your soldering skills, use solderless crimp connectors, which are also an acceptable choice for the other drivers.

The easiest way to fasten the drivers is with particleboard screws. McFeely's has some nice black square-drive screws. I used Allen screws and T-nuts, which somehow seem to look more professional. They are doing a good job for the woofer, but did not work as well for the midrange and tweeter, since they are a lot smaller, and the T-nuts tend to break out of the particleboard. I recommend using pan-head particleboard screws for the midrange and tweeter. Do not use flat-head or countersunk screws for them, since their conical shape will tend to break the tweeter flange and deform the basket.

Tighten the screws in a crossing pattern, as you would tighten the nuts on the wheels of your car, and do not overtighten them, which could deform the driver baskets. When you suddenly find yourself exerting more force to further tighten the screw, the

WORDS OF CAUTION

I would like to pass on some advice on safety.

- Wear goggles whenever you operate power tools, or even hand tools (especially chisels, which often cause eye injuries). Particleboard chips and plywood splinters can be really nasty.
- Wear ear protection, at least when you are working with the circular saw or router, which create an incredible sound pressure level at very high frequencies. When I used my router the first time, I did not bother with ear protection, and I paid with a ringing in my ears for nearly three days.
- Every panel attached to the speaker increases its weight markedly. I did not weigh the speakers, but they seem to be around 80 lbs each. They are extremely awkward to handle, as the weight is so unevenly distributed, so get help when you need to move or lift them.

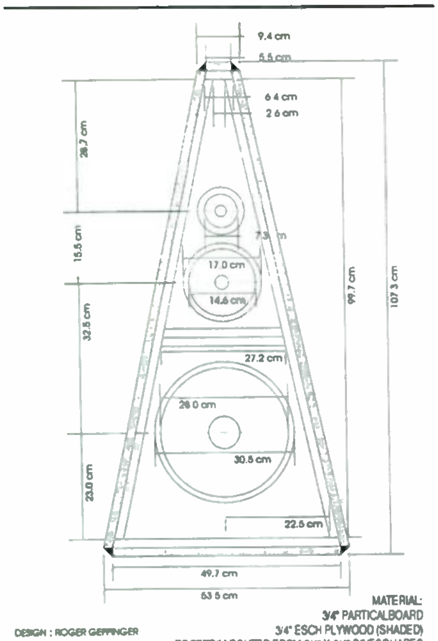


FIGURE 7: Dimensions—pyramid front.

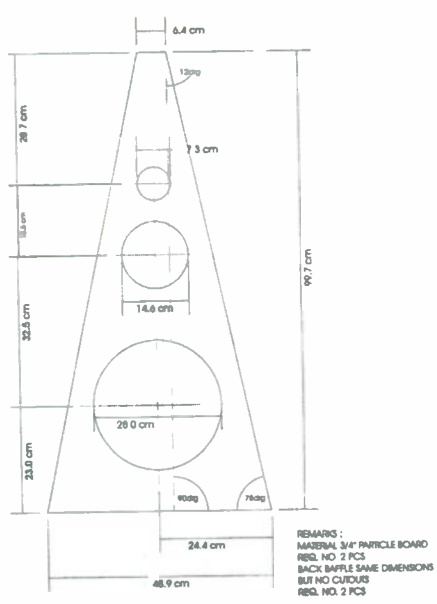


FIGURE 8: Dimensions—front baffle, internal.

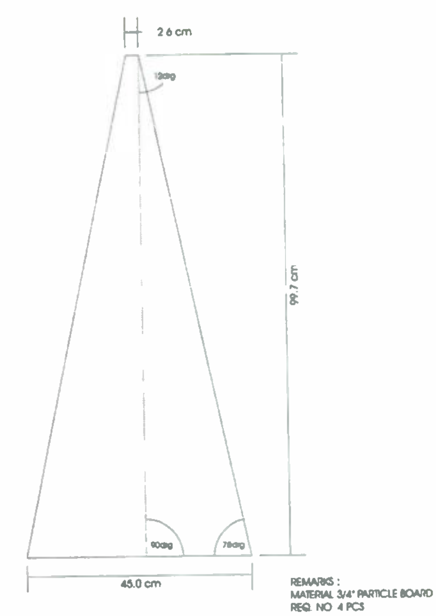


FIGURE 9: Side baffles—internal.

gasket is fully compressed and you should stop. Check the screws about one or two weeks after assembly. By this time, the gasket has fully settled, and the screws might require a little retightening. If you are using a grille, install it, and you have completed the construction.

TWEAKING THE SPEAKER

After all the time, labor, and money you have invested to build these speakers, you should not just "hook them up and get them playing." Your existing stereo system, the cables between the amp and speakers, and, most importantly, the positioning of the speakers in the room will have a tremendous effect on the final result.

You have used good-quality cable to construct the crossover and to wire the speakers in the cabinet. The cables from the amp to the speakers should be of the same quality. Keep them as short as possible, and make the left and right channel the same length. Be certain the polarity of the cables is correct.

The room will also have quite an influence on the sound of your new speakers. Try to keep them at least three feet away from any wall. A 12″ woofer produces a lot of low-frequency sound, and they are boosted by the surrounding walls—about 3dB in front of a wall, and about 6dB in a corner. In my living room, I placed the speakers about two feet from the back wall and three feet from the side wall. The bass was clean, deep, tight, and precise, and the transient response was good.

We tested the speakers in the apartment of a friend of mine, where it was necessary to place them right in front of the back wall, and, unfortunately, one of them in a corner. In consequence, the bass became overwhelming and muddy. In such a case, you might need to increase the stuffing in the woofer chamber or reduce the bass with your amplifier controls.

MIDRANGE AND TREBLE

The midrange and treble will also be influenced by the location of the speaker in the room—not as dramatically as the low end, but noticeably. In case the speaker is located too close to a side wall, its imaging capabilities will suffer. The ear needs to have a certain delay between the sound wave coming directly from the speaker and the first reflected wave. Although the ear is an amazing instrument, it will become confused and the sound stage will deteriorate if the two wave fronts arrive too close together. You can help this by angling the speaker towards the room's center or by hanging a carpet on the wall close to the speaker.

Every component of your stereo system has its own sound, the room will influence the sound, tastes are different, and the sensitivity of the ear to the different frequencies varies from person to person. To compensate at least a little for these variations, rather than resort to a fixed L-pad in the crossover, I used the treble-control potentiometer. By experimenting, you will find that some recordings sound best if the treble control is set to one certain position, while you might find that others sound better if you reduce or increase the loudness of the tweeter. It took me about two weeks to find out that to my taste the speakers sound best with the controls set to about 50% of full rotation. My wife prefers a little bit more.

Some might find this a bit laborious, but if you are a serious listener, which has nothing to do with the music you prefer, and you spend a few hours a week listening to music, you will find it very rewarding to experiment with the precise speaker location and the setting of the treble controls.

FINAL THOUGHTS

How do you judge your speakers? Frequency-response curves are a good start, but they tell less than half the story. These curves are either free-field measurements, done in a non-reflective environment, or done with maximum-length-sequence methods. Your normal listening environment does not even come close to these controlled conditions. There are some old designs around that have terrible flaws regarding frequency response, but they sound astonishingly good.

Transient response is another important measurement. It describes how precisely a driver follows a given signal, and how much uncontrolled and unwanted movement it does on its own until it finally settles back in the normal position of the diaphragm. But perfect transient response does not improve the sound of your speaker if the room is busy bouncing the wave around ten times longer than your speaker needs to settle down.

Don't get me wrong. Frequency- and transient-response measurements are extremely powerful tools for the speaker designer, and

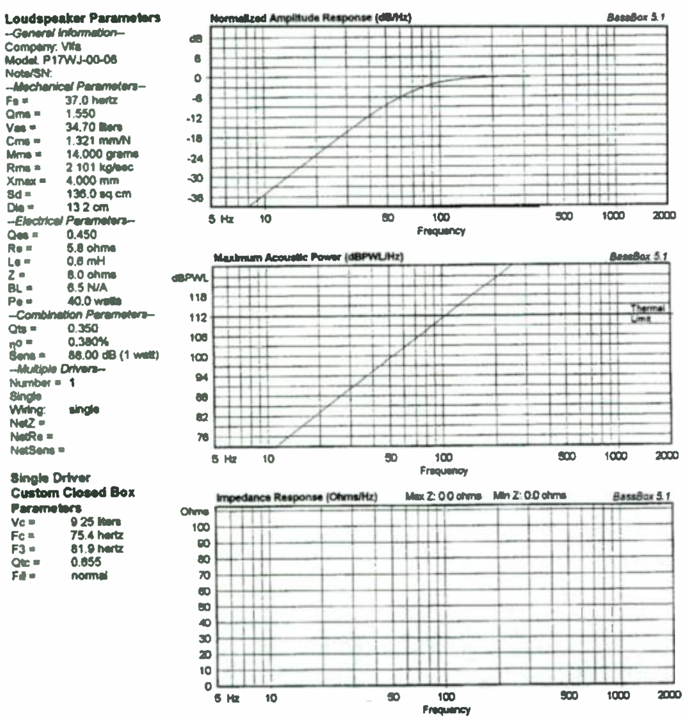


FIGURE 10a: Cabinet-design sheet for midrange, page 1 of 2.

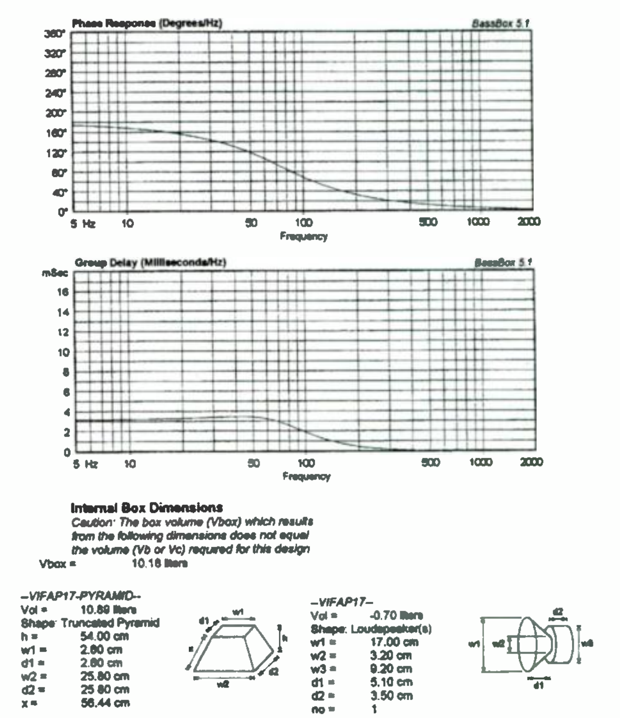


FIGURE 10b: Cabinet-design sheet for midrange, page 2 of 2.

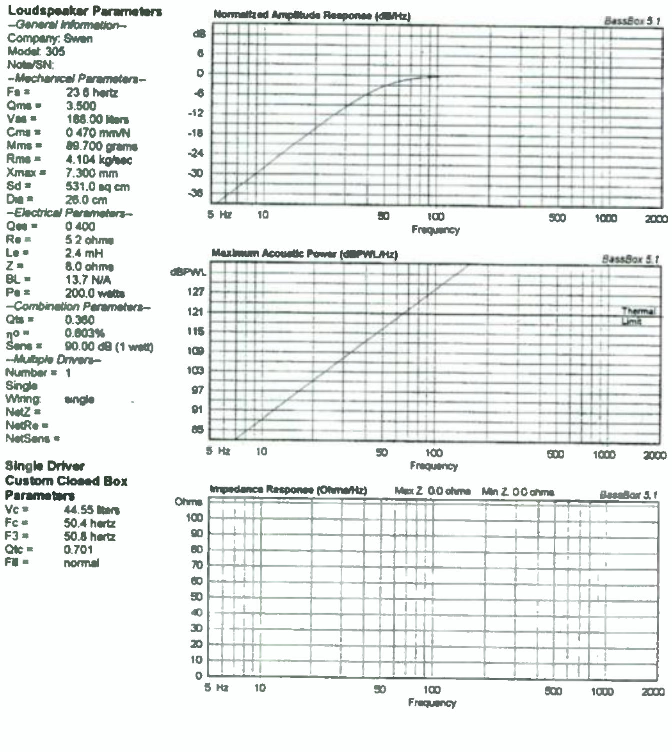


FIGURE 11a: Cabinet-design sheet for woofer, page 1 of 2.

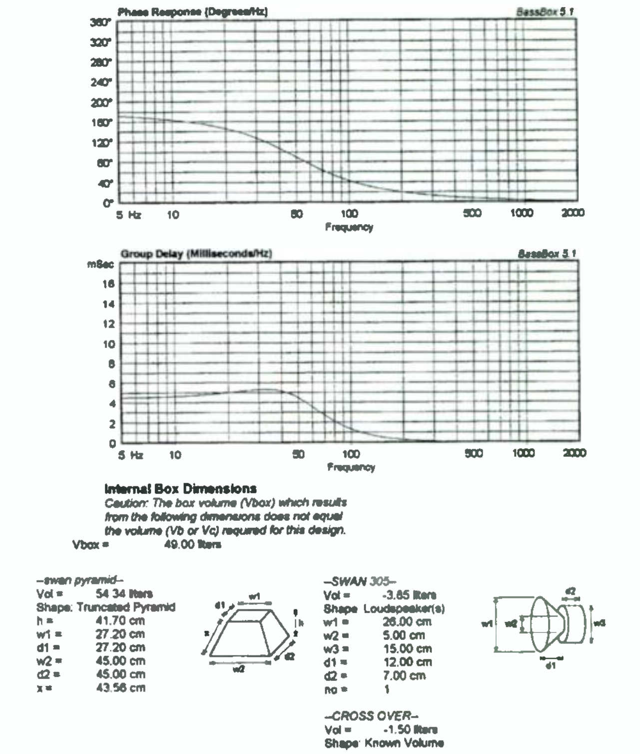


FIGURE 11b: Cabinet-design sheet for woofer, page 2 of 2.

have helped us tremendously in understanding and improving sound reproduction. If I had possessed these instruments, I would have included these curves, but I would still add the following remarks.

I am basically using five instruments to judge my designs:

1. I own a pair of old Smacks exponential horns, which are my reference in regard to transient response.
2. I use a Sony CD3000 headset to get an idea of the midrange, treble, and coloration of a speaker.
3. I use a pair of Lowther Classic 200 full-range exponential horns to see how "dynamic and lively" a speaker sounds, and how good its imaging capabilities are.
4. I take time, my ears, and a wide variety of music to judge the strengths and flaws of a speaker
5. Last, but not least, I get my family and friends to listen to the speakers. Fortunately, we all have different ears and tastes, and from their various reactions, I qualify my own impressions.

SPEAKER EVALUATION

How do my speakers sound? Their cut-off frequency is lower than any of the speakers I possess. The simulated frequency response of the LEAP design shows a –3dB point at approximately 45Hz, and I am positive that the speakers are capable of doing that.

Located about three feet away from the wall in a room about 18′ × 15′, with furniture and carpet, their transient response is nearly as good as the response of my exponential horns. The calculated Q_{tc} is around 0.7, and the final Q_{tc} should be between 0.7 and, at worst, 0.85, although I have not yet measured it.

The midrange shows very little coloration when compared to the headset. Due to its 6½″ size, the driver used as midrange does not have as good a dispersion as smaller midranges or dome midranges. However, this lessens the impact of the room on the imaging. The price paid for this is a relatively narrow sweet spot.

The treble is very clear and detailed. Tweeters such as the ScanSpeak D2905 are able to reproduce more detail, but they are far more expensive. Listening to the music with the headsets, I think I can identify few details that I cannot clearly recognize through the tweeters. But again, that might be an influence of the listening room. Overall, the tweeter sounds clear and never tiresome, with an astonishing amount of detail.

If you crank up the system, the woofer becomes quite impressive, easily able to generate vibrations in the walls, the flooring, and many things that are not properly fastened. The midrange and highs have no trouble reproducing with good quality at the same level.

ROOM FOR IMPROVEMENT

Would I do anything differently if I ever built the Pyramids again? Absolutely! If you are designing speakers, you are dealing with prototypes. I used a double-layer construction to minimize panel vibration, and this works up to considerable listening levels. However, if you really crank them up, you can feel panel vibrations on the side and back walls. To remedy this, I would install, on the side and back walls, diagonal braces made of ¾″ × 2″ particleboard scrap pieces.

I would use the Allen screws with T-nuts again for the woofer, but not for the midrange and tweeter. Two of the T-nuts came loose, and I had to cut the screws to remove the speakers. I finally rotated the midrange 45°, closed the holes for the Allen screws with hot glue, and used McFeely's black square-drive panhead screws to install the midranges.

If you are really into experimenting and tweaking, I would recommend installing the crossover outside of the speaker in a small box, and running all cables through the cabinet bottoms. Also, I would probably try a lower crossover frequency for the tweeter—around 2.5kHz—to see if this further improves the speaker's imaging capabilities.

I would start with a crossover assembled with lower-cost components and then experiment with more costly ones to see if they really make a difference. If you cannot hear any difference, it is not worth spending the money for the more expensive components. However, your failure to hear any difference might be due to the quality of your stereo system. If you upgrade your system in the future with a better CD-player or amplifier, it might be worth trying the higher-quality components again.

to page 62

SNAIL II: REDEFINING THE FOLDED HORN

By Bill Fitzmaurice

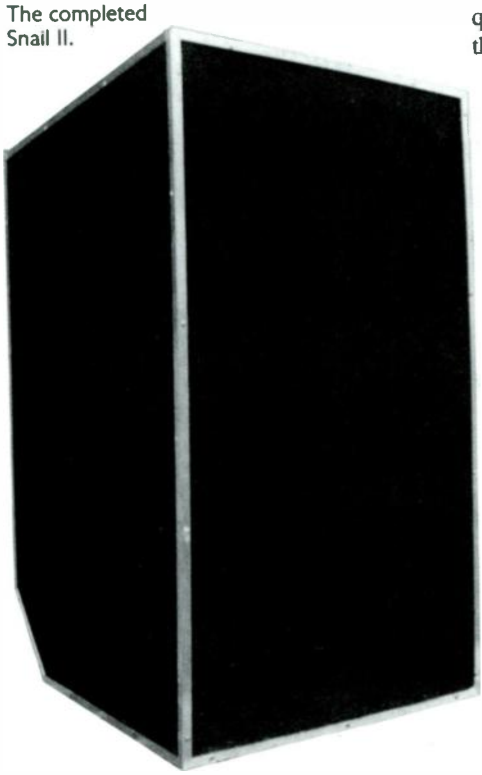
I was so excited by the performance of the original Snail folded-horn cabinet (*SB* 6/97) that I wasted no time before starting Snail II, with a cabinet almost double the volume of the Snail and utilizing a 15″ driver. The Snail's basic design remains: a folded horn with curved panels fed by a ported box, with the ducts exiting into the horn throat.

Part of the difficulty of working with curved panels is in having a removable panel for driver access; I solved this with the Snail by having a removable cabinet bottom, with the driver front-mounted on the baffle. But solving one problem created another in modifying the throat—a dilemma fixed with, of all things, a hubcap and PVC pipe.

SIDE-DOOR SOLUTION

With Snail II, I wished to modify the throat more easily, which I could do only by rear-mounting the driver. This made it impossible to have a conventional removable panel for driver access. The cure? A "side door" access panel to get the driver in and, if necessary, out.

The completed Snail II.



The hubcap in the Snail's throat showed me that sound waves close to the driver cone prefer a circular shape, so instead of the traditional square or rectangular baffle hole, I used a circular opening in Snail II. When I then tested throat reflectors, I found no major advantage to using curved shapes combined with the round baffle opening, and this simplified construction greatly. Another variation in the throat involves the use of extra reflectors that give the look of an old "sectoral" style horn. I think that two factors contribute to poor high-frequency performance from folded horns: first, a horn throat where the distance between partitions is such that waves reflect back on themselves, thus causing out-of-phase cancellations; second, a horn throat of 40in^2 or so for a woofer is too large to give any loading to high frequencies, since they are not boosted as are the lower frequencies, resulting in an effective loss of sensitivity.

Two extra reflectors in the middle of the horn throat reduce the distance the high frequencies can travel before being reflected, thus reducing phase-cancellation effects. In addition, these reflectors form a distinct second horn within the main throat area, with its throat starting directly over the driver's center dome, the point source of high frequencies.

High frequencies are loaded by the small inner horn, while the lower frequencies from the remaining cone area are loaded by all three of the throat's "sub-horns." In testing, I found that from 750Hz to 1.5kHz, the average sensitivity differential with and without the inner reflectors is 4dB.

DOUBLING CABINET SIZE

Almost doubling the overall cabinet size of the Snail increases both horn length and mouth area by about 50%. According to the theory that horn cutoff frequency is primarily determined first by mouth area and then by horn length, you might expect that the flare frequency of about 100Hz for the horn you saw in the Snail would drop to around 65Hz in Snail II. It decreases, however, only to approximately 80Hz.

The third element of the horn equation is the expansion rate, which I made 25% slower than the Snail's—curiously close to the reduction in the flare frequency. In the passband, Snail II's efficiency is about 3dB greater than Snail's.

My hypothesis is that the flare frequency of the horn is determined not by the area of the mouth or length of the horn, but by the horn's expansion rate. The efficiency of the horn is determined by the ratio of horn length and mouth size to expansion rate. In theory, even a small horn with limited length and mouth area will perform to a low frequency if the horn expansion rate is slow enough, with efficiency being sacrificed.

THE SNAIL II DRIVER

The driver for the Snail II is the JBL E-140, a 15″ 300W MI unit, chosen only because I had it on hand. Its parameters are f_s of 32Hz, Q_{ts} of 0.17, and V_{as} of 10.5ft^3. As I did with the Snail, I used Keele's calculator program for maximal flat response in a ported cabinet, arriving at a V_b of .97ft^3, f_B of 66Hz, and f_3 of 99Hz. Extrapolating from the nominal efficiency of 100dB, at 99Hz I got 97dB, while one octave down at about 50Hz

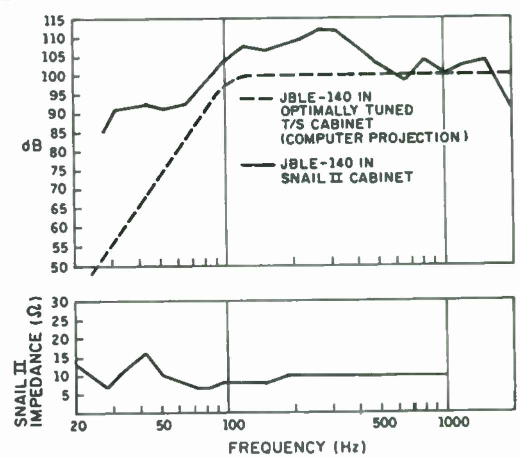


FIGURE 1: Driver response.

