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Good News

WALL OF SOUND

The Brick, River-Rock, Split-Face Cinderblock, and Weathered Stonewalls, are four speaker models from Rockustics. All function as inlays installed into new or existing walls, and with a removable faceplate, are powered by 100W rated, 6.5" Vifa drivers, and a 1" tweeter. Each cabinet is custom designed and constructed with crushed stone and weatherproof, environmentally-safe resins that can withstand harsh elements in all climates, including ultra-violet rays, heat, rain, snow, and wind. All come with a "Zero Defects" lifetime guarantee. Rockustics Inc.®, 15400 E. Batavia Dr., Aurora, CO 80011, (800) 875-1ROK, (303) 363-6161, FAX (303) 363-0011, Website www.rockusticsinc.com.

Reader Service #139

CANADIAN SPEAKERS

Newform Research's R645 loudspeaker is a beefed-up R630 with no loss of refinement. It is taller, more sensitive and dynamic, with greater bass impact, and features the Scan-Speak W15 Revelator 5" midbass. Also from the company is the No Holds Barred (NHB) 45, which is a practical version of the NHB Essential. It features superior drivers (R45 and SS W15), resulting in superior sound quality, and the flexibility of a much lower crossover point, according to the company. Newform Research Inc., PO Box 475, Midland, Ontario, Canada L4R 4L3, (705) 835-9000, FAX (705) 835-0081, E-mail ribbon@newformresearch.com, Website www.newformresearch.com.

Reader Service #135

A HOME-THEATER FIRST

Miller & Kreisel Sound (M&K) became the first speaker manufacturer to deliver a complete THX Select home-theater speaker system, according to the company. The 750THX system is comprised of the LCR-750THX front speakers, Center-750THX center channel, Surround-550THX surround channels, and Sub V-1250THX powered subwoofer. The design incorporates M&K's High-Frequency Prism system, which combines a mesh metal grille with a tweeter mounted at a 4.7° angle to optimize the speaker's imaging and frequency response. The system, which is used on the LCR-750, Center-750, and Surround-550, improves the speaker's off- and on-axis response by shaping a very smooth and extended flat high-frequency response over a wide listening window, which is directed towards the listening position, therefore optimizing imaging. Miller & Kreisel Sound Corp., 10391 Jefferson Blvd., Culver City, CA 90232, (310) 204-2854, FAX (310) 202-8782, Website www.mksound.com.

Reader Service # 138

TRUE SOUND

TRUESOUND has recently released the Dynamic Sound Improvement Processor (DSIP™) for enhanced speaker reproduction. Unlike other sound enhancement systems, DSIP maintains the phase relation of signal frequency while enhancing bass and treble output, according to the company. Also from TRUESOUND are four products: "travel," "travel luxe," "Universal TV," and "Universal audio." The travel products connect to portable audio devices and are adjustable to three DSIP levels. The Universal products include gold-plated connector cables and a UL-approved power adapter plug. SoundScience, Inc., (201) 767-3297, E-mail contact@soundscience.com.

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"PRACTICAL" READING

Practical Acoustics, by Stephen Kamichik, is a two-part study of acoustics, and was designed to help dispel the mysteries of how sound "works." Part 1 contains 11 chapters covering acoustical waves, ultrasonics, microphones, speakers, and more. Part 2 contains eight chapters of projects and problem solutions, as well as a glossary. Topics include speaker enclosures, crossover networks, and surround sound, among others. PROMPT® Publications, (800) 428-7267.

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RAIN OR SHINE

The WP1 weatherproof two-way loudspeaker from B&W includes an extended-response, aluminum-dome tweeter. Mounted via a specially engineered diffraction-free baffle and integrated by a computer-tuned, audiophile-grade crossover, these components ensure smooth, accurate response and wide dispersion, according to B&W, the product's manufacturer. It features a flexibly-adjustable bracket that accommodates horizontal or vertical placement, and incorporates two tapped brass (corrosion-proof) inserts for direct fixing to walls, soffits, or even marine bulkheads. The WP1 cabinet is constructed entirely of corrosion-proof composites with impervious, powder-coated steel grilles, and is available in matte black and (paintable) white finishes. B&W Loudspeakers of America, 54 Concord St., N. Reading, MA 01864-2699, (978) 664-2870, (800) 370-3740, FAX (978) 664-4109.

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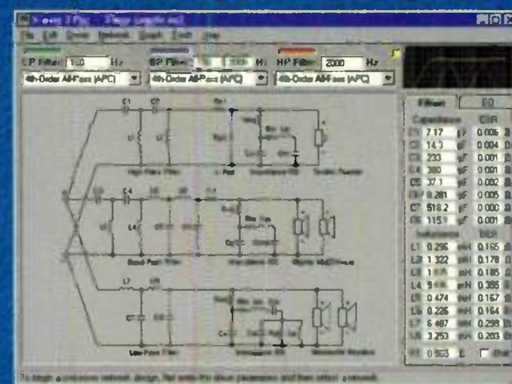

- BassBox Pro helps you quickly design many different types and shapes of speaker boxes. With its Design Wizard, advanced easy-to-use layout and on-line help it is a joy to use. As many as ten designs can be viewed at the same time.
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- Performance can be evaluated with 9 graphs, including 2 amplitude response graphs, max acoustic power, max electric power, cone displacement, vent velocity, impedance, phase & group delay.

- Acoustic data can be imported for drivers and listening spaces. Both automotive and architectural environments are supported.
- The response of a passive network can be entered or imported from X•over Pro and used to display the system response.
- Includes both driver and passive radiator test procedures.
- Create custom printouts with box drawings & parts lists.
- Includes a beautiful, well illustrated 204 page manual. Available on CD-ROM or diskettes.

BassBox Pro: $129.00* *U.S. dollars plus shipping and handling.

Shipping & handling: USA = $7; Canada = $9; All others = $23

- X•over Pro helps you quickly design passive crossover networks, low-pass, band-pass and high-pass filters, impedance equalization networks, notch filters and L-pads. Its straight-forward layout and on-line help make it very easy to use.
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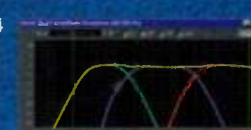

- The equivalent series resistance (ESR) of capacitors and DC resistance (DCR) of inductors can be estimated or entered.
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Reader Service #3

About This Issue

Scott Vonhof leads off this issue with an interesting cabinet design. Take a look at his loudspeakers, which he calls the Maverick 2s, beginning on p. 10. They feature a very small footprint and an open bottom with an isobaric woofer design.

Musicians tend to be a tight-knit group. So, it's not surprising that when a fellow performer needed some speaker help, **Bill Fitzmaurice** came to the rescue with one of his folded horn designs. He calls the result the Mid Ranger (p. 16), which produces good mid- and high-end response.

How many audiophiles have become frustrated trying to plot precise frequency-response values on logarithmic graphs? **Louis C. McClure** shows you an easier way, taking the guesswork out of this process ("Plotting 1/3-Octave Frequency-Response Curves," p. 28).

Who could say no to drivers in search of a home? Certainly not kind-hearted **Philip Abbate**, who quickly set about building a shelter for these orphans. The result is a pair of desktop speakers to accompany your computing adventures ("The Sammy Six Monitor," p. 30).

Fred Janosky shows you how to modify a B&W design for the look and feel of more expensive models, but well within the financial means of audiophiles on a budget ("An Improved Mini-Monitor," p. 36).

Tom Yeago had labored long and hard rebuilding the classic AR-3a (as documented in previous *SB* issues). Now it's time for him to reap the rewards of his efforts, as he turns them over to reviewer **Dennis Colin** for listening tests and to **Joseph D'Appolito** for lab examination. Read the results in "Test Drive," p. 42.

Finally, **Alan Ersen** offers some tips on adjusting the baffle hole for driver mounting ("Tools, Tips, & Techniques," p. 62).