I could expect 73dB from 1W. Down one more octave, at 25Hz, the sensitivity of 49dB is less than the average home's background noise. Snail II's improved figures result from using a larger box, lower tuning, and, of course, the unique Snail folded-horn geometry.

Should you wish to use a different driver, I'd recommend staying with an MI driver with parameters reasonably close to those of the JBL. Be forewarned that although the JBL has an unusually compact frame and magnet-structure assembly, it barely fits through the cabinet side access. An EVM 15-B probably would not fit without your doing some trimming to the access-door flange pieces. On the other hand, some 12″ MI drivers might work well, providing their f_s is less than 40Hz.

In tuning Snail II, I started with two 6″-long 3″-diameter ducts, giving the basic $2ft^3$ box an f_B of about 42Hz, which dropped to 32Hz when mated to the horn. Since Thiele/Small says this driver works best with an f_B of 66Hz, I also tried 3″ ducts, giving an f_B of 50Hz, which still dropped to 32Hz when mated to the horn.

The cabinet's performance was degraded, with reduced response across the board and a very sharp cutoff below 120Hz, resembling the response you might expect from a traditional folded horn with a sealed rear chamber. I surmised that since this design wouldn't work properly with the rear chamber tuned high, I tuned it low, this time with 9″ ducts. The result was an f_B of 32Hz, which dropped to 28Hz when mated to the horn.

Response came back, better in the midbass than with the 6″ ducts, and with a low-end efficiency this driver normally would not be able to produce: 91dB at 32Hz and 85dB at 28Hz—at least 30dB more at 28Hz than available from the T/S model. My conclusion was that despite the very low Q_{ts} of the driver, the Snail II design gained the most performance when the rear chamber was tuned at or even below the f_S of the driver, as was the case in the original Snail.

FULFILLING EXPECTATIONS

The final product was what I had hoped to fashion—the best medium-size-venue public-address cabinet I've ever seen with a $10ft^3$ box. PA for medium venues (200–500 seats) differs from large-venue requirements in that the primary function is to project vocals at levels understandable above the instruments on stage.

While the bass, guitars, drums, and key-

TABLE 1

PARTS LIST

All parts are cut from ½″ plywood except as noted. Part dimensions are nominal; exact dimensions will vary according to actual plywood thickness. Final dimensions and angles of cut must be determined during construction by careful measurement and trial fitting. The part numbers correspond to the circled numbers on *Figs. 2 and 3.*

1. Sides (2)	35″ × 24″
2. Baffle	19″ × 19″ (¾″ plywood)
3. Rear top	20″ × 4¼″
4. Lower back	20″ × 6″
5. Rear bottom	20″ × 8¾″
6. Bottom	20″ × 19″
7. Lower reflector base (4)	14″ × 3½″ (5/4 stock)
8. Lower reflector	18 15/16″ × 17″ (1/8″ plywood)
9. Upper reflector	18 15/16″ 3″ radius (6″ PVC pipe)
10. Back brace	(see text)
11. Rear horn braces	(see text)
12. Rear horn panel	18 15/16″ × 21 3/8″
13. Lower front horn braces	(see text)
14. Upper front horn braces	(see text)
15. Front horn panel	18 15/16″ × 29½″ (3/8″plywood)
16. Front top	20″ × 5 3/8″
17. Middle top	20″ × 15¼″
18. Baffle brace	19″ × 3″
19. Outer throat reflector	16″ × 3″
20. Inner throat reflector	15″ × 3″
21. Throat choke	8½″ × 4½″

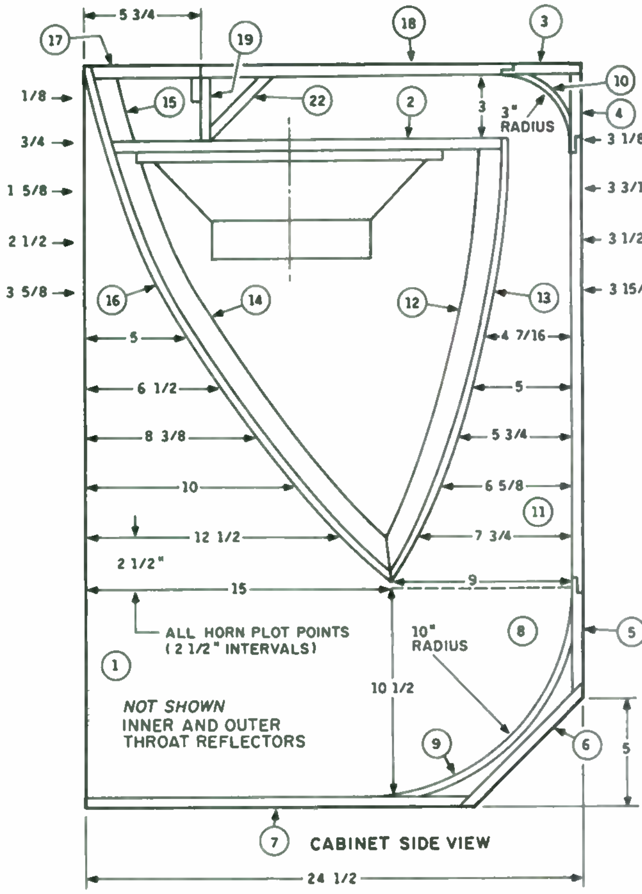


FIGURE 2: Side view of Snail II.

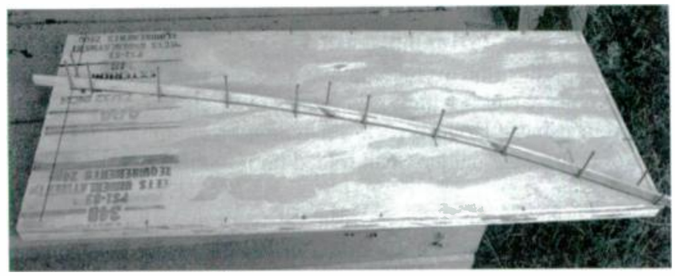


PHOTO 1: Tracing rear horn-brace pattern.

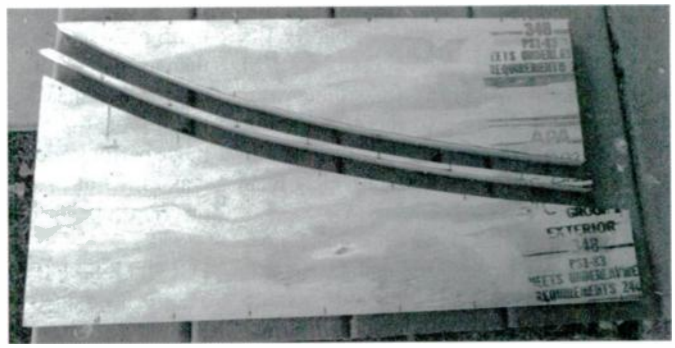


PHOTO 2: The rear horn braces.

PHOTO 3: The front horn braces.

boards are also fed through the PA to achieve a balanced sound, these instruments are amplified separately on stage (except the drums, assuming they are acoustic), and hence require far less presence in the PA than the vocals. A flat response all the way to the deep bass is not required or even desirable, while high efficiency in the fundamental vocal range from 100–500Hz is crucial both to project the vocals above the instrument levels and to keep amplifier wattage requirements and PA size reasonable. (Small venues where the bass and drums are not miked at all need virtually no response below 100Hz, while large venues that rely on the PA for virtually all the power to the audience need a flat response down to at least 50Hz.)

By way of comparison, consider a typical high-quality PA cabinet—the Carvin TR1801, a T/S cabinet of 9.6ft^3 loaded with an 18″ driver rated at 600W. It claims a frequency response of 37–2kHz ±3dB at 96dB SPL. This would allow a maximum output capability of about 124dB with 600W input. By contrast, the Snail II response curve (*Fig. 1*) shows an average efficiency in the 32–80Hz fundamental bass range of 93.5dB, not too far from the Carvin's.

In the critical fundamental vocal range of 100–500Hz, the Snail II's average SPL is 107dB, giving an output capability of 132dB—eight decibels more than the Carvin with only half the input power at 300W. Even two Carvins paralleled could only achieve 120dB, and would need an

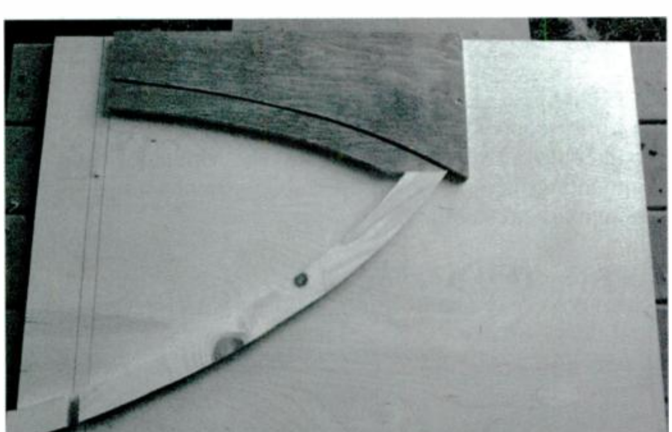


PHOTO 4: Marking the cabinet layout.

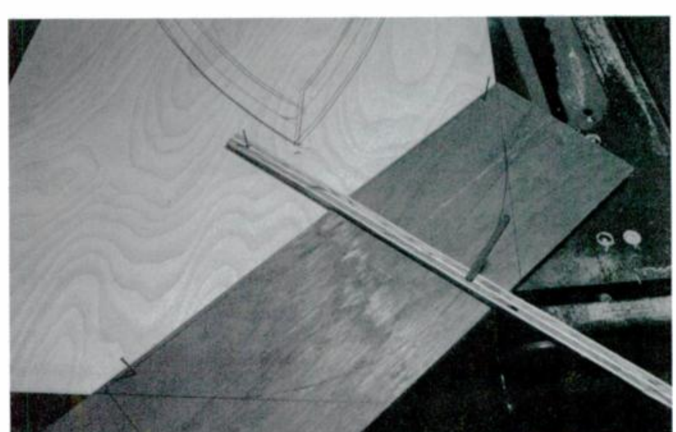


PHOTO 5: Creating the lower-reflector pattern.

TABLE 2	
SUPPLIES LIST	
JBL E-140 driver or equivalent (see text)	
14- or 12-gauge hook up wire	
Speaker jack	
Drywall screws	1″, 1¼″, 1 5/8″
3/16″ T-nuts	1½″ × 3/16″ bolts (driver mounting)
Woodworker's glue	
Construction adhesive (caulking-gun dispensed)	
Hot-melt glue gun and hot-melt glue	
Paint, carpet, or other finishing material	
Aluminum edging, #6″ × ½″ stainless screws for attachment	
3″ castors	
Heavy-duty handles	

amp capable of 1.2kW to do it. Advantage—Snail II.

From 64Hz to 1.5kHz, the Snail II still enjoys an SPL superiority, with an average of 101dB, and this despite the fact that Snail II is a folded horn and the Carvin is a direct radiator. Only at 2kHz, where the Snail II drops to 90dB SPL, does the Carvin again enjoy an advantage, which is probably moot, since most high-frequency drivers would be crossed over well below that (I recommend a crossover of 1kHz to 1.5kHz with Snail II).

CONSTRUCTION

Building Snail II is not difficult for the accomplished cabinet maker, but it is no project for beginners with modestly equipped workshops. Like the Snail, making patterns for the horn braces is necessary. Since this is a PA bin, and you'll probably build two cabinets, use your patterns to trace out two sets of braces before discarding the pattern. *Table 1* is the parts list, and *Table 2* lists the necessary supplies.

The cabinet is built mainly of ½″ plywood; a single 4′ × 8′ sheet is more than enough, but if you opt for Baltic birch in a 5′ × 5′ sheet, be forewarned that you'll need a couple of extra scraps on hand to do the job. You may opt for ¾″ instead if you're willing

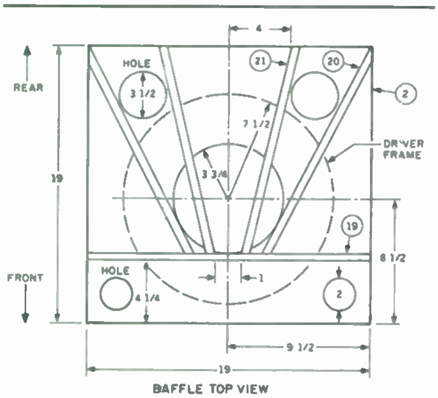


FIGURE 3: Top view of baffle.

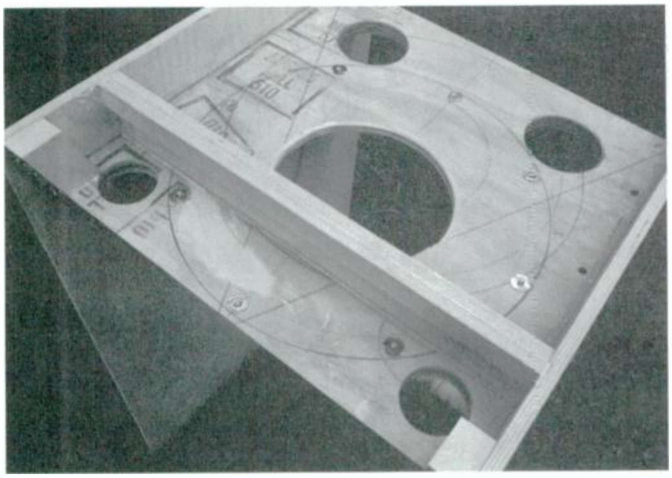


PHOTO 6: Baffle, top view.

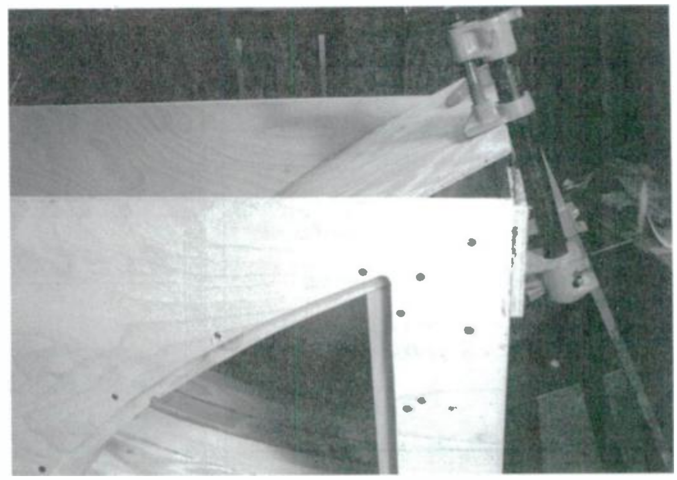


PHOTO 8: Pulling front horn panel into place.

PHOTO 7: Rear horn panel installed; note offset of braces to clear driver frame.

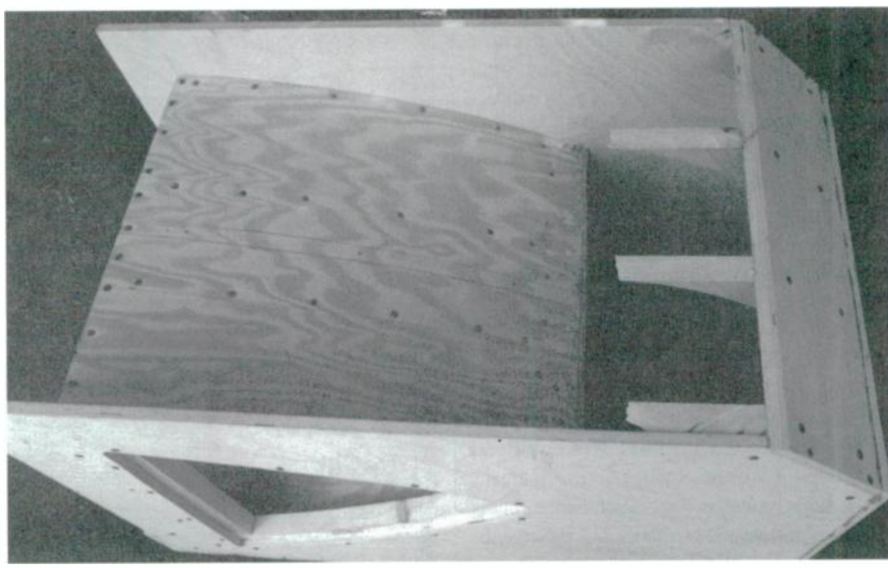


PHOTO 9: Rear view of cabinet at halfway point in construction.

to put up with the extra weight, but then alter the parts dimensions accordingly.

The horn panels are 3/8″ plywood; do not use birch here—it is too stiff. A cheap 3-ply is more flexible and works well. The upper reflector is made of 6″ PVC pipe, cut in quarters to arrive at a 3″ radius. You can make the lower reflector with 1/8″ plywood, ¼″ plywood with shallow dadoes on the rear to gain the required flexibility, cheap paneling that uses 1/8″ plywood as its substrate, or even 1/8″ masonite.

All joints are butted, fastened with drywall screws of 1″, 1¼″, or 1 5/8″, whichever is the longest that does not penetrate too far. You'll need woodworker's glue and construction adhesive, and a hot-melt glue gun. Use woodworker's glue for maximum strength at all joints with the exception of the horn panels and other joints as noted, which need the slower-setting construction adhesive to fill the wider gaps.

Predrill and countersink all screw holes. When joining two parts, glue and clamp them together to ensure correct alignment, and then drill, counterbore, and screw them with no more than 6″ between screws.

MEASURING AND CUTTING

Begin the construction by cutting out the two cabinet sides (*Fig. 2*). Cut the triangular pieces from each lower rear corner. Cut the jig for the rear horn braces and back brace from a piece of ¾″ plywood, 21¼″ × 9¼″. With the vertical dimension being the longer, measure up ½″ from the bottom of the piece and draw a horizontal line across it, and then more such lines at 2½″ intervals (see *Fig. 2*).

Starting with the bottom line, mark a point 9″ from the right-hand edge. On the next line up, mark a point at 7¾″ from the edge, and similarly on each subsequent line mark points at 6 5/8″, 5¾″, 5″, 4 7/16″, 3 15/16″, 3½″, 3 3/16″, and 3 1/8″. At each of these points drive a 1″ brad partway into the plywood. Cut a ¼″ sliver of 3/8″ plywood about 2′ long, and bend it so it presses firmly against the curving line of brads on their left side; secure it in place with more brads (*Photo 1*).

Trace along both sides of the sliver to mark the horn's taper, and then remove the sliver and brads. With your tablesaw, cut off the topmost and bottommost ½″ from the plywood (which should be at the top and bottom measured points), and with a band-

PHOTO 10: Detail of dado on cabinet's lower back.

PHOTO 11: Lower reflector installed.

saw cut along both the traced lines (*Photo 2*). The larger of the resulting pieces will be the back brace; use it to pattern a second if you are building two cabinets.

The smaller piece is the rear horn-brace pattern; draw a line 1½″ inside the cut line and trim off the excess. Use it to trace on either ¾″ plywood or 5/4″ stock (actual thickness 1″) three more identical pieces for one cabinet, and seven more for two (*Photo 3*). When its job as pattern tracer is done, it will itself go into the cabinet.

FRONT HORN BRACE

Using ¾″ plywood to cut the pattern for the front horn brace is overkill, since most of the pattern will end up as waste. Use a piece of scrap ¼″ plywood or, as I did, old paneling cut to a size of 25″ × 15½″. Viewing this with the long side vertical, again draw a horizontal line across it ½″ up from the bottom, and parallel lines at 2½″ intervals, with the last line ½″ from the top. Also draw lines at 3½″ and 4¼″ down from the top, to mark the location of the baffle.

Mark the points for the horn curve, starting on the bottommost line, measuring from the left edge as follows: 15″, 12½″, 10″, 8 3/8″, 6½″, 5″, 3 5/8″, 2½″, 1 5/8″, ¾″, and 1/8″. Drive brads into these points and mark the curve as before, this time with the sliver to the right of the brads. To allow for the horn-panel thickness, you now make the ac-

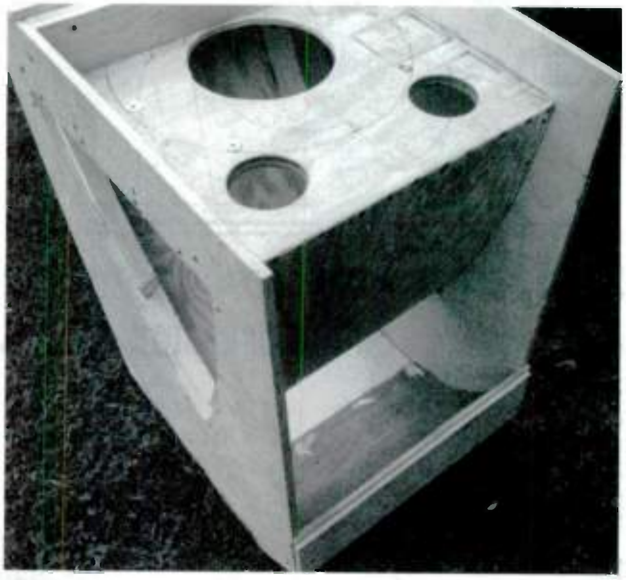


PHOTO 12: Top rear view prior to attaching back.

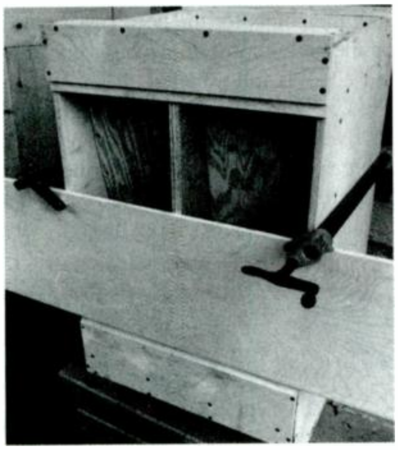


PHOTO 13: Using temporary plywood piece to align back brace.

tual pattern cut on the line to the right of the brad marks.

Now remove the areas above and below the first and last lines, as well as the area the baffle will occupy, resulting in two pieces that you likewise trim to a 1½″ overall width. Use the pattern to mark the appropriate number of braces for your requirements, four of the long pieces per cabinet, and two of the short.

On one side at a time, mark the locations where the baffle and horn braces will go. The baffle location on the side is defined by two horizontal lines, at 3″ and 3¾″ from the top, with the rear of the baffle 3½″ from the rear edge of the side piece, and the front edge of the baffle 1½″ from the front edge. The point of intersection of the two horn plates will lie on a vertical line drawn 15″ from the front edge. Lay the pattern pieces in place on the side to mark their locations, and repeat the process on the other side in mirror image (*Photo 4*).

You can easily make the pattern for the lower reflector braces by nailing a piece of scrap plywood to one side's rear bottom corner along the angled cut, and drawing on it an arc with a 10″ radius using a "compass" consisting of a piece of thin scrap with a ¼″ hole drilled through it to guide a pencil. Trace the locations of the cabinet sides as well, and cut out the pattern (*Photo 5*). Use the pattern to trace out four braces per cabinet.

On one side, draw a line 3/4″ below the baffle, continuing that line midway between the marked inside and outside edges of the horn braces; this will be the driver-access panel. Cut it from the side with a sabresaw, using a plunge cut to start—do not drill a starting hole. Attach the longer horn braces to this side, and also fashion and install a 1½″-wide piece of brace material below the baffle location to complete the driver-access-panel flange. The flange should be about ¾″ wide both inside and outside the cut line if you do it right. Attach the longer horn braces to the other side to mirror the first.

THE BAFFLE

The baffle (*Fig. 3*) measures 19″ × 19″, with one end cut at a 20° angle. The longer surface is the baffle top. Center the driver laterally, with the front of the driver rim 1″ from the front edge of the baffle. Use the driver as a pattern to mark the mounting-bolt-hole locations. Do not place the holes so that they align with the baffle's centerline—offset them. Drill ¼″ holes for the mounting bolts.

By drawing lines connecting at least two pairs of opposite holes, determine the driver centerpoint, and use this as the center of a 3¾″-radius hole cut in the baffle. Using a ¼″-radius cornering bit in your router, chamfer the edges of that hole from both sides of the baffle. To prevent the cone from slapping the baffle, rout away about 3/16″ of the inside of the baffle, from the mounting-gasket-flange contact area to the cutout.

Place a straightedge on the baffle top, with one edge aligned on the left-rear corner of the baffle and tangent to the left side of the baffle hole, and draw a line. Repeat from the right-rear corner of the baffle to the opposite side of the hole. These lines mark the positions of the outer throat reflectors. Draw another line horizontally across the baffle and tangent to the hole at its side toward the baffle front. This marks the position of the baffle brace.

The inner reflectors are offset 1″ from the baffle centerline at the points where they intersect the baffle brace, and 4″ from the centerline at the rear edge of the baffle. The throat choke runs from the joint of the baffle and baffle brace to the cabinet top at a 45° angle. After you mark the positions of the driver frame and throat reflectors on the baffle, drill four holes through the baffle—two of 3½″ diameter at the rear of the baffle for the ducts, and two of 2″ diameter at the front of the baffle. These 2″ holes open the space in front of the baffle brace to the chamber below it.

Position these last two holes so that some space separates them from both the driver and the baffle brace. The duct holes should be nestled as close as possible to the driver and reflectors, and as far as possible from the rear edge of the baffle. Install 3/16″ T-nuts in the mounting-bolt holes. Attach the baffle first to one of the cabinet sides and then to the other.

Measure the actual size required for the rear bottom; cut both edges at a 45° angle and install it. Install the baffle brace, adding to its front top edge a length of scrap to serve as a screw block for the front top. Install the two remaining small horn braces (*Photo 6*) and the front top.

Placing the cabinet top down, put the driver inside in its position. Make sure you can get it in and out through the access; if you need to trim the flanges, now is the time to do so. Cut two 10″ lengths of 3″ PVC pipe, and slide them into place in the baffle holes.

Locate the remaining horn braces as close as possible to the cabinet's middle without interfering with either the driver or the ducts (*Photo 7*). With their positions marked on the baffle, remove the driver and ducts. Attach the braces to the baffle, and cut additional pieces of brace stock to fill the areas between all four brace pairs at the "point" of the horn.

THE HORN PANELS

You should cut the horn panels a bit undersized at 18 15/16″ for easier installation. Before cutting, flex the plywood—it will bend more easily on one axis than the other. Use a flexible tape to measure along the braces and determine the exact length of the panels, and cut them about ½″ oversize.

Install the rear panel first, using construction adhesive and with screws 3″ apart. Attach the "point" of the horn first, using two long clamps to gradually pull the panel in place as screws are driven to hold it (*Photo 8*). When the front panel is installed, it overlaps the rear panel at the horn point.

You can easily look inside the cabinet through both the baffle and the access hole to check for proper attachment and glue squeeze-out. Use plenty of glue to fill all gaps at the horn point and the joints with the baffle and the top. Let it set for a day,

PHOTO 14: Driver in place.

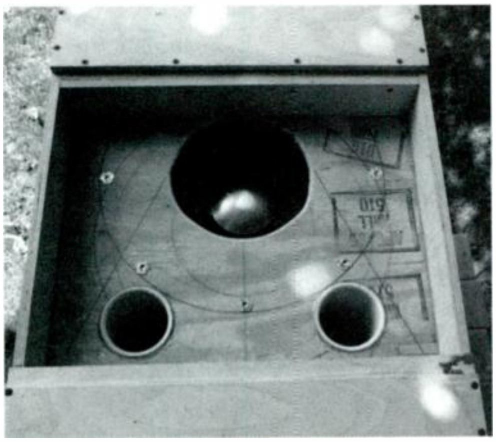


PHOTO 15: Baffle prior to installation of throat-choke parts.

and then use a belt sander to remove all the excess glue, as well as any overlap of the plywood, and to fashion smooth, rounded joints.

Next install the lower reflector braces, followed by the bottom. Space these braces evenly across the cabinet (*Photo 9*). The lower back is next, one edge cut at a 45° angle and the other dadoed to ¼″ deep, ¾″ wide, where the next piece will join it (*Photo 10*).

Working from the front of the cabinet, attach the bottom reflector to its braces, using plenty of glue and screws. While 1/8″ plywood may seem too thin to veteran builders, there is no acoustic pressure here, and it will not vibrate (*Photos 11* and *12*). Use progressively shorter screws as you approach the bottom and back of the cabinet, to prevent penetrating them.

Next, cut and install the rear top piece and upper back; both of these are dadoed at one end for mating with other parts. Temporarily clamp a piece of plywood across the open section of the cabinet back, using it as a jig to check alignment of the back brace. Trim the back brace as necessary to achieve a proper fit (it may be too long to clear the lower reflector) and attach it to the rear horn panel, driving screws from the cabinet interior (*Photo 13*).

The upper reflector is a piece of 6″ PVC quartered lengthwise and cut 18 15/16″ long. Chamfer the edges with a belt sander or jointer to arrive at a 3″-radius quarter-round piece. Coat the flat edges of the chamfer liberally with hot-melt glue, slide the part into place at the junction of the rear top and top back, and hold it there for three minutes or so while the glue sets. Then, with the glue gun, seal the gaps where the reflector joins the cabinet sides.

FOAM LINING

Line the interior of the front and rear horn panels (between the braces) with acoustic foam, and drill a ¼″ hole through the rear horn plate to accommodate the driver wire. Install the driver, connecting it up with 12- or 14-gauge wire, and seal the hole through the horn plate with hot-melt glue (*Photo 14*). Weather-strip the access-panel mounting flange, and screw the panel in place. If utilizing the JBL E-140 driver, use two 9″ PVC ducts, sealing them at the flange with hot-melt glue (*Photo 15*).

Run a 30–32Hz signal into the driver using a test CD or signal generator at about a 5V level, listening and feeling for cabinet leaks, and using the hot-melt glue to seal any you find. If you use a different driver, test different lengths of pipe to tune the box for maximum SPL output at 30–32Hz. Once you've tuned the box and verified it is airtight, remove the access panel and the driver.

Next, install the four throat reflectors and the throat choke, screwed to the baffle from the inside (*Fig. 3* and *Photo 16*). Note that the inner reflectors are cut at a 45° angle where they meet the baffle brace. The choke sits atop them and butt-joints to the outer reflectors. Cutting these parts to compound angles for a perfect fit is very difficult—go for a reasonable fit and use construction adhesive to fill the gaps.

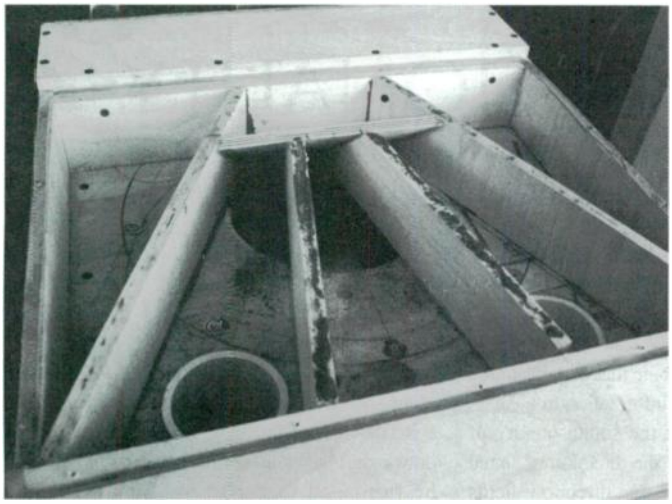


PHOTO 16: Completed throat choke; note chalk dust (see text).

Use a straightedge held across the cabinet top to make sure none of the reflectors extends too high, trimming as necessary with a belt sander. Cut the center top piece, dadoing both ends to match the front and rear top pieces. Sprinkle the top edges of the reflectors with contractor's chalk (*Photo 16*), and place the top over them, pounding on the top with your fist to transfer the chalk to the top. This allows you to see the location of the joints with the reflectors, and thus to drill pilot holes for screws in the correct locations.

Attach the top piece, again using construction adhesive to be sure all potential gaps are filled. In the same fashion, cut and install the remaining back piece, after attaching to it—and wiring to the driver—your choice of jack. Reinstall the driver and access panel, use a router with trimmer bits or a power sander to true up all exterior edges, and finish the cabinet.

FINISHING TOUCHES

A painted finish is the easiest and cheapest. A truly bullet-proof though expensive alternative is formica or ABS sheet. Carpet is easy to apply and relatively cheap, but should be combined with a vinyl cover for waterproofing. The basic design is fairly weathertight and normally would not need a cover.

In any case, you should use aluminum edging with whatever choice of finish to protect against road damage. With two 3″ castors attached to the lower back, you can tip the cabinet slightly backwards, allowing it to roll freely while otherwise remaining stable (*Photo 17*). A handle on the cabinet top makes rolling it easier, and you will want four side handles to make lifting the cabinet into a truck an easy two-man job.

Aside from PA, this cabinet will also

to page 62

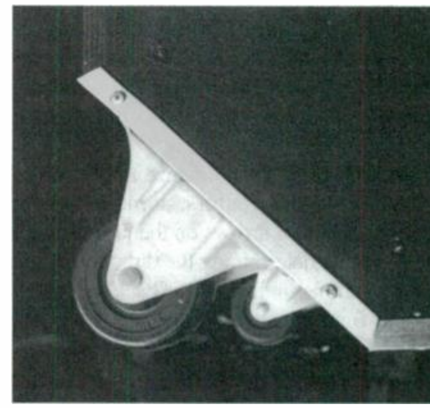


PHOTO 17: Castors in place.

DOES WIRE DIRECTIONALITY EXIST?

By Stephen Lampen

Ask someone with a high-end audio system, "Does wire directionality exist?" and you're likely to get a five-minute lecture. Whether cables, especially speaker cables, exhibit some directional property has been a subject of debate among top-of-the-line audio buffs for a long time.

We at Belden manufacture many cables for high-end distributors, some of whom require us to print arrows on the jackets, with the customer determining the direction of the arrows and then relaying this back to Belden for the final jacket printing. This does not apply to cables with telescopic shields (which need to be hooked up in a particular direction for most effective shielding), but to a specific attribute of the conductors themselves: directionality. Do they have it?

This led Belden to embark upon a double-blind study to determine whether directionality did exist. To obtain the necessary volunteers, we formulated a letter and presented it to two prominent magazines for publication. They both refused to publish it, claiming it was "too controversial."

After almost a year of our attempting to place it, the letter was accepted by Ed Dell, publisher of *Speaker Builder*. I would like to thank Mr. Dell in this public forum for the courage to undertake this "controversial" project. Mr. Dell also helped find the "third party" judge, David Moulton, of David Moulton Professional Services, Groton, MA, to keep the results truly double-blind.

So after almost two years of work, we are happy to present the results of this project. Here is the letter as it was published in the 6/96 issue of *Speaker Builder*:

VOLUNTEERS WANTED

Belden has been making professional audio cable for almost 100 years. As part of our determination to learn as much as we can about audio cables, we are interested in investigating the quality of performance of audio cables called "directionality."

Directionality is an attribute that pertains to the direction of flow of audio information in a cable. Some people believe that the sound quality of audio differs depending on the direction of signal flow through a cable, that one direction yields sound quality that is preferable to the other, and that this is related to the way the cable is created in the manufacturing process.

As Technology Development Manager at Belden, I felt we should investigate this attribute. In discussions with our engineering staff we came up with a simple double-blind experiment that should satisfy most of the concerns of critical music listeners. The goal of the experiment is to determine whether or not there is a correlation between "direction" in which the cable is manufactured and the quality of audio information flow in the cable.

We would like to invite readers to participate in this experiment.... We are seeking 100 volun*tears*, each of whom will receive ten pieces of single-conductor polyethylene-jacketed wire approximately 5′ long. The wire ends will be tagged with numbers chosen at random. Belden will maintain a master log of the "direction" each wire was drawn during manufacture, copies of which will be furnished to David Moulton, of David Moulton Professional Services, who has volunteered to be the third-party judge of the results.

The experimental task for each participant will be to audition the ten pieces, substituting the test piece for the positive lead from your amplifier to the positive connection for one speaker. This may be done at your convenience, and according to your preference, over a period of two months. During this time, you will try to determine in each piece of wire which "direction" you prefer.

Each participant should complete the answer sheet provided with the test wires and mail it in its postage-paid envelope to David Moulton Professional Services, Groton, MA, for tabulation and statistical analysis. This should be completed within 60 days (two months) after the receipt of the test wires. The wires do not need to be returned.

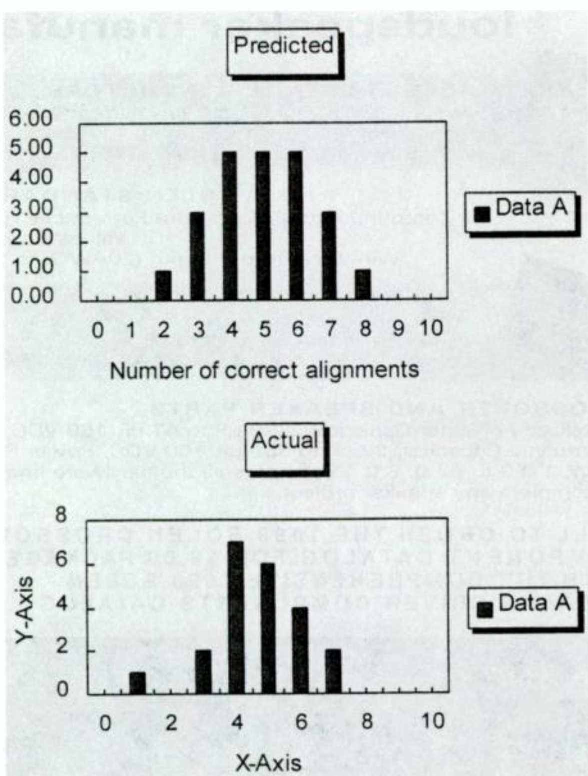


FIGURE 1: Graphs of predicted and actual results.

HOW IT WENT FROM THERE

We immediately set to work manufacturing the wire. Following are the specifications:

Conductor—Single 16 AWG bare copper conductor. We used solid copper so that directionality would not be confused by multiple strands that might have different directions.

Purity—ASTM B115 ETP copper, 99.95% pure.

Drawing—All the copper used in this test was drawn down (reduced in size) from one single copper ingot. Drawing consists of pushing the copper back and forth through a series of dies to achieve the desired gauge size. Unlike standard drawing, which takes place in both directions, all drawing for this experiment was done in only one direction in order to determine whether directionality is influenced by how the conductor is drawn.

Insulation—Each wire was covered with extruded high-density solid polyethylene, one of the high-

TABLE 1

TEST RESULTS

KIT NUMBER	OPINION OF DIRECTIONALITY BEFORE TEST	NUMBER CORRECT OUT OF 10 (AGREEING OR DISAGREEING)	OPINION OF DIRECTIONALITY AFTER TEST
3	Generally inaudible	6	Did not affect sound
4	No opinion	None marked	Did not affect sound
8	No opinion	6	Greatly affected sound
12	No opinion	7	Slightly affected sound
16	No opinion	None marked	Did not affect sound
19	No opinion	6	Slightly affected sound
22	No opinion	5	Slightly affected sound
24	No opinion	6	Did not affect sound
35	Generally inaudible	7	Did not affect sound
36	Generally inaudible	None marked	Did not affect sound
38	No opinion	6	Slightly affected sound
39	No opinion	6	Greatly affected sound
47	Generally inaudible	7	Did not affect sound
49	Generally inaudible	6	Slightly affected sound
51	No opinion	all "same"	Did not affect sound
58	Generally audible	6	Greatly affected sound
62	Generally audible	7	Greatly affected sound
64	Generally audible	9	Greatly affected sound
65	Generally inaudible	6	No comment
74	Generally inaudible	7	Did not affect sound
84	Generally audible	7	Greatly affected sound
85	Generally audible	6	Greatly affected sound

est grades of plastic available. It is very inert, extremely stable, and has very good electrical properties. The jacket material was colored yellow, green, or blue, and it contained no jacket marking of any kind that might give the test volunteers a clue as to the position of the wire on the roll.

Cutting—Ten pieces were cut in order off each roll. All the pieces were labeled with numbers randomly generated on a sheet of labels. The numbers were entered in the master log as the wire pieces were cut off and the labels applied, so the direction of each roll could be established. Toward the end of any roll, where not enough wire remained to allow cutting ten pieces in a row, the rest of that roll was discarded and a new roll begun. By proceeding this way, if directionality did in fact exist, then pieces cut in order off a roll should have exactly the same properties, and the volunteers should be able either to place those ten pieces in the same direction they were on the roll, or else all in the opposite direction.

Kit—The ten pieces, together with instructions, a tally sheet, and a stamped, addressed envelope, were mailed out as requests came in. The volunteer attached each wire to his system, then reversed it, determined which (if any) way it sounded better, and wrote those numbers in the answer-sheet boxes. He then mailed the answer sheet to David Moulton Professional Services, which correlated the statistical results.

RESULTS

We had hoped to solicit 100 testers, but by April 1997, we had sent out only 78 test kits, and of that number only 22 had sent back completed results.

One complaint that could be made about this study is the size of the resulting sample. However, both Dave Moulton and John Johnson, Belden's staff statistician, assured me that meaningful statistical results could be derived from a sample this small.

Why only 22 volunteers performed the test and returned the results is a matter of speculation. One possible reason is that directionality may not be the intense concern among high-end audiophiles that many believe. It may also be that the tests required a fair amount of diligent effort, perhaps more than a casual user might be willing to expend. If there were some flaws in the way this test was set up, we may never know, since we heard from so few of the participants.

All the testing kits were numbered. Since they were passed out at random, kit numbers go beyond 78, the number of sample kits distributed. The specific kit numbers are noted in *Table 1*. Volunteers were asked their opinion of directionality before and after testing. The "number correct" is the largest number either agreeing or disagreeing with our original log entries. "Five" would be the result of pure chance.

Each questionnaire returned was copied, and for each entry the positive or negative agreement with the original logged numbers were noted. This copy was mailed to each of the volunteers, so each one was aware only of his or her results.

The data resulting from the directionality survey appears to be normally distributed, with an average of 4.68 and a sample standard deviation of 1.39 (*Table 2*). There was no statistical evidence to support a difference between the predicted binomial distribution (5.0 average, 1.58 standard deviation) and the actual results (*Table 3*).

TABLE 2

STATISTICAL RESULTS

	X1 PREDICTED	X2 ACTUAL	F-TEST >2.10	X1–X2; CONFIDENCE INTERVAL
Average	5	4.68		32 ± .88 (–.56 to 1.20)
Std	1.58	1.39	1.29	
n	22	22		
				n = 22

CONCLUSION

This experiment offered no statistical evidence that directionality exists as a physical parameter of wire construction. The key faults in this study were the number of sample kits sent out (only 78 out of 100 prepared), and the even smaller number of responses returned (22 out of 100).

It should be noted that many of those who did respond said the direction of the wire greatly affected the sound, yet were unable to state how the cable was originally made. If this assertion is believed to be objective, and unrelated to any psychological or psychoacoustic phenomena, then the effect perceived, as indicated by the data, has nothing to do with how the wire was manufactured, and there is no indication that wire could be manufactured to exhibit this effect. ▶

TABLE 3

PREDICTED VS. ACTUAL VALUES

X	P 0.5	PREDICTED	ACTUAL
0	0.001	0.00	0
1	0.0098	0.00	1
2	0.0439	1.00	0
3	0.1172	3.00	2
4	0.2051	5.00	7
5	0.2461	5.00	6
6	0.2051	5.00	4
7	0.1172	3.00	2
8	0.0439	1.00	0
9	0.0098	0.00	0
10	0.001	0.00	0

REBUILDING THE AR-3*a*, PART 6

By Tom Yeago

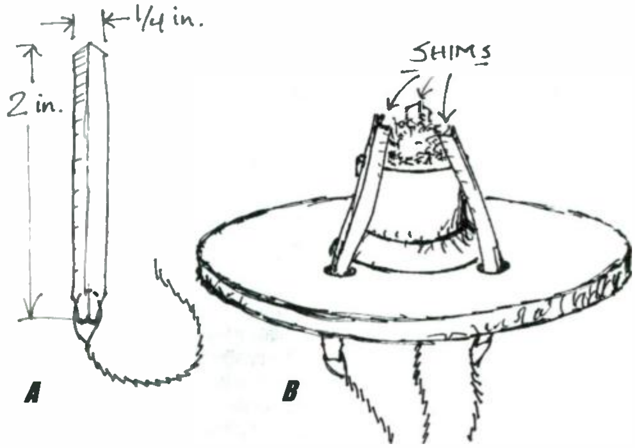


FIGURE 15: Shimming the treble dome. Fold the strip of masking tape back on itself and the wire to arrive at the device in **A**. Twist the wire into a pigtail about 2″ long. **B** shows how the shims fit through the holes in the bottom plate. The lengthwise fold helps them stay put.