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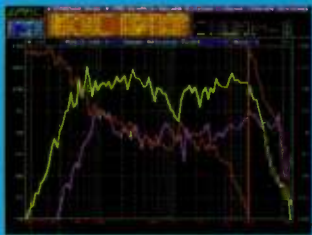
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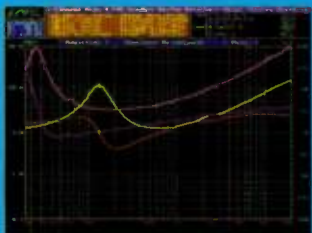
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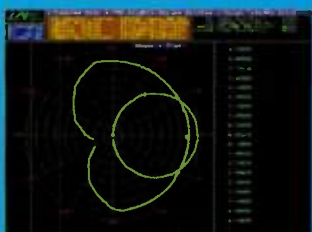
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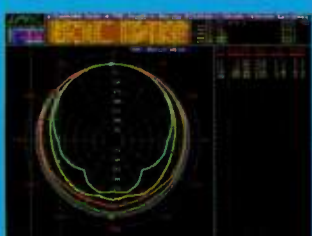
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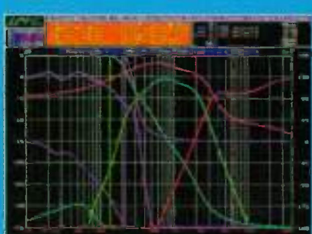
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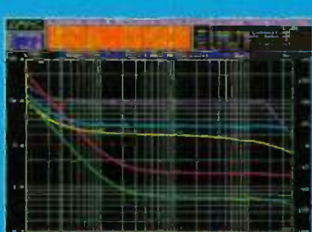
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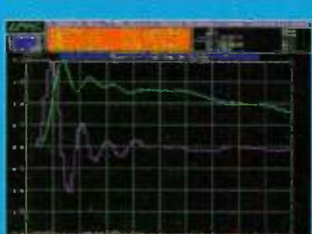
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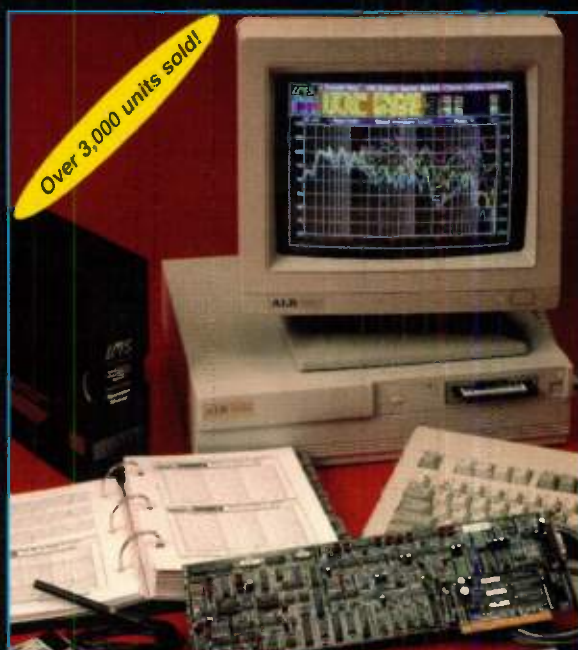

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FEATURES

DEPARTMENTS

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After his first set of speakers fell victim to an attack from his cat, this author devised a special design that uses a very small footprint and an open bottom with an isobaric woofer design.

The Maverick 2

By Scott Vonhof

PHOTO 1: The finished Maverick speaker.

I recently decided that my first speaker project no longer fits the needs of my current lifestyle (not to mention that my cat, Maverick, decided to use the passive radiators as his scratching post, and he ruined one of the midrange surrounds). I desired something with a smaller footprint, since I live in a condo and have a 35″ tube TV that takes up a large portion of the living room. I also realized that my emphasis was now on home theater more than stereo sound, so I wished to be able to match timbre across the room. This is not your usual speaker with six walls and three holes on the front face. It has a semi-open bottom, which is used for the mounting of the woofers (*Photo 1*).

It all started about six years ago. I was into car audio and wished to improve the sound in my home stereo. I conceived the novel idea of combining a sealed woofer system with a passive radiator. I had heard the arguments for and against sealed and ported speaker systems and desired to achieve the best of both worlds in one package. I decided to use 8″ Peerless drivers (831709) for the bass, and I didn't care as much about the rest of the sound, so I just bought whatever the sales guy recommended.

ABOUT THE AUTHOR

Scott Vonhof has a degree in electro-mechanical design, and has been interested in speaker design for about ten years. He makes his designs using Pro-Engineer software, a solids-modeling package that enables him to run interference checks. He does all his own woodworking, and finds speaker building a very enjoyable hobby.