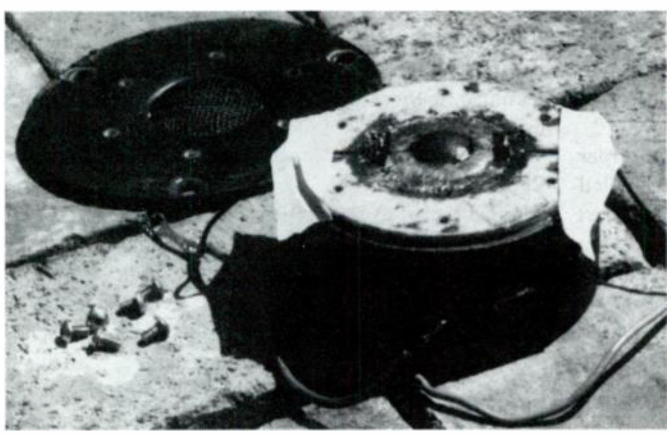


PHOTO 13: Treble dome with mounting flange removed.

A little gluing, tightening, and tweaking is all that's left in this final installment of the AR-3*a* project.

First, make the shims to hold the tweeter's gap during glue-up. Mine consist of two playing cards plus two thicknesses of masking tape, 5/8″ wide. You'll need three, to fit in the gap spaced between the notches in the top plate while the epoxy sets. Now make a Faraday ring for the central pole, as you did for the midrange dome, and glue it in place at the shoulder of the pole piece.

It's easiest to glue the whole assembly at the same time, so clean up all the parts and mix some epoxy. First glue the magnet (right way up) to the top plate. Then put your three shims in place around the central pole. Align the three notches in the top plate with the three holes you drilled in the bottom plate, and you must make sure the shims fit in the gap between the notches, so arrange things accordingly.

Spread epoxy on the bottom plate and magnet, and put the whole thing together. Twist the parts slightly to spread the epoxy evenly, but make sure everything is still lined up when you finish. Clamp the parts. After ten minutes, retighten the clamps. Let it set for 24 hours.

When the glue is cured, pull out the shims. Pull a small tuft of poly fluff through the chamfered ¼″ hole in the pole piece, glue it with DAP and shape it as you did for the midrange dome. The fluff should not be so dense through the hole that it effectively plugs it, and you must trim it well clear of the gap.

MOUNTING THE DOME

Here's how to mount the dome to the magnet structure. First, you need to shim the motor former out from the pole piece. This is where those three holes in the bottom plate come in. I used two thicknesses of masking tape in strips that I placed between the dome's former and the center pole, under the blobs of RTV that form the dome's suspension. After the dome is in place and the final layer of RTV has hardened, you remove the tape shims by pulling them through the holes in the bottom plate (*Fig. 15*).

Make the shims of masking tape, folded back on themselves over the wire "pigtail" and trimmed to the size shown. Two thicknesses worked for me, and the shims are arranged as in *Fig. 15* (magnet and top plate deleted for clarity). You just yank on the pigtails after the RTV has set, and out the wires come. The lengthwise fold helps the shims stay in place. The only thing even mildly challenging about this is threading the wire pigtails through the gap and finding the holes in the bottom plate. Once you get the wire threaded, pull the shims through until they're arrayed as shown, between the notches and the pole piece.

The next step is to push the dome assembly down into place—but how far, since the coil should be centered vertically in the gap? If your dome is like mine, you should have 0.8mm between the top of the gap and the top of the motor coil. So measure up 0.8mm from the top of the coil and put a small dot on the former with a fine-tip marker. Do this every ¼″ or so around the former. Now give the gap a final cleaning with masking tape and gently press the dome into position.

Match the RTV pads on the former with the RTV blobs in the notches, and make sure the shims stay in place. Adjust for depth all around, with the dots on the former even with the top of the gap. This can be difficult to judge, but do your best with good lighting and magnification.

Once the dome is in place, get out your thin-blade Xacto and work some fresh RTV between the blobs and the pads on the form, completing the glue joint. Using this tool as a small palette knife lets you spread RTV across the whole face of the joint with good control. It's better not to cover much wire with RTV, since ferrofluid goes in there. Check for depth one last time, cover with a jar lid, and let it set for 24 hours. After the RTV has set completely, pull the tape shims out of the gap through the holes in the back plate.

DOME EXTENSION

Now it's time to make your little dome extension. For a membrane, I elected to use more epoxy-impregnated tissue paper. I

Now Distributed by OLD COLONY!

Now available, from the makers of CLIO, the complete and reliable electroacoustic measurement system, **CLIOLite** is the entry-level version of the software at an unbelievable price! With the **CLIOLite** system, you get the 4.0 version of the CLIOLite software and the HR-2000 PC board. By special arrangement, the North American package includes Mitey Mike II's calibrated microphone capsule and wand, making this the most impressive, inexpensive measurement package available to the loudspeaker designer and tester.

CLIOLite includes many of the important features of the professional **CLIO** including:

- **Programmable signal generator**
- **AC Vrms, dBu, dBV, dBspl meter**
- **C & L meter (real-time)**
- **Dual channel oscilloscope**
- **Sinusoidal frequency response**
- **Sinusoidal impedance (CV,CI, Int)**
- **MSE Thiele/Small parameters**
- **Distortion vs. frequency (2nd, 3rd)**
- **True MLS analysis**
- **Impulse response**
- **Energy time curve (ETC)**
- **RTA 1/3 octave analysis**
- **Help on-line**

The **CLIOLite** measurement system package is a great value and is introductory priced at $599! For those who already own a testing microphone, the introductory price is $489! (Upgrades to the full **CLIO** v.4.0 are also available to **CLIOLite** purchasers.) A demo disk is available.

CLIOLite software, HR-2000 PC Board & Mitey Mike II calibrated microphone & wand.
Shipping wt: 4 lbs.

KC-CLIOM **$599.00**

CLIOLite software & HR-2000 PC Board only.
Shipping wt: 3 lbs.

KC-CLIO **$489.00**

Call toll-free in US 1-888-924-9465

Old Colony Sound Laboratory, PO Box 876 Dept. B98, Peterborough, NH 03458-0876
Phone: 603-924-6371 Fax: 603-924-9467 E-mail: custserv@audioxpress.com

NOTE: These products available in North America and selected other countries only. Call for availability in your area. Prior sales of MM II excluded from this special pricing. HR-2000 PC Board not available separately.

taped some bumper-sticker backing paper to my glass surface, taped an uncreased 3″ × 6″ section of tissue down flat, and spread on a thin, even coat of epoxy with a playing card. Work the epoxy across the tissue in several directions to make sure you're working it into the fibers. Squeegie off any excess. Let it cure, and very lightly work a thin coat of epoxy into the other side, just in case. Let that cure.

For each dome, you need a circle only 1.75″ in diameter, so pick out two likely looking patches. I colored mine light gray with a magic marker. Cut a 17mm-diameter circle out of the middle of each; then, out of the resulting "donut," cut two small notches 180° apart to accommodate the flex leads you epoxied to the dome.

Now you need to do a little work on the dome and top plate. You might wish to add a little RTV to the blobs to smooth out their profiles and even them up. They should climb up the side of the dome a mm or so above the front of the top plate. Now's the time to add ferrofluid, too. Stick a small piece of masking tape to the dome as a splash guard, then add 0.07cm^3 of ferrofluid. "Burp" the dome slightly to make sure the fluid gets through to the inside, examine the gap to see whether there's enough, and add 0.02cm^3 or so more if it's not full.

Now cut a piece of felt large enough to cover the front plate, and cut a 2.4cm hole out of the middle. Glue this down onto the top plate with a light coat of DAP. Use your soldering iron to trim the hole back to the top edge of the chamfer, giving the notches a little extra clearance. Then find your six tapped flange mounting holes and cut out around them.

Now glue the tissue donut to the dome. Mix up some epoxy and use a needle to spread it around the underside of the 17mm hole's edge and notches. Stand the Litz flex leads up and out of the way, and lower the tissue donut down into position. I held the tissue donut level by laying three coins (cents) on the top plate, and then laying the tissue on these.

To hold the tissue in place, I weighted it down by laying more coins on top. The idea is to get the tissue level and to get a good glue joint where the tissue meets the dome, a couple of millimeters forward of the top plate. Monitor the epoxy as it sets, and when it begins to turn tacky, press on the tissue/dome joint to get a good fit with a nice thin glue line.

After a couple of hours, mix up a little more epoxy and use it to fill any gaps in the tissue/dome glue joint. Pay special attention to where the wires come through the notches in the tissue.

Once that's cured, you need to glue down the perimeter of the tissue. I used an alloy collar with a 1 1/8″ inside diameter as a clamp. You could make something just as useful by cutting out a 1.75″ disk of Masonite and boring a 1 1/8″ hole in it. Make two, so you'll have enough thickness to clear the dome. Then spread some DAP on the felt under the tissue at this diameter. Center your 1 1/8″ ring on the dome, and weight it down with a couple of lbs to flex the tissue down into a shallow cone onto the DAP, and compress the felt. Put this where you won't bump into it, and leave it alone a few days.

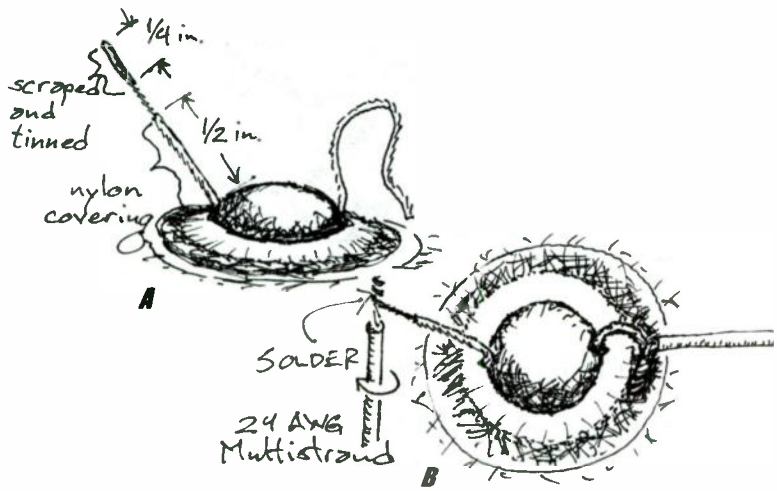


FIGURE 16: Preparing the Litz flexible leads for connection. ***A*** details stripping and tinning. ***B*** shows connection and dressing to 24-gauge insulated multistrand. Lead at left is ready to be soldered, then more Litz is twisted onto the 24 AWG to adjust length of loop, right.

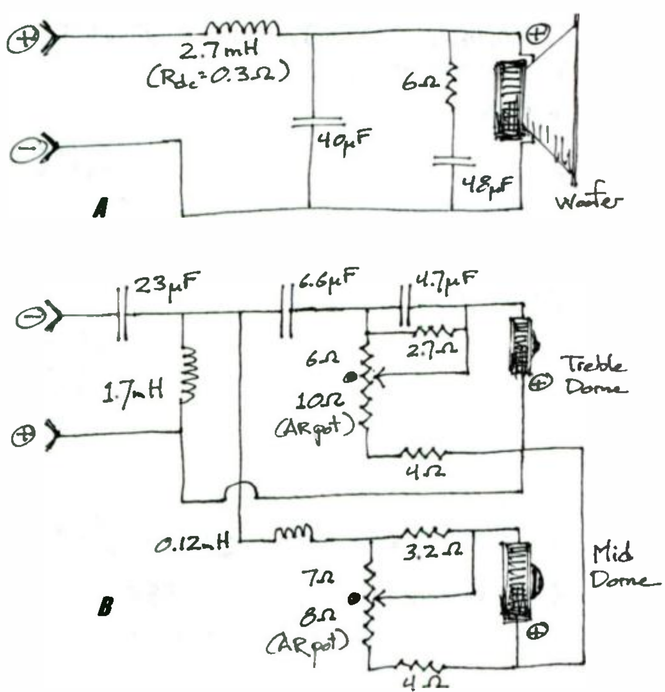


FIGURE 17: The crossover. ***A*** pertains to the bass, a textbook B2 @ 500Hz. ***B*** is everything else; the high-pass is B2 at 800Hz, another textbook solution made possible by a resistive load.

MORE WIRING

Now attach the Litz flex leads coming off the dome to something more substantial. I used 6″ leads of insulated 24-gauge multistrand. With each Litz lead, at about ½″ from the dome, melt the nylon covering and strip it away to the end of the lead. At a point ¾″ from the dome, start scraping the varnish off the Litz strands, twist them back together, heatsink, and tin the remaining ¼″ to the end (*Fig. 16*).

Now wind two or three turns of the tinned Litz around the tinned 24-gauge and solder. Then twist the 24-gauge, winding on more Litz until you reach the nylon sheathing. Then bend the 24-gauge until it fits into the groove cut in the flange plate, insulate the connection, tape it down, and form the

BRUCE SCHULL'S COMMENTS

Tom Yeago suggested last fall that I borrow his refurbished AR loudspeakers to give him a candid, nonaudiophile opinion on their sound. I didn't know Tom very well at the time and wasn't quite sure what I was getting into, but it seemed like a reasonable request.

The company I work for builds mechanical-action pipe organs, and I make my living, in part, judging subtle tone color and volume characteristics in organ pipes. My job requires the ability both to detect small differences in the sound of the pipes, and to decide what to do to them to achieve the desired tonal quality. I have owned a stereo system since the late '60s, which, although it has evolved over the years, is by no means state-of-the-art. My CD and record collection contains, among other things, quite a number of organ recordings—mostly solo, but some together with voices, brass, or full orchestra.

My first clue that these were no ordinary loudspeakers came when I stopped by Tom's apartment to pick them up. There is some serious mass in these units! I set up the speakers at home in my dining room and tried them out first with a favorite CD that features the large Fisk organ in the Myerson Symphony Center in Dallas. Both the building and the organ were constructed within the last decade, and the sound produced by the organ and orchestra and developed by the hall is considered to be among the finest anywhere.

The reproduced sound from the speakers was immediately arresting—better than I would have thought possible. Aside from being able to handle prodigious amounts of power from the amplifier without apparent distortion, the sound was equally satisfying at low volume levels.

The speakers possess an evenness of presence that is difficult to describe. Percussion is especially effective. There is a tight, clean quality to the sound. You are not aware of any frequency range that is overly strong or weak.

Subsequent listening to many recordings on disc, DAT tape, and CD has affirmed my impression that these speakers are remarkably even in their sound production. They perform well under all sorts of listening conditions. Tom has done an amazing job in rebuilding these speakers. I had no idea such results could be obtained. I hope to learn more about them.

½″ of Litz flex into a nice arc. If you need more room, untwist some wire off the 24-gauge. I daubed a tiny bit of DAP onto the Litz at the dome for stress relief. Keep in mind that the front plate holds the screen grille against the top plate, so don't let anything interfere with that fit.

Next, mount the backing magnet. I used the magnets from my two spare tweeter assemblies, so the backing magnets were the same size as the main ones. DAP will hold them just fine.

Now is the time to test and mark the treble unit for polarity. A 1.5V dry cell won't affect the dome enough to tell if it's moving in or out, so you can either use five or six volts (but briefly!) or use a little lever to magnify the dome movement. Lay a broomstraw or soda straw 3″ or so long across the dome so the free end sticks out 2½″ or so and the short end is held fast. The lever will magnify the dome's twitch, and you can mark the leads. (If the dome twitches outwards, mark the lead positive that's attached to the plus side of the battery. If it twitches inwards, mark the lead positive that's attached to negative terminal.)

FINAL ASSEMBLY

There's little else to do but screw on the

TABLE 4

TREBLE DOMES

	M_{ms}	C_{ms}	f_s	V_{as}	Bl (est.)	R_{dc}	Q_e*
Stock	0.24gm	0.07mm/N	1.2kHz	1cm³	1.4 T•m	3.5Ω	3.1
Modified	0.28gm	0.1mm/N	775Hz	4.4cm³	2.8 T•m	5.1Ω	0.88
	S_d	R_{ms} (est.)	Q_m	Q_{ts}*	Q_{cb}*	f_{cb}	
Stock	3.1cm²	0.5	3.6	1.6	2.25	1.7kHz	
Modified	4.5cm²	1.7	0.8	0.42	0.61	1.15kHz	

*Again, level set pots and any other components in series with the motor coil will affect Q_e and everything calculated using it.

front plate. Be absolutely certain your screws aren't too long, or they'll pop the top plate loose and cause no end of trouble. I speak from experience. If you're uneasy about the screen grille pressing against the wiring, nip some cut-outs on the flat flange of the screen; they won't show.

Make sure the insulated leads fall into the grooves on the plate's underside, and screw the front plate down. It needs to be snugly tightened, but not highly torqued. Wind steel wire (or steel wool) and DAP into the grooves between the magnet and both the front and back plates, just as with the other two drivers.

V_{as} FOR A TWEETER

Although measuring it wasn't fun, I'll stand by my 0.15mm/N compliance figure. Let's put it this way: it was more than 0.1mm, but less than 0.2mm. That gives a V_{as} of 4.4cm³, and with 1cm³ under the tissue surround, and approximately 1.5cm³ under the dome and in the bore, I needed about another cc to make this an infinite baffle system. The f_s would go to about 1.1kHz in such a "box." So I plugged the three holes in the back plate, installed a single thickness of felt and some shims to hold the plug 1mm from the back plate, and bunged in the plug—another sheetrock disk sealed with DAP, just as on the midrange dome.

Then I glued on a chunk of masonite with two solder lugs screwed to it (you could as easily screw a terminal strip into the sheetrock). For the connections, I soldered the 24-gauge leads and foot-long heavier-gauge wire to these lugs.

Since I'm picking up loose ends here, I'll mention my concerns with the RTV blobs. The RTV stuck well to the former and paper dome, but I couldn't get it to adhere properly to the top plate. So I worried about that joint coming loose, especially with the ferrofluid in there. But then I realized that the stressed-tissue donut would keep the RTV blobs under pressure and in place, jammed against the little shelves at the bottom of the notches. So even if the RTV lets go from the steel, they're not going anywhere—the dome stays centered.

THE NUMBERS

See *Table 4*. If I couldn't do a Bl test on the midrange dome, I sure couldn't do one on the treble. The stock dome has 1.12m of wire in the gap; I think a typical B is at about 1.4T. The modified treble has 1.7m of wire in the gap, and I figure the B there at about 1.7T. My little iron probe gizmo is problematic with this structure because the chamfer on the top plate keeps me from placing the iron flat across the gap. The M_{ms} numbers are good. I guessed R_{ms} by extrapolating from R_{ms} figures on other ferrofluid domes. Z was 5.9Ω to 1.5kHz, so I stopped measuring.

THE CROSSOVER

The crossover I cobbled together is shown in *Fig. 17*. It's fairly straightforward except for two things. First, the midrange-treble crossover is in the ground leg of the circuit. I did it that way because AR did it that way. Second, both the midrange and treble units are fed by the high-pass (a B2 at 800Hz). I did this to save displacement in the treble dome and because the impedance from the two units is so resistive in character that it was an option, so I took it. Also, this gives the treble dome the same feed as a biamp setup with an 800Hz high-pass. I guess I'll

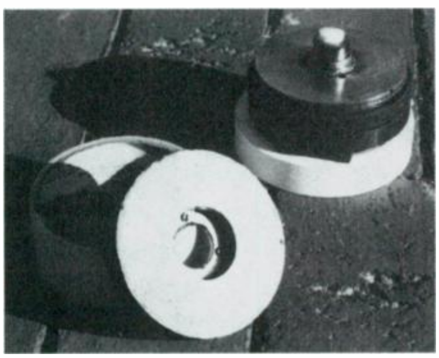


PHOTO 14: Treble-dome magnet structure.

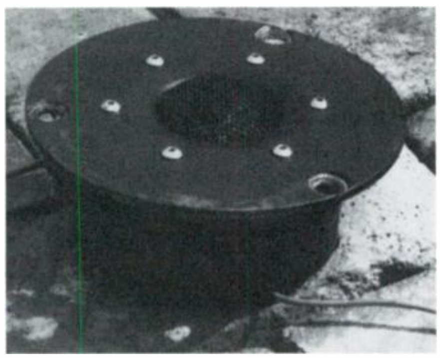


PHOTO 15: Assembled treble unit.

STILL MORE ON GLUE

The last time around, I was complaining about the 250°F working temperature of common epoxies, and found out that Loctite 271 "Red" Threadlocker had them beat. Well, now I've discovered a 400° industrial epoxy from a firm called Master Bond. So I called them up and found out that the smallest quantity they sell is enough to mix up one pint, and this costs $175.

So I set about figuring. How many crazed speaker builders are out there? Enough to use up a pint amongst us? Maybe. So I wrote Ed Dell proposing I take the monumental financial risk of buying enough for a pint and hawking it to speaker builders through these pages. Ed Dell agreed to this.

Here's the deal: I buy this strange and exotic epoxy then divide it into 10cm³ quantities, which I make available for $5.50, postpaid, in the US as long as it lasts. I don't know what to do about Canadian or overseas orders. I'll worry about that if it happens.

To give you some idea of the quantity, the little duplex plunger tubes of Devcon epoxy have a net volume of 25cm³. So this stuff is about seven times as expensive. But for about one-fourth of what you'll pay for ferrofluid, you solve the nagging adhesive problem. 10cm³ is plenty to do a pair of these speakers. I'll also send along the tech sheet.

It's only fair to point out that my speakers have been in service almost two years now, with no known glue-related problems. And from 250° to 400°F is just 2dB more of power handling, but some of us do like loud music.

If you're up for this deal, send a check or money order made out to me for $5.50 for each 10cm³ of high-temperature epoxy. No credit; no charge cards. If I run out before your order comes in, I'll return your order and check, uncashed. Mail to: Tom Yeago, P.O. Box 713, Staunton, VA 24402. *—TY* get around to trying that one day, so I decided to keep the crossover comparable.

I fed the woofer with a second-order low-pass at 500Hz (B2), and that, together with the Zobelled motor-coil inductance, gives a total of three poles. Because the low-pass and high-pass are "gapped" (i.e., at 500Hz and 800Hz), and because in addition to the phase lead from the crossover, there's also the phase lead from the midrange's resonance (second order at 400Hz), the woofer and midrange are very close to being in phase through the two-octave transition—well, less than 45° apart. I was concerned that the woofer might be a little down on output, but figured that its increasing directivity (beaming) in this range would hold things up on axis.

For capacitors, I waited until Madisound had a sale and loaded up on cheap film units. I wound my own coils, checking them (the larger two, anyway) with a voltage divider, using a 60Hz source (my Variac) and a load R about equal to my target inductance at 60Hz.

The midrange-treble crossover is a first-order arrangement, with the crossover points overlapped, i.e., the midrange's high-cut is at 5kHz and the treble's low-cut is at 4kHz. The overlap is needed because even though the treble dome's natural rolloff is almost two octaves lower (at 1.1kHz), there's still too much phase lead; but overlapping the drivers like this lets you keep much closer to quadrature through the crossover range here.

TABLE 5

EFFICIENCY AND SENSITIVITY FIGURES*

	AR woofer Stock	AR woofer Modified	AR midrange dome Stock	AR midrange dome Modified	AR treble dome Stock	AR treble dome Modified
Efficiency	0.36%	0.37%	0.26%	0.43%	0.06%	0.22%
Sensitivity**	90.5dB	89dB	89dB	89.5dB	83dB	86.5dB

*Calculated using the f_s–V_{as}–Q_e method per Dickason in *LDC*

**Assuming ½ space conditions, and that stock drivers have a 4Ω impedance, and modified drivers have a 6Ω impedance. Note also that treble levels will be louder on-axis due to higher directivity over their range, i.e., they're beaming.

I kept AR's pots, but rebuilt them where possible. I soldered little gold-plated pads (from pc boards) onto the contact points of the wipers, and I sealed the shafts with some thick grease (as thick as roofing cement, but it doesn't harden). Epoxy resin or hardener (whichever is less volatile, i.e., smells less) would probably work as well to seal the shaft—but use it sparingly.

I padded out the pots as shown to restrict their action power-wise and give the crossover a more consistent load. The 4.7µF cap shunting the top of the treble pot is a kludge to compensate for losses in the linen grille cloth. If you glue more masonite to the inside back, you'll need to drill about 1/8″ into it to give clearance for the pot. You also must discard the rubber washer on the bushing and clip off the key tab on the front. My

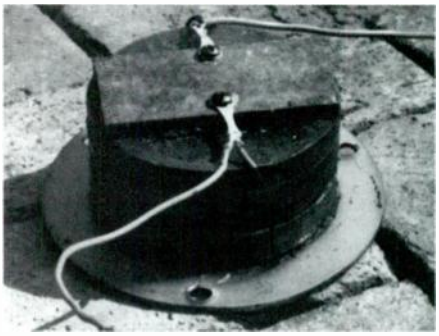


PHOTO 16: Back view of treble unit.

1½″ hole saw worked admirably on the masonite.

LEVEL-SETTING

Table 5 shows the calculated sensitivities and efficiencies of the various drivers, before and after. The sharp-eyed reader will note that these figures do not jibe with the levels set in *Fig. 17.* I installed the pots twisted to these levels at the indicated reference (the dot) because both domes sounded a little hotter than the calculations, and they measured slightly hotter, too.

My best guess is that at reference (which is *not* the same as correct) levels, the midranges may be 1 or 2dB shy of the woofer overall, and the treble dome is probably about 4dB down from the woofer, which is probably what AR intended anyway. Personally, I like them with the midranges advanced a little, and the treble a little more. Maybe I underestimated the flux densities in the domes' magnet structures. Or perhaps my typical room placement prevents the woofer from "seeing" the environment as half-space.

OTHER CROSSOVER QUIBBLES

You might also wonder about the 0.12mH in series with the midrange dome, when the

YET ANOTHER WOOFER UPDATE

As you've probably gathered, I've based what I've written on the single stamped-frame woofer I rebuilt. Well, I've been busy since, and can now report on a larger sample of these drivers, all known as AR part #200003. Now that I've had a little more experience, I can confidently surmise that the first woofer I rebuilt was a replacement unit. It had a Nomex® motor former (with no vent holes in it) that's similar to the formers I've found in the AR 8″ woofers.

You'll probably run into woofers with paper motor formers, and they're vented at that, with six 7/32″-diameter holes above the motor coil. This weakens a former that already looks marginal to me; in fact, of the three woofers I've seen that have this former, all were beginning to buckle. Two were just bulging, but one was actually creased. I wonder what such a weak linkage to the cone sounds like?

The last woofer, from an AR-11, had a hefty (if vented) aluminum motor former that showed no signs of distress. You probably won't find this woofer on a pair of 3*a*s. It is very late AR-11 production, but you can spot it by looking closely. The paper-former woofers had dust caps with sizable cloth flanges. The metal-former woofer had a dust cap with no flange—it was all dome.

Another difference was the extremely compliant suspension (or spider) on this particular woofer. Its floppiness caused me concern, so I gave it a good dose of spray starch and zapped it with a heat gun to cure. It's still not as stiff as the others, but it's getting there.

Speaking of the dust cap, it's probably wiser to leave the flange on the cone. Any solvent that would free the flange would probably do too much damage to the spider/cone joint. So just cut the dome part of the dust cap away, and then slice the flange over the two wires so you can pull them through and free. I've taken the flange off two woofers, but I always pull off a fair amount of paper with it. Better to leave it as is.

There are also differences in how lumpy that back of the cone is, but I can't take that seriously. AR is bound to have changed details of manufacture over the years.

Magnet differences? Just one: the Nomex-former woofer had a magnet with three deep indentations in its perimeter, as though to provide clearance for three bolts.

POOR GLUING

I've also run into some of that shoddy gluing I've come to expect in the midrange and treble units. I found woofers with magnet structures having too little glue, or which were so poorly clamped that I could slip a 0.01″-thick piece of stock in between the steel and the magnet, sometimes as deep as 3/4″. Weak glue joints make this woofer hazardous to ship. Whenever I ran into this, I crammed the crevice full of steel razor-blade stock and epoxy as best I could.

Finally, a couple of words on the replacement surrounds. These must be scrubbed thoroughly to take off the mould release before the silicon will stick to them. Maybe using isopropyl alcohol isn't such a great idea. When I started cleaning the surrounds for this new batch of woofers, I doused one surround with isopropyl, and it curled up like burning paper. I don't know whether it was the cooling from rapid evaporation or something else, but it made an impression on me. Sure, it flattened out all right, and I can't find any damage, but if you use alcohol, water it down. For the other surrounds, I relied on vigorous rubbing with white vinegar and rinsing thoroughly with water.

And when you're spreading the RTV on the surrounds, you'll find you get good results with a firm, straight spreader—no profile-cutting necessary. I wound up using a single-edge razor-blade with a layer of masking tape over it, and it worked fine. —*TY* textbook solution would seem to dictate 0.19mH. Well, yes, but the dome has a motor-coil L of about 0.09mH, which is isolated to some degree by the padding resistances. All I ask is a simple, everyday, ordinary first-order low-pass at 5kHz. So I lumped as best I know how, and 0.12mH seems right. Besides, first-order circuits are on the forgiving side, electronically at least. They can lobe like the dickens, but that's a placement problem.

This brings up the touchy topic of driver placement. The way my phase relationships work out with the physical placement of the drivers on the baffle, things don't look too bad. If I stand them so the woofer's on the bottom, there may be some slightly upward lobing at 500–800Hz, but considering how long the wavelengths are here, I can't take it seriously.

For the midrange-treble transitional region, with the two drivers at quadrature, there will be a lobe pointing down and to the left, looking out from the speaker. But again, consider the wavelengths involved. They're short, compared to the distance between drivers; 90° at 5kHz is 2/3″. So I don't worry about lobing. Interference (comb filtering) between the two domes is a concern, but that's the nature of first-order filters.

I considered the woodwork involved, and left driver placement as it was. A mirror-image pair would have been nice, but too much work. Maybe next time around.

IN USE

With the first one I built, I fed the domes with a high-pass (B2) at 1kHz. I didn't like it much, so I moved the crossover point down to 800Hz and have been satisfied ever since. I ran the speakers with a 100W/channel solid-state amp, and they seemed very happy—plenty of dynamic range. I consider them to be very capable speakers with regard to power-handling, bass extension, and transients. They'd be a natural for a tube amp on the 4Ω tap. Of course, it should come as no surprise that I like my own handiwork.

Speaker builders yield to no one when it comes to self-delusion. But I wanted a qualified opinion, so I sent the 3*as* off on long-term loan to Bruce Shull, a fellow I know who works for a local firm that builds tracker pipe organs. Bruce is responsible for voicing the organs, among other things, and his wife is the organist at the Lutheran church, but neither one is an audiophile (see sidebar). That was more than six months ago, and all reports have been positive. He wants to build a pair, in fact. Glad to help out, I said.

LOOSE ENDS

If you biamp these things, I would feed the midrange-treble units through about 130µF of capacitance (including lots of films) to add a little more phase lead and to protect the dome midranges from DC should it appear if the amp fails.

If you're thinking of meddling with the similar AR variants, I can't offer much specific advice. With LSTs, for example, I don't have any clever ideas on what to do about that array of eight dome units. It might be best to leave a pair of midrange domes on an inner-angling face and find new housing for the rest of the domes, forming a vertical array. I'd ditch the autotransformer and use a more conventional arrangement of pads and switches, and I'd definitely biamp, probably moving the woofer/midrange point down 1/3 octave.

For the AR-5, and other models using the 10″ woofer, I just don't know. I think AR's 10″ woofer is difficult to work with. It just doesn't seem as susceptible to improvement as the bigger woofer. I find AR's 8″ woofer (in the 4-series models, and probably used as the mid-woofer in the model 9) similarly frustrating. So if you intend to hot-rod a 9, my advice is to find another midrange dome and some small cones you like and build a big D'Appolito.

Now for the magnet question. What will it cost, you may wonder, to get all those magnets? Not much. Bypass your local Radio Shack, which sell laughably small magnets for $1 a pop, and trot down to your local junk-car emporium with a pair of aviation snips. Talk to the counterman, and he'll let you cut the magnets out of those vile stereo speakers screwed into the parcel shelf of his junkers. He might charge as much as $1 per. It's your best source for cheap backing magnets. You can practice on taking

AFTERTHOUGHTS

I've been adding to my collection of *SB* back issues and have come across a couple of items readers might be interested in.

- Winslow Burhoe was another person involved in the AR-3*a* mid-dome and tweeter development ("We Visit Boston Acoustics," by Bruce Edgar, *SB* 2/87, p. 33). Maybe Moses Gabbay, too; I couldn't tell from the text.
- My memory of the *SB* letter was a little off. The reader was looking for more guidance than I recalled. (*SB* Mailbox, 3/88, p. 56). Mr. Dickason wasn't specific as to what's needed for an air-suspension woofer and extended bass response, but he did compare those woofers of yore to dinosaurs and (how could I forget?) silver certificates. Andy Petite (*SB* 2/87, p. 34) also had an interesting comment on how you wind up with the AR 12″ woofer.
- Speaking of woofers, I also misremembered the NHT 1259 12″ woofer. Its Bl product is less than 10 (versus the 12 I remembered), and S_d is 491cm^2 (versus 560). I confused it with the redoubtable Swan 305 12″ woofer (S_d, 560cm^2 calculated, Bl of 16!), which would be a good AS woofer but for its stiff spider and resulting high f_s of 24.5Hz and V_{as} of only 167 ltr. Another near-miss would be the Eclipse W1238R: Bl = 14 Tm, S_d = 532cm^2, f_s = 19Hz, and V_{as} = 260 ltr. I suspect another stiff spider.
- And finally, I found someone writing about measuring compliance, but haven't been able to find the piece again for attribution. The point was that measuring compliance by plopping a weight on the cone and measuring deflection (the static method, my method) was apt to give a less than accurate result by underestimating compliance. OK, if you say so. —*TY*

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 System • Build and Use a White/Pink Noise 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 •

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 •

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 •

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:

There's More ☞

NAME

STREET & NO.

CITY STATE ZIP

Please send me the following back issues of Speaker Builder

❑ 1997 $32	❑ 1996 $32	❑ 1995 $32	❑ 1994 $32
❑ 1993 $25	❑ 1992 $25	❑ 1991 $25	❑ 1990 $25
❑ 1988 $23	❑ 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
$61.00-130.00 - $6.50
$131.00-220.00 - $8.50
$221.00+ - $10.50

Canada: Add $6.00 per year.
Foreign Air: Europe add additional 40% of total order.
Other destinations: 50% of total order.
Foreign Surface: Add additional 20% of total order.

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 ❑ VISA ❑ MC ❑ American Express

DISCOVER/MC/VISA NO. EXP. DATE

Total Enclosed $

Speaker Builder Post Office Box 876 Dept.B98, Peterborough, NH 03458-0876 • (603) 924-9464 • FAX (603) 924-9467

these apart, too, before you start disassembling the AR drivers.

If you must go nuts on treble, you might order a more powerful magnet for the treble domes. Get a C-5 ceramic magnet of the same dimensions from Magnet Sales & Mfg. (part # 63B3312425, $6.21 each, plus shipping, 800-421-6692). Almost twice the coercivity (assuming AR used C-1 magnets) means pushing the steel further into saturation, probably 3 or 4 more dB of sensitivity.

There's a $30 minimum, so find someone else rebuilding a driver and band together with your friends. The Magnet Sales catalog serves as a good magnet primer. For example, that's where I found out about ceramic magnets' susceptibility to high temperatures below the Curie point. Unfortunately, the catalog doesn't list high-coercivity alternatives for the other drivers.

If you don't wish to buy a pipette from Electronics Goldmine (Scottsdale, AZ, 800-445-0697), you can use the little extension nozzles that come with carb cleaner and WD-40. They have a 1mm inside diameter; figure it out.

Now we come to the issue of ferrofluid. I paid Parts Express $10 for 5cm^3 about five years ago. So, being a quasidutiful author, I called to see if they still had it in bulk. No. They've gone with the brand name, the official Ferrofluid, and it comes in "retrofit" kits, i.e., prepackaged little squeeze ampules.

Paul at Parts Express was very helpful, telling me the best deal is P.E.'s part #340-443, the kit for some big EV drivers, which has a 0.45cm^3 ampule of ferrofluid. Five kits, which should be enough, cost $19.50, plus shipping. But P.E. has a $20 minimum, so buy more, or find something else you need. Twenty bucks seems a lot, but it's pretty cheap insurance, and ferrofluid lets you pump a lot of watts through the drivers, making the simple-minded crossover possible. If someone out there knows of a bulk source, write in.

I don't know how to advise here. Maybe if they get enough calls, they'll carry the bulk quantities again. Perhaps a competitor will see this and step in. Maybe someone out there is selling the balm already. I'd hate to see builders pay more for the ferrofluid than they did for the speakers. But maybe I'm just being excessively cheap. So watch "*SB* Mailbox" for news.

I relied on the following sources: Colloms (*High Performance Loudspeakers*, Pentech, mine is the third edition); Beranek (*Acoustics*, McMillan, '54); and Dickason (*Loudspeaker Design Cookbook*, fifth edition).

ACKNOWLEDGEMENTS

First of all I want to thank the mysterious S. Robert Russell, who produced the single best piece of audio journalism/how-to-ism ever in the July '62 *Audio*: "Thirty Pounds of Magnet and an 18 Inch Cone." This guy surveyed the market, found it lacking, and so built his own woofer from the ground up, except for the cone, which he purchased. Not only is it a formidable woofer, but the telling is top notch, far better than audio geeks have a right to expect. I think of him as the Sage of Key West, and wonder what became of him and his woofer.

I also want to thank Charles McShane for the time he spent on the phone with me.

SOURCES

AB Tech
800 225-9847, FAX 508 478-9816
3*a* replacement woofers

Electronics Goldmine
800 445-0697

Magnet Sales & Manufacturing
800 421-6692
High-coercivity tweeter magnets

Master Bond
201 343-8983
Glue

Parts Express
800 338-0531
Magnetic fluid

Stepp Audio Technologies
800 747-3692
Surrounds

Speaker Builder encourages reader feedback in the form of letters, queries, and comments. Send correspondence to:

Speaker Builder, Editorial Dept.
PO Box 494, Peterborough, NH 03458
FAX (603) 924-9467,
E-mail Editorial@audioxpress.com

Be sure to reference the issue, title, author, and page number of the article or letter in question; and, if you request a response, please include a self-addressed envelope (or FAX number and E-mail address, as applicable) with a loose stamp or postal coupon. All letters will be considered for publication unless you indicate otherwise. *Speaker Builder* reserves the right to edit letters for length and clarity.

Product Review

CLIOLITE

Reviewed by Dick Pierce

CLIOLite by Audiomatica s.r.l., Via Faentina 244/g, 50133 Florence, Italy, (+39) 55-575221, FAX (+39) 55-5000402, E-mail audiomatica @mclink.it, Website www. mclink.it/com/audiomatica. Also available from Old Colony Sound Lab (PO Box 576, Peterborough, NH 03458, 603-924-6571, FAX 603-924-9467, E-mail custserve@audioxpress.com).

These days it seems as though everyone is coming out with loudspeaker-measuring software. Products range from freeware and shareware packages that run on nearly anyone's PC soundcard to complete hardware and software packages for $3,000 and more.

Besides a better mousetrap, what the world *really* needs is a reasonably low-priced, versatile, dependable, relatively easy-to-use package that serves the needs of both an advanced amateur as well as the professional. CLIOLite, from Audiomatica s.r.l. in Florence, Italy, promises to be such a package for around $500. And, for the most part, it keeps that promise.

PRODUCT DESCRIPTION

CLIOLite, as the name implies, is a somewhat stripped-down version of the CLIO 4.0 product. Several missing features are MLS waterfall plots, THD measurements, FFT capability, automatic polar diagram measurement, the QC functions, and some more relatively esoteric items. More important, however, is what remains. Advertising claims for the Lite version include a generator and millivoltmeter, an LC meter, a dual-channel oscilloscope, sinusoidal response, impedance and woofer parameter measurement, distortion versus frequency, MLS analysis, impulse response, energy/time curves, and one-third octave "real-time" analysis.

The product comes as a single half-length eight-bit ISA card (the HR-2000) and three diskettes (I also received a MIC-02 ¼″ electret microphone, which I'll not review here). There is no paper documentation packed with the product; instead, "online" documentation is provided, using a copy of Adobe's Acrobat reader and a document file. More on that later.

Computer requirements are not very stringent: a 386 DX-33 or better with 2MB of RAM, hard disk, and VGA display running MS-DOS 3.2 or later. I tested it in one of my laboratory machines, a 386 DX-40 with 8MB of RAM, 512MB of SCSI hard disk, an HP DAT tape backup system, MS-DOS 6.22, and the Thompson Shell, a Unix-like C-shell emulator.

The machine is somewhat unusual in that it's physically very small; this desktop case measures only 12″ wide × 15″ deep × 4″ high with a small keyboard and a very nice, very small (8″ diagonal measure) IBM full-color VGA monitor. The small footprint makes it very convenient to use and transport. It's also important to note that crammed into the same computer is the DRA MLSSA system, which is my standard for loudspeaker measurement.[1]

INSTALLATION

Installation of the board is simple and straightforward. The manual recommends placing the card as far away from the video card as possible, a recommendation I strongly endorse for any board handling low-level analog signals.[2] In my system, noise levels in the region of the MLSSA and CLIO board

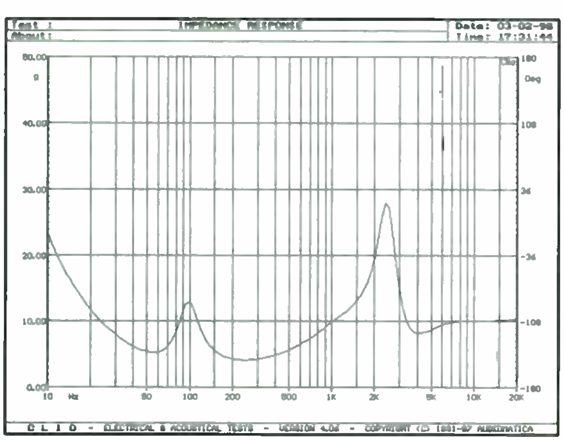


FIGURE 1: Impedance response.

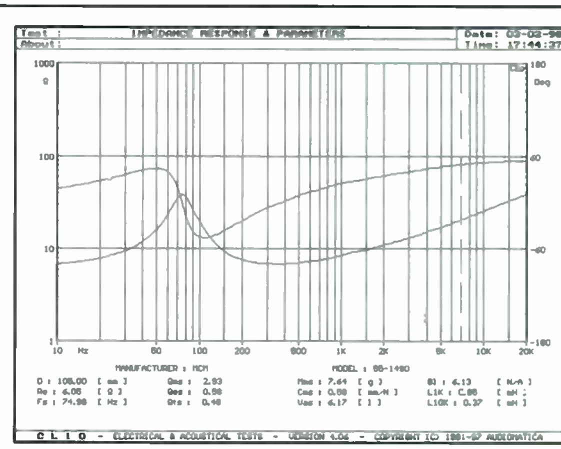


FIGURE 2: T/S parameter measurements.

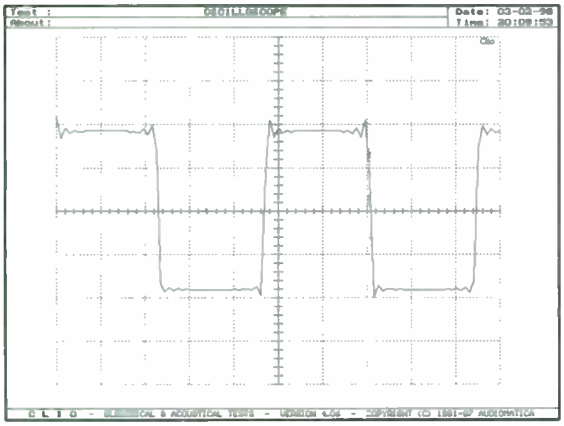


FIGURE 3: CLIO as oscilloscope.

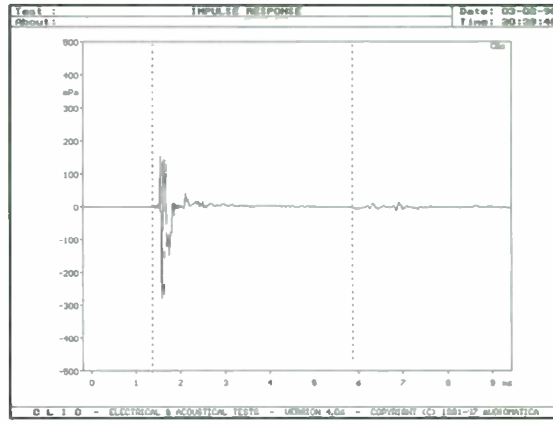


FIGURE 4: Impulse response.

are especially low because they are isolated from the others with a shield board plugged into a spare ISA slot. This two-sided board has nothing but copper screening connected to ground.

Software installation is also simple. Insert the installation disk, enter the name of the installation batch file, and you're done. The installer creates a directory, \CLIO, in the root of the destination drive (by default, the C: drive) and copies the necessary files there. More on this later as well.

Next, it's time to install the user manual. This requires a system with Windows 3.1 or Win95 to run the Adobe Acrobat reader software. I have more machines than I can shake a stick at, so I chose my laptop with Win95B. Again, installation was relatively straightforward.

To read the manual, simply click on its icon and Adobe Acrobat is launched, bringing up the document: apparently a Pagemaker® document. Now, one of the claims in the advertising brochure is that the document is "easily readable and printable from any PC," any PC running Windows, that is.