TABLE 1
MATERIALS LIST (PER PAIR)

1″ × 12″ clear oak	(¾″ × 11¾″ finished)
2×	42″ × 10¾″ (grain lengthwise)
2×	11¾″ × 10¾″ (grain lengthwise)
4′ × 8′ sheet, ¾″ oak plywood	
2×	41¼″ × 9¼″ (rear)
4×	41¼″ × 11¾″ (side)
4′ × 8′ sheet, ¾″ MDF	
4×	21¾″ × 11″ (wall stiffener)
4×	13¼″ × 9¼″ (midrange backing and midrange/tweeter sub-cabinet rear)
4×	11″ × 8¼″ (shelf braces)
8×	11″ × 9¼″ (woofer separator, woofer mounting panel, top woofer sub-cabinet)
1″ × 4″ clear oak	¾″ × 3¾″ (finished)
4×	14″ × 3¾″ (side trim)
4×	12″ × 3¾″ (front and back trim)

CABINET CONSTRUCTION

For the unit to be aesthetically pleasing, I wished to match the wood colors with some of the other furnishings in the room. I decided to use oak plywood for the cabinet and solid oak ¼″ round moldings for the edges. In retrospect, if I were to make these again, I would use solid oak for the front and top panels and round the edges with a ¾″ round-over bit for the edges just prior to sanding and finishing. In doing so, I wouldn't need to worry about the round over extending down into the base and making a strange-looking joint that I would need to fill or fix in some other way.

Table 1 is the materials list for the

PHOTO 2: The subwoofer portion of the cabinet before addition of the finished walls.