While I don't mind online help, I don't like having the entire manual on-line. Furthermore, I need to run two computers—one for CLIO and the other to view the documentation (there's no indication CLIO will run under Windows, and I never bothered to try). This seemed to me awfully silly, so I decided to print the documentation to make my own manual.

Four hours and 142 pages later, I was finally done. Trying to print more than 10–15 pages at a time turned out to be a very arduous and painful affair. The lack of paper documentation is one of the more serious drawbacks of this product, and wrestling with Acrobat didn't help much. Audiomatica or its distributor would do well to supply a printed manual...and in a 6½″ × 8½″ format so it fits on the same shelves as nearly every other piece of PC documentation.

Aside from the printing problems, the manual is reasonably well written, with some minor grammatical goofs and punctuation and spelling errors, but nothing a good proofreader with an hour of spare time couldn't finish up. Occasionally, you encounter a strange construction that sounds more like Italian than English (many manuals for Far Eastern products are far, far worse). Other than that, the documentation was reasonably clear and easy to follow. Most importantly, it helped me to get up and running in very little time—a blessing, to be sure.

Once everything is in place, the first step is to run a calibration cycle. Using a loopback cable, simply select Calibration from the Disk menu and let it run on its own. Audiomatica recommends the system be running for at least 15 minutes before calibration or any serious work, a recommendation I followed for all subsequent work.

MEASUREMENTS

I first tried to measure the impedance of a pair of KEF C15s I use for casual listening. CLIO supports three impedance-measuring

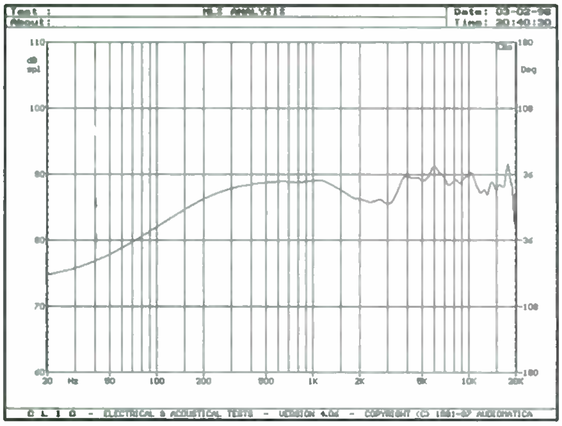


FIGURE 5: MLS analysis.

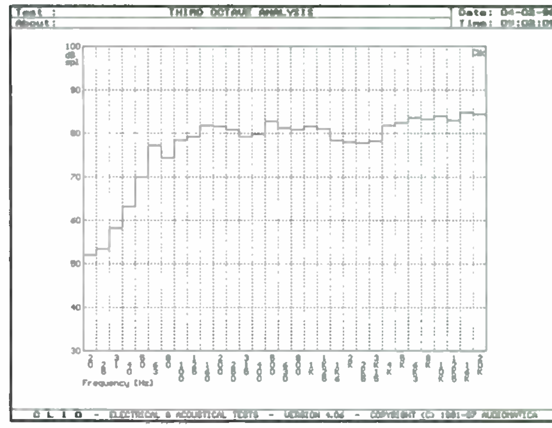


FIGURE 6: Third-octave analysis.

methods—"internal," constant current, and constant voltage. I started with the internal method, the simplest of the three. As the manual directed, I connected the "A" outputs and inputs in parallel to the speaker terminals. From the menu, I selected "Sinusoidal Measurements" and "Impedance," and then, using whatever default settings were enabled, selected "Go."

Within 45 seconds, I had a complete impedance curve drawn on the screen (*Fig. 1*). Accuracy was very good, in that the data agrees to within a couple percent of that obtained by the other three systems. For a beginning user who hadn't bothered to read the manual, I was doing well.

The data was measured every 1/12 octave from 10Hz–20kHz. You can change the settings to measure at intervals from 1/3 to 1/48 octave. The graph is well displayed and easy to read, and the data is free of anomalous jumps and wiggles that I have unfortunately witnessed in some widely used software packages.

Next, I decided to try the Thiele/Small parameter measurement feature (*Fig. 2*). Hookup is the same, using the internal method. Two impedance curves are run, the first as a "free-air" curve, which takes about the same time as the normal impedance measurement. The second uses either added mass or volume. I chose the added-mass method, which over the years I have found more dependable.

Again, guided not by the manual but by instincts, I selected sinusoidal parameters and, after staring at the screen for about five seconds, decided to select Q factors. CLIO asked for the manufacturer, model name, and the DC resistance. I disconnected the leads from CLIO, hooked them to a precision DC multimeter, measured 6.05Ω, entered the data into the dialogue box, and hit "Enter." Whoops! CLIO started measuring right away, before I had a chance to switch leads back again. Here's a good place for a confirmation prompt, or even better, a "Go" command.

Once again, CLIO took about 45 seconds to measure a complete impedance curve. When finished, it displayed the results. Then I selected "Added Mass." The program asked for the added mass (10g in this case) and the driver's diameter. I presumed CLIO meant the effective emissive diameter,[3] which is 105mm for the driver (5¼" coaxial). CLIO then proceeded with the second impedance curve, but measured to only about 400Hz, really all that's needed.

About five seconds later, it displayed a complete set of Thiele/Small parameters. I was pleased to see, again, that the results were in good agreement with other measurement methods. I was especially pleased that CLIO displays voice-coil inductance at two frequencies—1kHz and 10kHz—showing the obvious frequency-dependence (in the example, 0.85mH at 1kHz and 0.37mH at 10kHz). Programs which give a single inductance figure are, at best, misleading and, generally, are simply wrong. Voice-coil inductance is much more complex than that.

I measured several other drivers and, overall, am very pleased with the accuracy and consistency of the results. The procedure is a little slow on my platform for driver production use as is, but that's okay.

SMALL DIVERSIONS

So much for the fancy stuff. I wanted to try out some of the simpler features, so I explored the Tool menu, which includes a two-channel triggered sweep oscilloscope, generator and millivoltmeter, and an LC meter.

The oscilloscope tool behaves exactly as I would have expected. It has calibrated horizontal sweep times and vertical gains over a very wide range. Switching the sweep time and gain is as simple as using the horizontal and vertical cursor keys. It's very simple to use and quite useful, though there are a few conventional features that I miss.

For example, finer control on the trigger point, single-shot capture, and easy trace positioning would be handy. Sine-wave measurements show the real bandwidth to be in the realm of 25kHz, although don't be surprised if a pure 15kHz sine wave doesn't look perfect. You're seeing the "connect-the-dot" effect without the benefit of the reconstruction filter found in a DAC, a prerequisite for proper reproduction of audio samples. This is not CLIO's fault, but rather a charac-

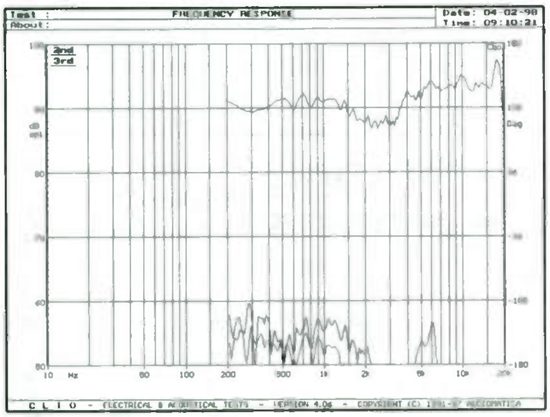


FIGURE 7: Sample sinusoidal response graph.

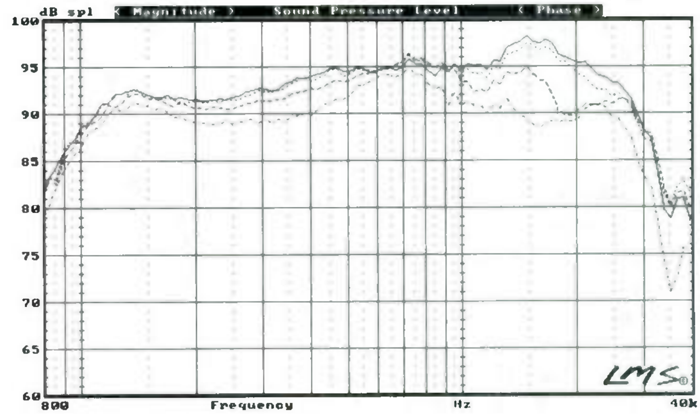


FIGURE 8: Author's minimonitor response comparison.

teristic of looking at raw digital data. A 1kHz square wave looks almost textbook perfect, with essentially symmetrical pre- and post-overshoot and ringing, indicating nearly perfect linear-phase response (*Fig. 3*).

Next, I tried the GenLvl tool, a combination function generator and millivoltmeter. You can set the generator to any one of a number of signal types—single sine wave, dual-tone sine wave with variable frequency and amplitude ratio, pink, white, and MLS noise. Each keypress of the F7 and F8 keys changes the amplitude by 1dB (shifted, by 0.1dB). A very useful feature here would be to allow playing WAVE files, either as a single shot or looped.

The voltmeter portion can display voltage, dB volts, or acoustical pressures with appropriate calibration. The generator and meter together are very easy to use and can easily be set to measure a wide variety of stimuli.

Last on the tool list is the LC meter. Using this is almost worth the price of admission. It is simplicity in the extreme. Again, connect the CLIO board as though you are measuring impedance. Instead of a driver, connect any unknown inductance or capacitance. Within a second or two, you get an accurate display of the inductance or capacitance.

I have a set of General Radio secondary standards that I keep around for checking, and CLIO gave me readings over the range of 0.5µF–100µF and 0.1mH–10mH to within 1–1.5% worst case error. It's nearly as accurate as my GR 1650 bridge, but much faster. Using it is very reminiscent of the old GR DigiBridges. Clio developers did an excellent job on this particular feature, one which I'm sure will see much use. My only complaint is that it does not show dissipation factor or Q, but that may be asking a bit much.

ACOUSTIC MEASUREMENTS

As a long-time user of the DRA MLSSA, I was curious to see how well the developers implemented the MLS measurements in CLIO. As in the other features, setup was fast, and the defaults provided a reasonable starting point. Externally, I used an HP 467A power amplifier (about 10W into 8Ω, but with an extremely wide bandwidth of DC to about 2MHz, and very stable gain) for driving the speaker, and an HP 465 as a microphone preamplifier. For most of the tests I used Audiomatica's MIC-02 Lite, though I also used several of my reference B&K microphones.

In setting up an MLS measurement, you must window the data to start at the first direct arrival, and stop immediately before the first room boundary reflection. In MLSSA, this is done by moving the cursor with the arrow keys and pressing the F9 and F10 keys (I can never remember in which order). In CLIO, you also move the cursor, but instead, you select the Start and Stop keys, much easier to remember (*Fig. 4*). Not only that, but the selected portion of the screen is highlighted in a way that, to me, is easier to visualize than MLSSA's instant zoom feature.

After I selected a ½ Blackmann/Harris

window, CLIO took about two seconds to calculate the frequency domain response (*Fig. 5*). The MLS sequence length is only 16,384 samples (order 14), about one-third of a second long at the top sample rate of 51.2kHz. While this would allow measurement bandwidth to extend to as low as 3Hz (with a 3Hz frequency resolution across the band), I would like to see a selection of sequence lengths up to 65,536 (order 16).

Finding an environment with 300ms before the first reflection shows up is difficult, but it has uses. Considering, though, the potentially wide target audience for the product, 16k is not a bad choice, which I could live with. The MLS screen provides a display of energy-time curves as well as normal and minimum-phase display.

ONE-THIRD OCTAVE "REAL-TIME" ANALYZER

CLIO provides a one-third octave real-time analyzer. Filtering is done computationally in the digital domain.[4] As in the other operating modes, setup is simple, and the default operating mode is usually close enough to get most users up and running with little hassle. Any stimulus could be used, but for measuring loudspeakers, the internal pink-noise generator works well. Pressing "P" toggles the generator on and off.

The analyzer operates in averaging mode. It accumulates and averages multiple measurements, each taking about one second on my machine. The default is for 300 averages, six-minutes' worth of measuring. Most of the time, I set the number of averages to 10 or 20. My lab is quiet enough not to require long averages to reduce the influence of noise. After a run has completed, you can either reset and start another, or continue averaging until you hit "Stop." As before, operation is simple and the display is straightforward and easy to read (*Fig. 6*).

A couple of nits: First, it's not really a "real-time" analyzer in the traditional sense. The data displayed is, on average, one-half second or so old, since the data is updated about once per second. Second, I would prefer to see a continuous, non-averaged mode in which each new display is for only the current measurement period. This is useful for looking at the moving spectral characteristics of noise and music. I find this, along with the ability to "capture" a particular snapshot, valuable in analyzing the spectral distribution of short passages of music. Also, a peak capture feature is useful.

SINUSOIDAL FREQUENCY RESPONSE

The sinusoidal response feature uses either stepped or gated sine waves, and also measures second- and third-harmonic distortion versus frequency. The gated measurement is similar to the technique used by the LMS system and others. To be honest, it's not my favorite way of measuring loudspeakers. Other systems that use it have produced what I consider undependable results unless great care is taken in measurement setup.[5]

Be that as it may, I proceeded. In the Setup screen, I selected 1/24 octave, the second- and third-harmonic distortion display (leaving most of the rest at the default), and automatic delay measurement. This last setting starts a measurement cycle by putting out one or more narrow 10kHz tone bursts as a way of measuring the exact acoustical distance between the speaker and the microphone.

Pressing "Go" starts the whole process. The gate width selected is 10ms wide, so the measurement started at about 250Hz (lower frequencies require wider time windows; remember that time-frequency uncertainty I mentioned a little while ago?). It took about 30 seconds to complete the entire sweep. Occasionally, the system stopped and repeated a measurement here and there. When completed, the response curve, along with a plot of the second- and third-harmonic distortion, is displayed (*Fig. 7*).

COMPARISONS

I carefully set up a loudspeaker measurement for a prototype mini-monitor and measured the axial frequency response using the three tools provided by CLIO. I exported the data into ASCII text files (which is very easy to do with CLIO, and a major feature for me). I then normalized the curves at 1kHz and plotted all three together using an audio graphing tool I developed years ago.

It's pleasing to see that the three methods agree as well as they do. Above 400Hz, they agree extremely well, often to within a fraction of a dB; below that frequency, we see clearly the effects of the room, of truncation of time domain data, and other non-speaker effects (*Fig. 8*).

By the way, I mentioned earlier that it's easy to export ASCII data. This is an important feature since I often use measurement data in further simulation and design programs. Audiomatica chose a simple ASCII white-space separated format, which is the easiest to interpret and the most versatile and usable choice. With other manufacturers, such a simple and fundamental feature is often missing or seriously flawed, but not here.

OTHER MISCELLANY

CLIO supports standard printers, such as HP LaserJet and IBM and Epson compatible dot-matrix printers, along with selectable printer ports. It also supports bit-map file output, which is how I was able to include most of the graphs in this review. Hard copy via an HP LaserJet 4MP is generally very good quality—crisp, clear, and easy to read. It appears much better than simple screen-dump printing provided by many other measurement programs. In addition to bit maps, I would have liked to have an Encapsulated Postscript output capability, but maybe it's asking too much for a measurement company to also support electronic publishing.

You can also select from one of seven precooked color palettes. These allow you to choose among different foreground/background color schemes. I found the default palette selection perfectly acceptable. The biggest use for this feature is the ability to support monochrome displays, but who has black-and-white video displays these days?[6]

You can calibrate the entire system to provide acoustic values instead of simple input voltage. A setup screen allows you to set the input sensitivity separately for each input channel. I set one channel to a sensitivity of 164mV/Pa for my Brüel & Kjaer 4133 and the 20dB preamp that goes with it.

And, by pressing "Ctrl + F1," you can access on-line context-sensitive help as well. It seemed to work well in all modes except the top-level menu. The help content was moderately well written and helpful, though it could stand a little improvement here and there. A pop-up screen showing the hot keys would be a welcome addition; page 37 of my hard-won printed manual is nearly worn out looking up hot keys. To be fair, there's not a huge number of them, and I ended up using only about eight of the more important ones.

CRITICISMS

Next to the fact that getting a hard copy of the manual is a lot of work with what appears to be a balky program, my biggest complaint about CLIO (and this applies to many other programs as well) is that you must run it from the install directory and you are essentially forced to use Audiomatica's notion of what a correct directory structure should be. My measurement data is spread over several disks, organized by clients, research projects, and so on. CLIO forces me to run the program under the C:\CLIO directory, and all the measurement data is to be found in C:\CLIO\DATA*.

Sorry, Audiomatica, but the rest of the world doesn't work that way. Having been involved in large, complex software development projects, I know full well that this restriction is completely unnecessary and exists only for the convenience of the product developers, not the product users. There's no reason, for example, why an environment variable named CLIOPATH could not be set to the path where CLIO needs to find its operation files, enabling CLIO to run wherever the user wishes.

There are several other minor quirks, some of which I have mentioned previously, but none of which would stop me from recommending the product. For example, in some screens, to start the measurement, you press "S" for Start; while in others it's "G" for Go. To go to the setup screen from some places, you press "S" for Setup, while in others it's "E" for sEtup. Some pop-ups are confirmed with Enter, while for others, you must use either the Tab key to get to the confirm button, or the K key (from oK). It's a little confusing and wouldn't be difficult to clean up. Basically, a consistent use of keyboard shortcuts is needed across all applications. This is a basic user interface principle.

CONCLUSIONS

CLIOLite is, in my view, the best of the low

REFERENCES

1. Though the MLSSA software will not run because of a DMA conflict, apparently with CLIO, it may be possible to reconfigure either CLIO or MLSSA to remove the conflict, although I made no attempt to do so. This would be an unusual combination in any case. CLIO did not exhibit any problems, though, cohabitating with the MLSSA card.

2. In fact, the inside of an IBM PC is a very hostile place for analog signals of any kind, what with all the clock signals running around. The mere fact that most soundcards do not sound totally dreadful should be proof that miracles really do happen. Anything you can do to tame this nasty environment will forever befriend you to any analog signal you may want to measure.

3. The CLIO manual is, in fact, a little vague on this point. It only specifies the "diameter" and a range of 15–1,000mm. Clarification would be very helpful in this area. I picked what I knew to be the emissive diameter, which, given the resulting consistency with other methods, appears to have been the correct choice. When I have written software to measure T/S parameters, I request the surround inside and outside diameters, and then derive the emissive diameter. Maybe Audiomatica might consider a similar approach.

4. Looking at the filter characteristics with sine waves, the bandpass shape is nearly perfect—little if any ripple in the passband, nearly infinite slopes at the band edges, and very high attenuation outside of the passband. This type of response is nearly impossible to achieve with analog filters. For this purpose, I believe that a well-designed digital filter is in every way superior to even the best analog-based analyzer.

5. To be honest, all measurement processes are fragile in the sense that if you don't take care to ensure the limits of the measurement technique are understood and not violated, the results will be useless. I have come to know and respect the limitations of FFT-based measurements and act accordingly. What system manufacturers and users alike often don't understand is that the same limitations imposed by fundamental time-frequency uncertainty relationships apply just as well to gated sine, swept sine, steeped sine, chirp, TDS, MLS, and FFT measurements. It's just that often those using gated sine systems are unaware of these limitations and thus obtain the erroneous results.

6. Color-blind people, that's who. This is an important feature for about 7% of the population!

and midrange loudspeaker measurement products I have used to date. Even though it is a restricted version of the full CLIO product, there's enough here to benefit both the amateur and professional user. It's extremely easy to learn. Even though I griped about the manual, a person familiar with loudspeaker measurement systems in general could quickly get up to speed without referring to the manual much at all. I spent perhaps no more than an hour playing around with CLIOLite before I was ready to do serious measurements. Other systems force a much longer and steeper learning curve on the user. CLIO's smooth operation and good default settings are two significant advantages over other products.

CLIO is not as versatile as DRA MLSSA, which has much more measurement capability, wider bandwidth, and better time resolution. The CLIO input subsystem uses a 16-bit oversampled delta-sigma A/D converter running at a maximum 51.2kHz sample rate and performing the antialiasing being done in the digital domain (allowing for near-perfect linear phase behavior in the passband), while the MLSSA uses a 12-bit A/D and tunable analog antialiasing filter with sample rates up to 150kHz. But CLIO is far easier and faster to use. And when the two are compared under similar conditions, they produce similar results, but CLIO clearly wins in ease of use. CLIO is also about one-sixth the price.

Compared to Liberty Instrument's AudioSuite, CLIOLite is more similar in capability than different. But I find, again, CLIOLite wins easily in ease of use. Its data export and hard-copy facilities are better as well. And despite my complaints about CLIO's manual, it's far and away an easier read than AudioSuite's, which is, by comparison, dense, poorly organized, and difficult to navigate.

In competition with LMS, I find CLIO significantly more versatile, having a wider range of measurement capability and sacrificing nothing in terms of measurement accuracy. I also find it significantly easier to use for those functions the two have in common. It is, of course, also lower in price.

Ranking the various systems in terms of usability, versatility, accuracy, and cost, I would put CLIO first because of versatility and cost; Liberty AudioSuite a qualified second because of its low cost; MLSSA a close third because of its very high cost and unfriendly user interface; and LMS after them all because of its lack of flexibility and a less-than-good user interface.

And, I must repeat, CLIO's LC meter is really neat and a joy to use!

Manufacturer's response:

Dick Pierce's review appears quite positive and deals with several pertinent and very well-supported criticisms. Mr. Pierce, in fact, seems to have quickly understood CLIOLite in detail. It is difficult to comment, therefore, if we avoid dealing with the positive aspects of the product.

Starting with the user's manual, we perfectly understand the complaints, and we often face the same painful frustration in using Acrobat and printing lengthy documents as data sheets. We wish to add that CLIOLite runs perfectly as an MS-DOS application under Windows95, thus permitting you to swap back and forth online between the program and the manual. This allows you to start working almost immediately using only one computer. Nevertheless, the reviewer is correct in saying that sooner or later, the manual must be printed and that Windows is required.

Finally, we are committed to enhance the software and to keep the manual constantly updated, which can be done at a reasonable cost only in the online form. Users should also know that they can find further help in our Website, and we offer direct support via E-mail.

Regarding T/S parameter measurement, Mr. Pierce noted the lack of a confirmation prompt between the first and the second impedance test. We can only say that it happens every time to us, too, and, whoops, CLIOLite starts measuring again! For "diameter," the emissive diameter is intended. The manual covers this very sensitive and critical parameter, and we tried to force the user into a deeper understanding of it. Mr. Pierce's suggested method for deriving it is valid, but must be considered one among others that have been proposed in the literature.

Referring to the whole sinusoidal menu, the reviewer states that "occasionally the system stopped and repeated a measurement here and there"; this has created panic in many users, but not to the reviewer, who was interested mainly in the final result. There is a simple reason for this behavior: CLIOLite autoranges input gain for achieving the best dynamic range.

Overall, we accept and agree with Mr. Pierce's criticism about the directory structure of CLIOLite.

Mauro Bigi and Maurizio Jacchia,
Audiomatica s.r.l.

Driver Report

SCAN-SPEAK'S 18W/8546

By Vance Dickason

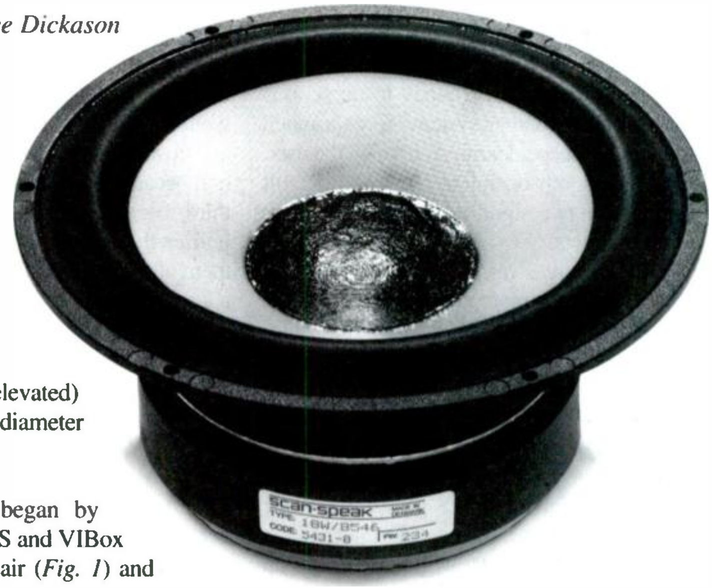


PHOTO 1: Scan-Speak's Model 18W/8546 Kevlar mid/woofer.

This Driver Report focuses on the 18W/8546 (*Photo 1*), a Kevlar® cone high-end woofer from European manufacturer Scan-Speak. The 18W/8546 is a fairly recent release for the company.

Features: This 7″ mid/woofer is based on the patented high-linearity SD-1 motor system (a proprietary extended-pole configuration). Features include a cast frame, woven coated Kevlar® cone, patented rubber low-resonance surround, inverted dustcap, 4″-diameter cupped (elevated) spider, and 42mm-diameter voice coil.

TABLE 1

T/S PARAMETER SET FOR THE 18W/8546

	SAMPLE A	SAMPLE B	FACTORY (PRELIMINARY)
f_s	24.5Hz	24.6Hz	2.50Hz
R_{EVC}	5.55	5.50	5.5
Q_{MS}	2.04	1.86	2.91
Q_{ES}	0.32	0.31	0.23
Q_{TS}	0.28	0.27	0.21
V_{AS}	59.4 ltr	57.0 ltr	70 ltr
Sens.	87.7dB	87.5dB	89.8dB
X_{MAX}	6.5mm	6.5mm	6.5mm

Measurements: I began by using LinearX's LMS and VIBox to measure the free-air (*Fig. 1*) and test box delta compliance impedance curves. I accomplished this by producing separate 1V and current curves and then dividing the two curves to produce impedance plots. I imported data from LMS into LEAP and produced the parameter set shown in *Table 1*.

Although my Q_{TS} data was higher than the factory preliminary data, it was still close enough to consider the measurements valid, so I proceeded to do both sealed- and vented-box computer simulations. Volume for the sealed box was 0.3ft^3 with 50% fiberglass fill material, and the volume of the vented enclosure was 0.48ft^3 tuned to 36Hz. Response curves are shown for 2.83V and 18V in *Fig. 2*, with the 2.83V group-delay curves provided in *Fig. 3*.

The 18V excursion curves in *Fig. 4* represent the maximum linear output of the driver with the maximum excursion equal to approximately X_{MAX} + 15%, about 7.5mm for this driver. The f_3 for the sealed box was at 60Hz with a –3dB phase angle of 93°, making the box Q_{TC} roughly 0.75. The vented box had an f_3 of 48.9Hz. Both box simulations had a midband output of about 102dB at 18V. With an f_3 = 60Hz in a compact sealed box, this would likely be my choice for a box design for this woofer.

Mounting the Scan-Speak 18W/8546 in a small enclosure with a 15″ × 8″ baffle yielded the on- and off-axis response curves depicted in *Fig. 5*. The response of the 18W/8546 is quite smooth and the peaking at 4kHz is well damped for a Kevlar-type cone. 3dB down at 30° off-axis (relative to the on-

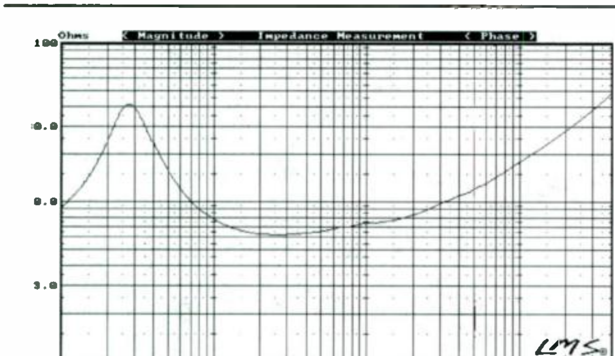


FIGURE 1: Scan-Speak 18W/8546 impedance plot.

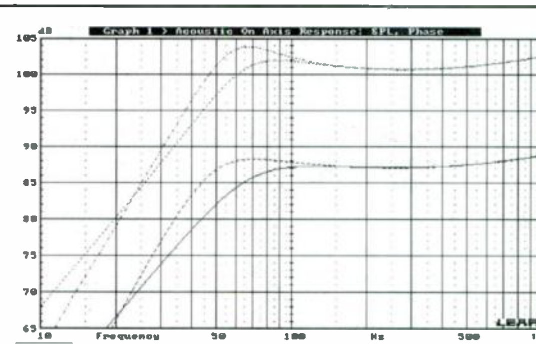


FIGURE 2: 18W/8546 sealed- and vented-box response simulation at 2.83V and 18V (solid = 2.83V sealed, dot = 2.83V vented, dash = 18V sealed, dash/dot = 18V vented).

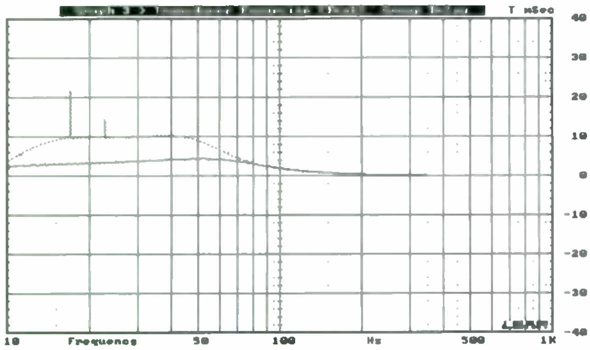


FIGURE 3: Group-delay curves for *Fig. 2.*

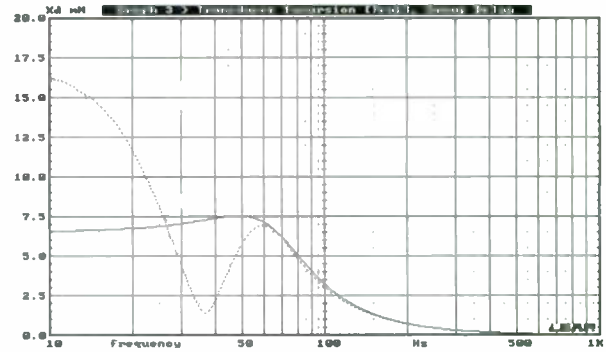


FIGURE 4: 18V cone-excursion curves for *Fig. 2.*

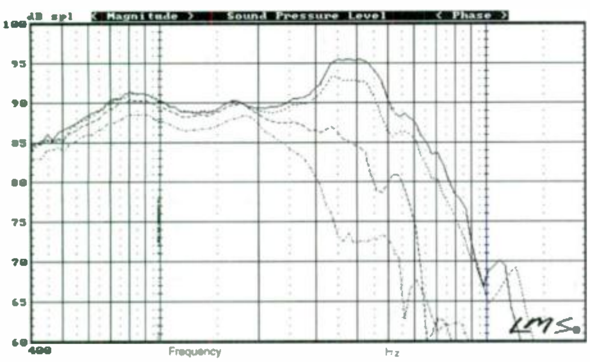


FIGURE 5: On- and off-axis frequency-response curves (solid = 0°, dot = 15°, dash = 30°, dash/dot = 45°).

FIGURE 6: 18W/8546 two-sample SPL comparison.

axis curve) occurred about 2.5kHz, indicating that a 2–2.5Hz crosspoint would work well with this driver.

Figure 6 is the two-sample SPL comparison for the Scan-Speak woofer, showing the drivers to be well matched, although the area between 2–3kHz is about 1.5dB off. I would not consider this particularly significant for a company with such a good reputation for fine quality and consistency.

The 18W/8546 driver is available for consumer purchase from Madisound Speaker Components (8608 University Green, PO Box 44283, Madison, WI 53744, 608-831-3433, FAX 608-831-3771, E-mail madisound@itis.com, Website www.itis.com/madisound), Meniscus Audio Group (4669 S. Division Ave., Wyoming, MI 49548, 616-534-9121, FAX 606-534-7676, E-mail meniscus@iserv.net, Website www.iserv.net), and SpeakerCity U.S.A. (115 S. Victory Blvd., Burbank, CA 91502, 818-846-9921, FAX 818-846-1009, Website www.speakercity.com.

REMINISCING

Speaker Builder's reprint of the Karlson ("The Karlson Speaker Enclosure," *SB* 7/97) triggered my memory. During the '70s I had access to an anechoic chamber with good test facilities. I used these to conduct over 1,000 tests (mostly on professional sound equipment, but also on some home-type items). One of these was a Karlson enclosure.

This unit was scaled down by 20% for a 12″ speaker, but I cannot vouch for its accuracy. It was home-built and a bit rough, but I decided it would provide a reasonable indication of the design's characteristics. I installed an available driver, which was an extended-range professional unit. For comparison, I ran the same driver in a ported enclosure, whose characteristics I do not remember. The results are shown in *Fig. 1*.

The Karlson certainly imposed its own characteristics. Whether or not these are desirable is a matter of interpretation. The most striking response feature in the enclosure was the deep nulls at 350Hz and 700Hz, which may be explained in terms of the cavity's dimensions in front of the driver. The slot configuration clearly affects the high-frequency characteristics, while the enclosure size probably accounts for the low-frequency performance.

I still run occasional loudspeaker tests (usually outdoors), but my primary activity is measuring and optimizing the performance of sound-reinforcement systems. I have designed and built a few loudspeaker systems, and, with the help of *Speaker Builder*, I intend to build more.

G.R. (Bob) Thurmond
Austin, TX

CLUB SPEAKER

Loudspeaker design engineers who know their way around a calculator (computer) but have never used their own product behind a mixing board in a "club" setting (500–1,000 capacity) should do so before foisting another sloppy 15″ low-mid speaker or distorted high-comp driver/horn on the public, and should stop using the same old compromises.

Being a live-sound engineer for 20 years has given me some insight into what sounds natural and what works in applications. In my patent-pending design (*Fig. 2*), I "fix" the breakup in a 10″ speaker, so that it can be used up to 5–6kHz for high mids, and mount it in a small horn. A tweeter (bullet, slot, dome, ribbon!) covers the remaining frequencies from 5–6kHz up to 20kHz+, and is mounted on the high mid-horn phase plug.

The high-mid/tweeter assembly is then mounted in the throat of the low-mid horn, in a coaxial arrangement. The low-mid horn is loaded with two additional ten inches and crosses to the subs at 80Hz. The horns cross to each other at 600Hz—one practically inaudible crossover, in the range of the human voice, between equally transient speakers.

The 80 and 600Hz crossovers are more useful in applications (stage noise frequency response is basically between 80–600Hz; the amount of "reinforcement" in this range can be controlled from the crossover at the FOH [front of house]). Since the system is coaxial, the respective speaker components can be delayed against themselves to move in-phase response zones—centered at crossovers that are themselves able to be adjusted up or down—about a room. In addition, the cabinets can be flown sideways, as in-line array, and will couple up to 10kHz.

Weighing in at only 125 lbs, these loudspeakers are extremely versatile, are excellent in reproducing sounds from the delicate to the demonic, and add a 3-D muscularity to the sound that is human.

Charles Hanson
New York, NY

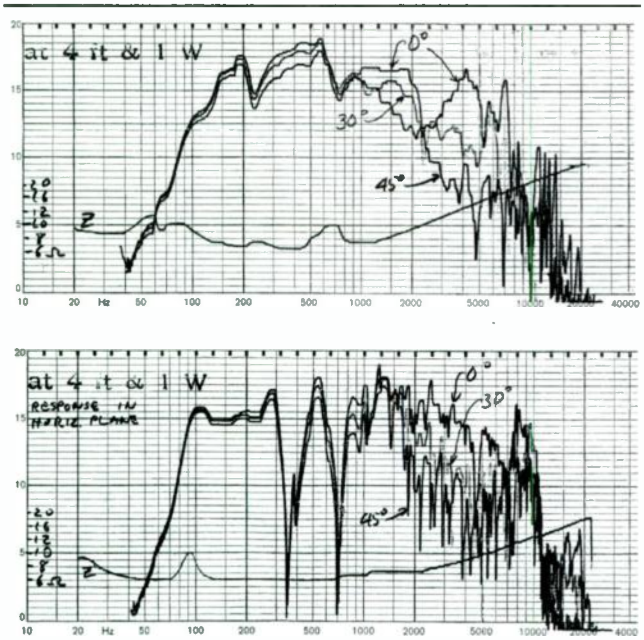


FIGURE 1: Altec 412C responses in STD box (top) and in Karlson enclosure (bottom).

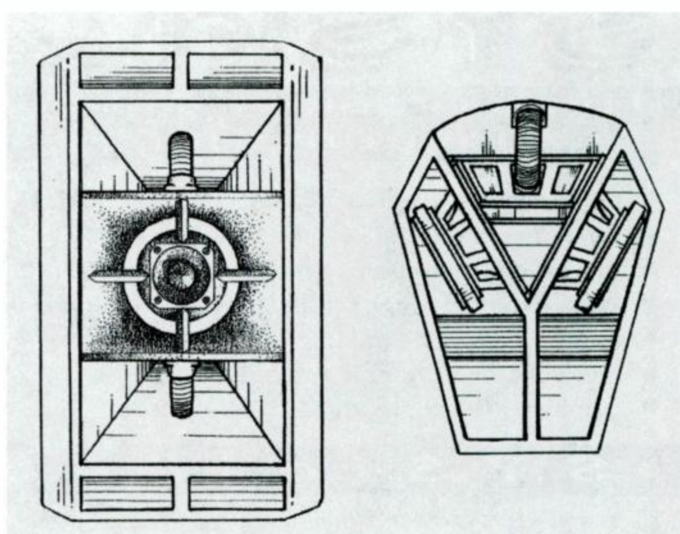


FIGURE 2: You can see and hear this patent-pending design at the Elbow Room, 144 Bleeker St., New York City.

HORNS RULE

I wish to congratulate Bill Fitzmaurice on his fine article, "The Snail Horn" (*SB* 6/97).

My partner and I are horn enthusiasts, and we are happy to find someone who shares many of our views concerning the design and operation of horn-type speaker enclosures. We do not accept the generally held theories and assumptions concerning horn design and operation, but have built some very successful horns featuring considerably smaller mouths and larger throats than conventional wisdom would suggest.

Also, we do not place our drivers in a sealed chamber. In fact, in the most successful horns we have built, there is no rear chamber as such. We mount the driver at the top of the horn, which acts as a direct radiator in front, and load the rear of the driver into a smooth, 180° folded exponential horn.

The throat is approximately equal to the square of the nominal cut-out diameter of the driver. For a 12″ driver, this would be equal to approximately $(11 \text{ in})^2$, or 121 in^2. The mouth may be only three times the area of the throat. The maximum inside length of the horn from the top of the driver to the bottom of the mouth is approximately 75″.

The sides of our horns are at an angle with respect to each other in a trapezoidal arrangement. The rear of the horn is continuously curved 180° from the top of the driver to the bottom of the mouth. We make the curved rear of the horn by laminating thin pieces of plywood together—normally three thicknesses of 1/8″ plywood.

There is a cavity built into the front of the horn to maintain the smooth exponential expansion of the horn's cross-section from the throat to the mouth. This is also a convenient place to locate the tweeter. However, in future models we plan to put the tweeter above the 12″ driver, at approximately 40″ above the floor.

We do not like to use flat planes or abrupt angles, because they are not used in brass instruments. The sides of our horns are flat, but not parallel; the rear is a smoothly curved panel that, in conjunction with the flat, angled sides, forms a true exponential horn, in which the interior cross-section expands smoothly in an exponential manner from the top of the driver to the bottom of the mouth.

We always use MI (musical instrument) types of drivers, which have a wide frequency response (up to 6kHz), a Q_{TS} of 70, and an f_s of 50–60Hz. The bass is not as strong as we like, but when used with a suitable subwoofer, is not a problem. The midrange and high frequencies are excellent. We have found that rubber or foam surrounds do not work well in our horns because they tend to sound "mushy."

We do not use conventional formulas in designing our horns, which are truly exponential, and are the result of years of experimental designs. People like what they hear from our horns, and some have placed orders for $2,995 a pair. Our horns do not require a corner placement, although any speaker will sound better when placed in a corner—even ours!

Bill Fitzmaurice mentioned that he was using the EVM-12L driver, which we have also considered using, but have not as yet. We have used an Eminence, a Pyle, and a Celestion, as well as the EV-DH3 tweeter driver and an HPT-94 constant-directivity horn, which work well.

Our horns achieve a maximum sensitivity of 106–107dB/1W/1m. We use a pocket-model AM/FM receiver, with the headphone output driving them to over 90dB with program material. That gets people's attention!

For banquets or parties, we use a MacIntosh 2300 amp, which will deliver over 300W/channel and has a range switch with 0dB, −10dB, and −20dB steps. On the −20dB step, +3dB equals 3W; on the −10dB scale, +3dB equals 30W. For banquets, we usually operate on the −10dB scale and between −7 and −5dB, respectively, for an equivalent output of 3–4.7W when playing in auditoriums accommodating approximately 350 people. We have never measured the maximum output at 1m, since our SLM reads up to only 126dB.

See why we are horn nuts, too?

Louis McClure
Van Buren, AR

Bill Fitzmaurice responds:

I am pleased to hear of your work with horns and your appreciation for mine. Your "chamberless" design is intriguing. It actually is a variation of an old design—the rear wave was fed into a chamber which was then vented by a horn—only you omitted the chamber. Your woofer is then loaded by a horn on the back wave and free air on the front, which is why it works best with high-Q MI drivers and not so well with lower-Q hi-fi drivers.

With the front wave direct-coupled, you achieve a good midrange response, although at the expense of deep bass. If you enclose the driver with a ducted box tuned to the driver f_s and direct the port output into the horn à la the Snail, you'll get better bass, but then the midrange will suffer. There are always tradeoffs.

The question of the "corrected" throat opening, horn length, and rough opening remains unanswered; the computer has not yet supplanted the table saw as the primary tool of horn design. My Snail II and Snail III cabinets have proven that my hypotheses first postulated in the Snail article are on the right track. Horns do not need to be exceedingly long, nor mouths extremely large, and rear chambers—if you use a rear chamber at all—should not be sealed.

The speaker industry has long ignored the horn, favoring ducted boxes because of their simplicity. If the work begun on horns in the 1930s and '40s had not ceased due to the availability of high-power amplification, perhaps the horn cabinet would have evolved to resemble our designs. Now that it appears the ducted-box has been taken to its limits, perhaps the horn will be resurrected. [Especially with the SE-amp aficionados' needs for higher-efficiency systems.—Ed.]

I have one problem with your designs, however. Why have you not sent them to SB for publication? Any cabinet worth $1,500 is worth sharing with the rest of us. If enough of us horn aficionados publish our designs, maybe the rest of the world will wake up to what we already know—horns rule!

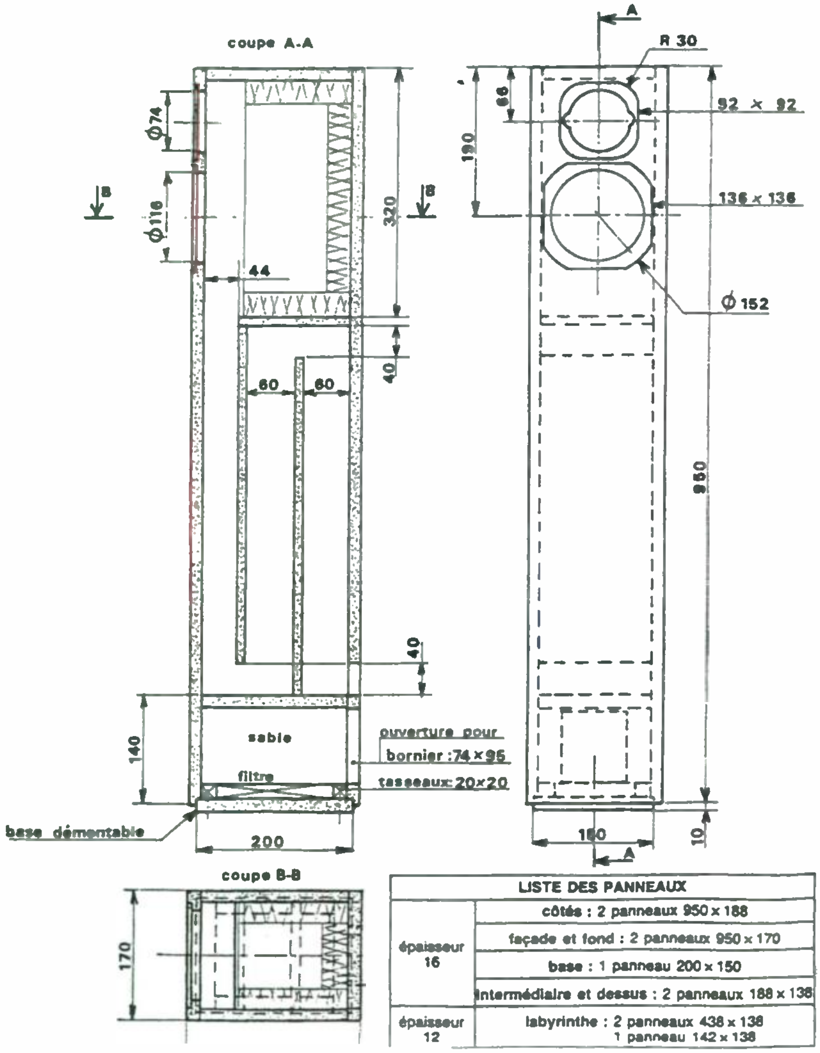
DALINE DESIGN

I read "Doing the Daline" in *SB* 8/97 with great interest; I am thinking about making one for myself. Unfortunately, the author failed to include a copy of the cabinet design. I am interested in knowing the "reinforced" design with panels thicker than the original thinner panels from JM Lab.

Bing Yang
bingyang@pop.wt.net

Jeffrey Viola responds:

*Unfortunately, my drawing of the "improved cabinet" was lost. However, I include the manufacturer's drawing (*Fig. 3*). As my article indicated, this and other plans are available from Orca Design & Manufacturing Corp. (1531 Lookout Dr., Agoura, CA 91301, 818-707-1629, FAX 818-991-3072) and possibly Zalytron (469 Jericho Tpke., Mineola, NY 11501, 516-747-3515, FAX 516-294-1943).*



LISTE DES PANNEAUX	
épaisseur 16	côtés : 2 panneaux 950 x 188
	façade et fond : 2 panneaux 950 x 170
	base : 1 panneau 200 x 150
	intermédiaire et dessus : 2 panneaux 188 x 136
épaisseur 12	labyrinthe : 2 panneaux 438 x 138 1 panneau 142 x 138

FIGURE 3: Daline cabinet design.

ISOBARIK DRIVER MOUNTS

I am confused by the speaker connection in two Isobarik speaker projects: "The Wonder of a Symmetrical Isobarik" (*SB* 5/90, p. 10), by B. Schwefel, and "Isobarik Tower" (*SB* 5/97, p. 10), by P.L. Kittinger. The drivers are mounted back-to-back in both projects but are connected in-phase in the first article and out-of-phase in the second.

T.S. Lo
Auckland, New Zealand

Paul Kittinger responds:

It is interesting that you cited the article in SB *5/90 when asking about driver wiring for that article and mine in* SB *5/97. When I was designing my speaker systems, I acquired several* SB *back issues containing articles about using an Isobarik configuration. One of these was issue 5/90.*

Although it may not be clear in Mr. Schwefel's article, I believe his drivers are mounted back-to-front (all four drivers have their cones facing forward, with the rear drivers mounted from the back of the enclosure before attaching the rear, crossover panel). Thus, his drivers had to be wired in phase (with the drivers in each pair wired in series with each other, then both pairs wired in parallel across the crossover output).

Because my drivers are mounted back-to-back, they had to be wired out of phase. I'm sure you can understand why these different wiring phases are necessary. If either configuration is wired incorrectly, the cones of the paired drivers would be working against each other, mostly canceling out any sound output.

Thanks for inquiring about my speaker design. It's very satisfying to know someone is interested in my work. If you build my design, I'm sure you will be pleased with the performance (if you make some improvements, I'd like to hear about your results).

to page 58

Classifieds

VENDORS

AD INDEX

ELECTROSTATIC electronics, transformers, Mylar®, information. From author ***ROGER SANDERS***, (404) 696-1998.

WE RECONE all home, auto, pro, and vintage speakers. ***TRI-STATE LOUDSPEAKER***, www.nauticom.net/www/speakers, (724) 375-9203.

FOR SALE

Audiophile Collector's Estate Sale

Some items are new (N). Others are like new (M). Most in original cartons and packing.

NAD517 five-disc CD player	N	$350
Two Adcom GFA-565 power amplifiers (with fans)	N	$1200 (pair)
Rotel 865BX CD player	M	$320
Marantz 7T preamp		$500
db Systems DBR 15B/2A in walnut cabinets	M	$700
Adcom GFP-565 preamp	N	$550
NEC T710BU tuner	M	$160
Marantz 15 amplifier		$500
Adcom GFP-555II preamp	M	$350
NAD 1020 preamp		$75
Adcom GFA-555II amplifier	M	$550
Adcom GTP-50II preamp/tuner	M	$350
Variance Hi-Fi (Germany) FM tuner/headphones	N	$60

William, 603-642-4338 (Lv. message on machine if necessary), up till 10:30PM EST; P.O. Box 666, Danville, NH 03819.

Nakamichi 670 black rackmount cassette deck, top quality; single Altec 515E 15″ woofer; pair 418B 15″ woofers; pairs Altec horn drivers: 802D, 902, 806, 291; pairs JBL drivers: 175, 2470, 375; pair JBL 1200Hz crossovers; pair Altec 800Hz crossovers; pairs Altec horns: 511, 811. (914) 688-5024.

Pair Raven R2 ribbon tweeters, $280 each; pair of Focal Audiom 7K midranges, $110 each; pair Morel MHT-36 double-magnet cloth dome horn tweeters, $47 each. All drivers hardly used. Contact John, (617) 623-2219.

Bozak (2×) 8″ and (2×) 6″ mids, and (12×) 2″ Z-3 tweeters; (4×) ¾″ Dynaudio 21AF tweeters; (4×) JVC HSW1011-01A ribbon tweeters; (4×) 1″ Philips tweeters; (1×) 1″ Dynaudio 28AF tweeter. All in very good condition. Bob, (310) 676-4629.

WANTED

Altec horn speakers, woofers, horns, crossovers, 515, 515B, 515C. Horns: 805, 1005, 1505A/B, 311-90, 329, 604, 605, 288B/C, 288-16 G/H. Larger corner speakers and console speakers, Laguna, Paragon; Western Electric horns, woofers, drivers, parts; Tannoy dual concentric, Goodman, E-V Patrician. Sonny, (405) 737-3312, FAX (405) 737-3355.

Speaker Builder sets 1982 through 1987, part or complete. Hans, PO Box 4636, Mt. View, CA 94040, (650) 961-3390, FAX (650) 938-2250.

CLASSIFIED

To place your own classified ad, turn to page 60.

INFORMATION

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 Int'l	*Hi-End Drivers*	1-905-889-9296
Antique Electronic Supply	*Tubes, Transformers, Books, More!*	1-602-820-4643
Burnett Associates LLC	*Sub & Power Amps, Aluminum Cones*	1-603-924-3392
Gasoline Alley LLC	*Acoustasheet*	1-785-827-9337
Goertz	*Inductors*	1-203-384-0586
Harris Technologies Inc.	*BassBox and X*over*	1-616-641-5738
Hovland Company	*MusiCap Film & Foil Capacitor*	1-209-966-4632
Kimber Kable	*Speaker Cables, Interconnects, Etc.*	1-801-627-6980
LinearX Systems Inc.	*LEAP*	1-503-612-9344
Markertek Video Supply	*Unique & Hard-To-Find Accessories*	1-914-246-1757
MCM Electronics	*Speakers, Woofers, & Speaker Boxes*	1-937-434-6959
Morel Acoustics USA	*Loudspeaker Drivers, Car Speakers*	1-617-277-2415
Mouser Electronics	*Free Electronic Components Catalog*	1-817-483-6803
Newform Research Inc.	*5″, 8″, 15″ & 30″ Ribbon Kits*	1-705-835-0081
Solo Electronics	*CFAC Inductor*	1-510-887-1657
RCM Akustik	*Sub & Power Amps, Aluminum Cones*	1-603-924-3392

Don't Delay, Fax Today!

from page 55

DELAY DILEMMAS

I have been an amateur speaker designer for over 30 years. For the last 10–15 years I designed speaker systems using active crossovers, which is why Dick Crawford's article ("The Phase Redeemer," *SB* 5/97) greatly interested me.

I have always wondered about time-delay (phase) distortions in speaker systems. As I know from the literature and personal experience, we face time-delay distortions caused by three major factors: the nature of the driver mechanism; the passive or active crossover network; and, the placement of the drivers.

In many cases such time delays produce audible distortions that affect the overall quality of the speaker system. We are not in a position to address problems caused by the drivers, because only driver manufacturers can remedy such imperfections.

The second kind of distortion occurs when a crossover is not symmetrical; for example, when a crossover-frequency band has a different filter order. In symmetrical crossovers, group delay at crossover frequency is equal for high- and low-frequency drivers.

You can handle the third type of distortion by offsetting drivers so that all voice coils are in the same plane. When this is not possible, you need to implement time-delay circuits (all-pass filters) to solve the problem.

Most audible phase distortions occur at crossover frequencies when two sound waves are generated by adjacent drivers. Out-of-phase arrival of two signals causes dips up to 6dB in the frequency-response curve. Part of this problem may be solved by using active or passive (lattice) all-pass time-delay filters, which, when used in passive crossovers, are very expensive to build and inefficient. In active crossovers, you can build all-pass filters using cheap components, and the results are more obvious. This type of time-correction circuit is widely used by manufacturers of professional audio equipment.

I understand that Mr. Crawford's article addresses this third type. Using FilterCAD software, I emulated filters similar to those he used in his project. The results are shown in *Figs. 4–8*. Delays of the all-pass filters are different for each because of different center frequencies used, but all add time delays into both low- and high-frequency bands. This leads me to a couple of questions:

First, why did Mr. Crawford place all-pass filters before the crossover and not just into the HF section? From his description, I understand he wished to delay HF signals.

Also, why did he use different center frequencies for each stage of the delay line?

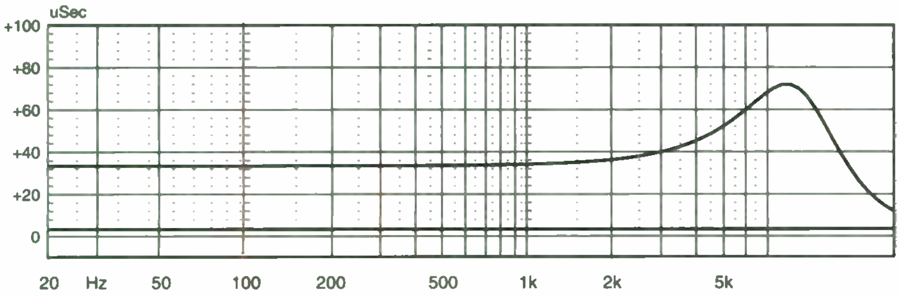


FIGURE 4: Group delay of all-pass filter IC1B.

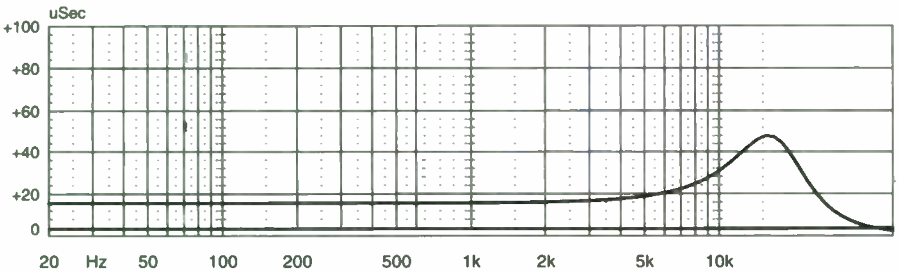


FIGURE 5: Group delay of all-pass filter IC2B.

You can build a delay line using all-pass filters with a center frequency of 30kHz, and each filter of this type will add 16ms of delay (*Fig. 8*). This filter will equally affect all frequencies from 20kHz down. If you use a filter with 20kHz center frequency, then the added delay will be 32ms in each stage for most of the spectrum, with a drop to 16mS at 20kHz (*Fig. 9*).

Alex Martinov
Concord, CA

Dick Crawford responds:

My article dealt with the delay distortions caused by the crossover network, which is the second group in your list. I discussed the delay distortion created by a symmetrical crossover, namely, the 12dB/octave Linkwitz-Riley (L-R). The point here is that even symmetrical crossovers have delay distortion.

Perhaps I should explain that it is true that symmetrical crossovers may have the same

to page 62

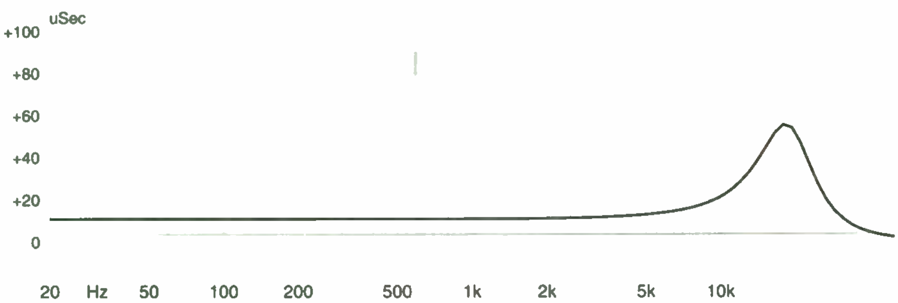


FIGURE 6: Group delay of all-pass filter IC3A.

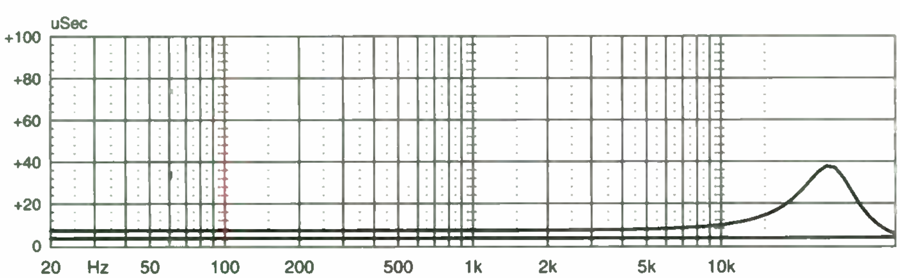


FIGURE 7: Group delay of all-pass filter IC3B.

SPEAKER BUILDER
CLASSIFIED INFORMATION

Three Classified Advertising Categories are available in *Speaker Builder*

VENDORS: For any business or professional private party selling equipment, supplies or services for profit.

FOR SALE: For readers to sell personal equipment or supplies.

WANTED: Help readers find equipment or services.

HOW TO ORDER AN AD

REGULAR CLASSIFIED (ads without borders):
$1.50 per word. $10.00 minimum.
Deduct 5% for a 6X contract.

CLASSIFIED DISPLAY (all ads with borders):
1" $65.00, 2" $115.00, 3" $150.00
Deduct 5% for an 8x contract

PAYMENT MUST BE ENCLOSED with your ad and mailed to *Speaker Builder* c/o, AAC Classified Dept., PO Box 576, 305 Union Street, Peterborough, NH 03458-0576. Ads can also be submitted by FAX (603) 924-9467 or by E-mail, audiodiy@top.monad.net. (*faxed and E-mailed ads must include MC, Visa, Discover or AmEx payment*).

SUBMITTING COPY: A word is any collection of letters or numbers with a space (*a slash (/) is counted as a space*) on either side. All hand written ads must be block printed on the form below. Please circle or underline all words to appear in bold. Illegible ads will be discarded. Submit copy by mail, fax, E-mail or on disc (QuarkXPress, Wordperfect, Microsoft Word 2.0 or 6.0, Word for DOS, Windows Write, or Word Star). If submitting by disc, include a list of fonts and graphics used and a printout of your ad.

SUBSCRIBERS! Subscribers are invited to run a word classified ad of up to a maximum of 50 words in the FOR SALE or WANTED sections for only a $10.00 flat processing fee (*per ad, per magazine*). Ads that exceed 50 words will be charged the regular rate of $1.00 for each additional word. All ads are run only once, and then discarded. Simply complete the Classified Order Form and include your subscriber number in the space provided.

CLASSIFIED ORDER FORM

Please check what type of ad you will be running.

☐ VENDORS ☐ FOR SALE ☐ WANTED

Advertisers are required to use this convenient form when hand printing your ad. Use block letters. No abbreviations.

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

Please charge to my: ☐ DISCOVER ☐ MASTERCARD ☐ VISA ☐ AMEX

CARD NUMBER EXP. DATE

☐ Check/Money Order Enclosed

Subscription Account Number: A ☐☐☐☐☐☐☐

NAME

COMPANY

STREET & NO.

CITY STATE ZIP

PHONE

AAC Classified Dept., PO Box 576, 305 Union Street, Peterborough, NH 03458-0576
FAX 603-924-9467

ALL ADS SUBJECT TO RUN AT DISCRETION OF PUBLISHER / AD DIRECTOR

SHOCKWAVE

ELECTROSTATIC SUBWOOFER

Let's face it, some of you are hard-core bass addicts. You're not happy unless the walls are shaking and the neighbors are complaining!

I don't care how much you paid for your subwoofer, it will never come close to the electrostatic bass produced by SHOCKWAVE. It makes ALL subwoofers sound like boomy mush. No matter what type of system you own — conventional box speakers, horns, electrostatics (ESLs), planar magnetics, or dipoles of any type, SHOCKWAVE is the ultimate solution to attaining extremely deep and detailed bass.

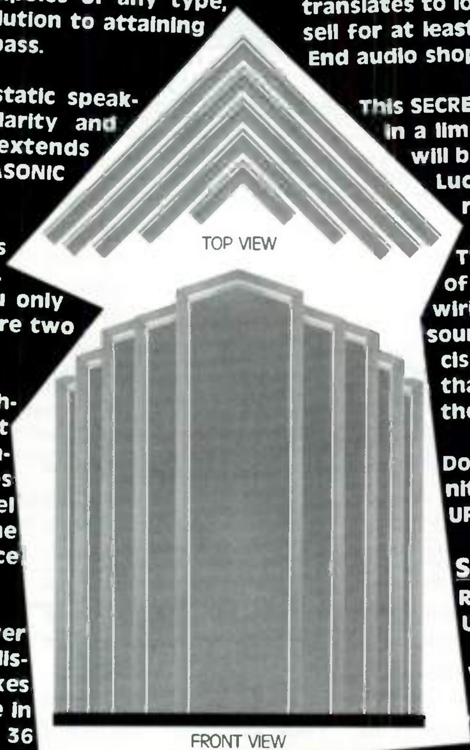
Everyone recognizes electrostatic speakers for their unparalleled clarity and accuracy and SHOCKWAVE extends these attributes to the INFRASONIC (10. Hz).

This milestone product mates with, and vastly improves, ALL types of loudspeakers and you only need one unit, even if you desire two channel bass.

SHOCKWAVE uses the latest technology to produce articulate but EAR-SHATTERING bass. Phase cancellation (anti-noise) principles plus compound or parallel diaphragms, give SHOCKWAVE the equivalent electrostatic surface area of over 108 square feet!

Truly EXPLOSIVE acoustical power that exceeds 120. db at your listening position. And it only takes up 1.5 square feet of floor space in a "V" shape. The height is just 36 inches and it may be placed in ANY corner, behind one speaker, or at the center of your two speakers.

But the best part is that it connects into your system without the need of conventional active or passive crossovers (set your crossover point with a simple resistor from Radio Shack). AND YOU DON'T NEED A SECOND AMP TO DRIVE IT! Use your current amp for stereo or mono bass. Frequency response is 10. Hz to 500. Hz. Nominal impedance is 8 ohms and it requires only 30. watts to drive it (300. watts max.).



SHOCKWAVE is fast and easy to build and most of the parts can be obtained from your local hardware store. Depending on your system, materials on-hand, exterior trim and grill cloth, SHOCKWAVE will cost between $100. to $500. to build. But most of you will end up spending about $250. And please don't think that its low cost translates to low performance, since this design would sell for at least $5,000.00 to $8,000.00 at your local Hi-End audio shop!

This SECRET OF THE CENTURY will be revealed to you in a limited-edition manual and only 500 copies will be printed and personally signed by David Lucas. A true collectors item in every respect.

This extensive manual covers the theory of operation, step-by-step construction, wiring and circuit diagrams, a parts list, and sources of supply. Plus you also receive a precision hand-made model of SHOCKWAVE so that all construction details are as clear as the thunderous bass it produces.

Don't miss out on this limited time opportunity. YOU REALLY CANNOT AFFORD TO PASS IT UP!

SEND $99. TODAY TO RECEIVE THE RAREST OF AUDIO SECRETS AND ENJOY UNCOMPROMISED BASS THAT HAS NO EQUAL!

We accept any form of check or money order in US dollars. No credit cards or CODs.

FREE SHIPPING AND INSURANCE!

MAKE ALL CHECKS PAYABLE TO: DAVID LUCAS.

ALL ORDERS SHIP THE SAME DAY!

THERE ARE NO SHOCKWAVE BROCHURES. THIS AD IS IT!

Note: You must be at least 18 years old to order. All sales final. Also, we assume you have a general or basic working knowledge of electrostatics, high voltage, and electronics. We assume no responsibility for the use or misuse of our products. If you have any further questions regarding SHOCKWAVE, please write or fax (412-828-0422).

Disclaimer:
We cannot be held responsible for any vibrational damage done to your home or contents.

DAVID LUCAS
924 HULTON ST.
OAKMONT, PA 15139

Twenty Years and More. . .

The 1978 C.E.S. in Chicago was the very first time that Morel Acoustics USA, Inc. presented their product to the public. It became clear, early on, that the loudspeaker industry was in need of high quality speaker drivers. Shortly thereafter we introduced several drivers and established the MDT-28/30 as one of the most popular and highly demanded tweeters on the market.

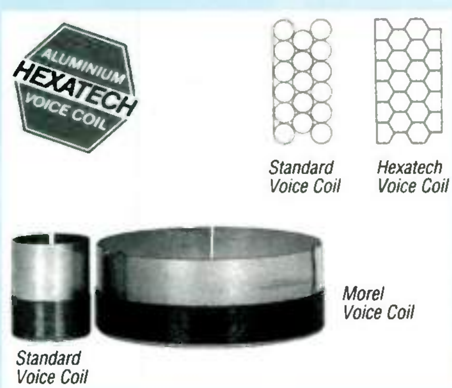
Through the course of the years Morel brought many unique and innovative products to the speaker industry. The introduction of the 3″ voice coil in a 5″ basket, using hexagonal shaped aluminum wire, utilizing a double magnet system and ducted design woofers and mid-basses are a few examples of the company's breakthroughs. Also introduced were the Integra concept (single motor system for both the tweeter and woofer) and the Push-Pull 8″ and 10″ subwoofers (dual motor system, dual voice coils with a single cone).

Integra

Push-Pull

Double Magnet

Morel Acoustics USA, Inc. has come a long way since 1978. Currently, the company has a diverse line of exciting products which includes over 40 models of tweeters, midranges, mid-basses, woofers and subwoofers. Being a leader in the field of speaker design, for our 20th year anniversary we are scheduled to launch several new products that are sure to attract attention.



Typical double magnet ducted woofer.

Double magnet tweeter

For further information please contact:

morel acoustics usa, inc.
414 Harvard Street
Brookline, MA 02146 USA
Tel: ++ 617-277-6663
Fax: ++ 617-277-2415
E-mail: morelusa@gis.net

Reader Service #15