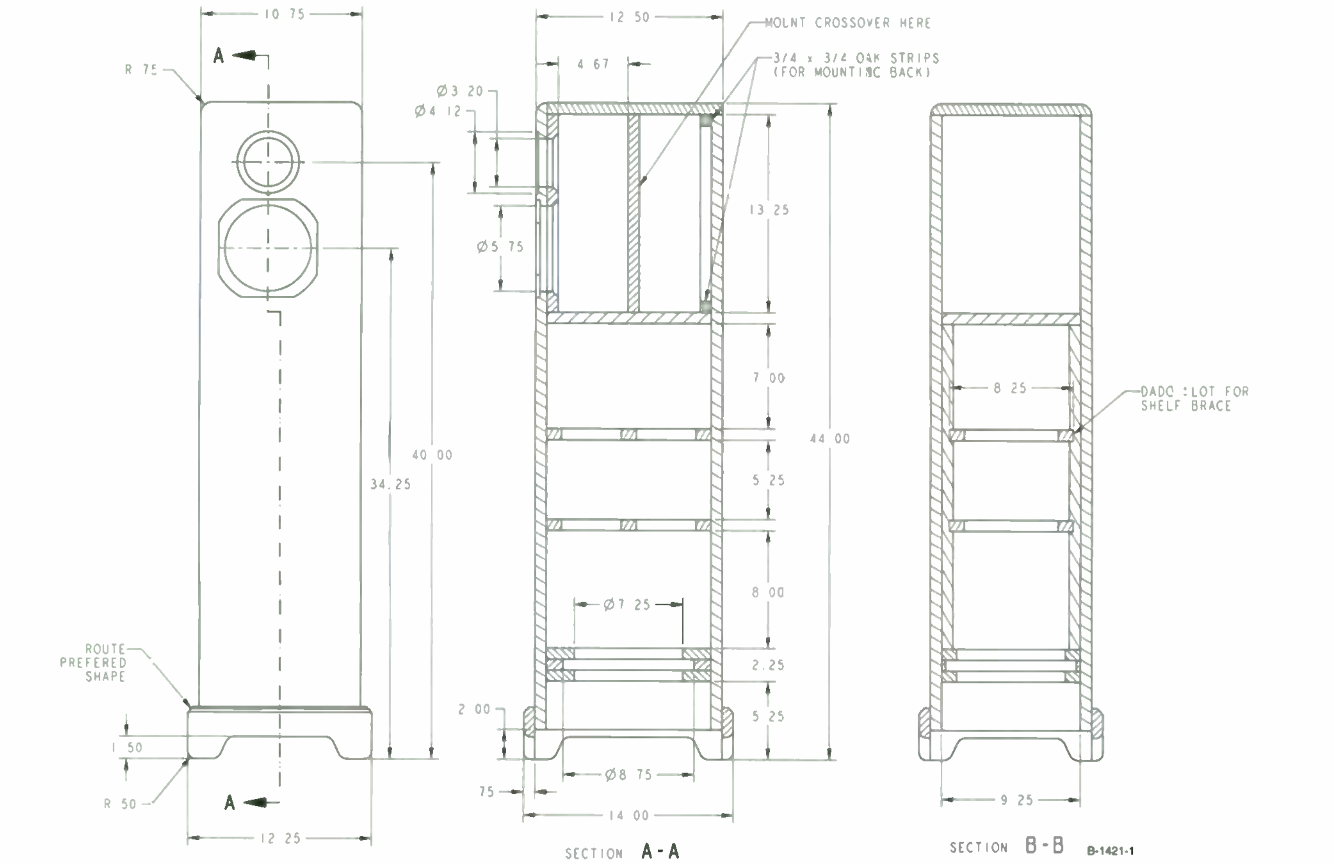


FIGURE 1: Construction drawing with all inner parts made of MDF and external parts made either of oak plywood or solid oak.

Maverick 2 and *Fig. 1* is a construction drawing. I decided to set up a cutting schedule before I even purchased the wood. This enabled me to cut all pieces that were the same width at the same time, which made for quick work, with only a few saw set-up changes.

In constructing the cabinet, I aimed for more stiffness in the upper portion of the cabinet since the bottom is open. I decided that because the side walls were to have a greater surface area than the front, they should be made with a double thickness. To do this, I used MDF only on the inside of the subwoofer cabinet. The top of the cabinet has two separate sub enclosures, one for the crossover and the other for the midrange and tweeter (*Photo 2*).

The front panel has recessed holes for mounting the tweeter and midrange and a piece of MDF attached to the back of the midrange/tweeter area so there is more material for the screws to grab (*Fig. 2*). I chamfered the MDF on the inside to allow for better airflow for the midrange. The inside wall stiffeners should have dado cuts (*Fig. 1*) to accept the shelf braces, so the cuts should be ¾″ wide and ¼″ deep. You should glue all joints and then seal them with silicone to prevent air leakage (*Photo 3*).

The last pieces I assembled were the three bottom panels to which the woof-

TABLE 2
PARTS LIST FOR SINGLE CROSSOVER

1	Sidewinder 4.0mH #16 AWG iron-core inductor
2	100μF Bennic 100V bipolar electrolytic capacitor
1	3Ω 15W sand-cast resistor
1	2.5mH #19 AWG standard air core inductor
1	1.1mH #19 AWG standard air core inductor
1	3.9μF Carli 150V polyester film capacitor
1	8μF Carli 150V polyester film capacitor
1	8Ω 15W sand-cast resistor
1	5μF Solen polypropylene 450V capacitor
1	.25mH #20 AWG standard air-core inductor
1	2Ω 15W sand-cast resistor
1	23Ω 15W sand-cast resistor
1	92B 3-way glass expoxy circuit board

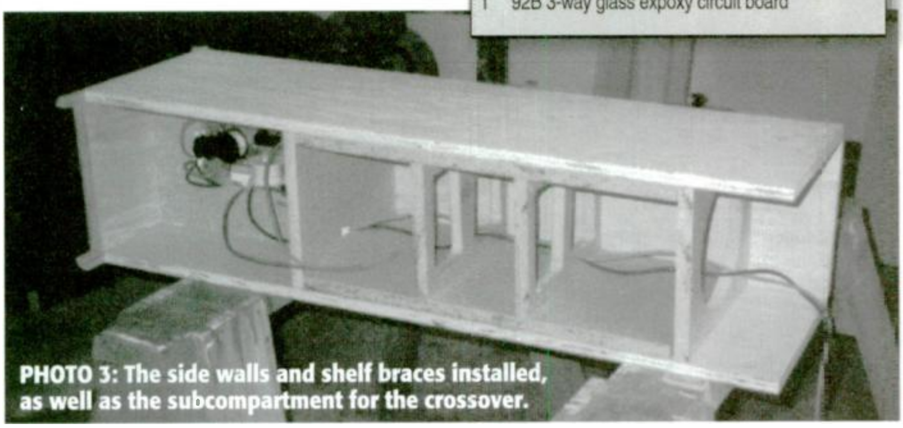


PHOTO 3: The side walls and shelf braces installed, as well as the subcompartment for the crossover.


PHOTO 4: The crossover and the mid-tweeter subenclosure.


PHOTO 5: The front view of the cabinet before application of the finish.

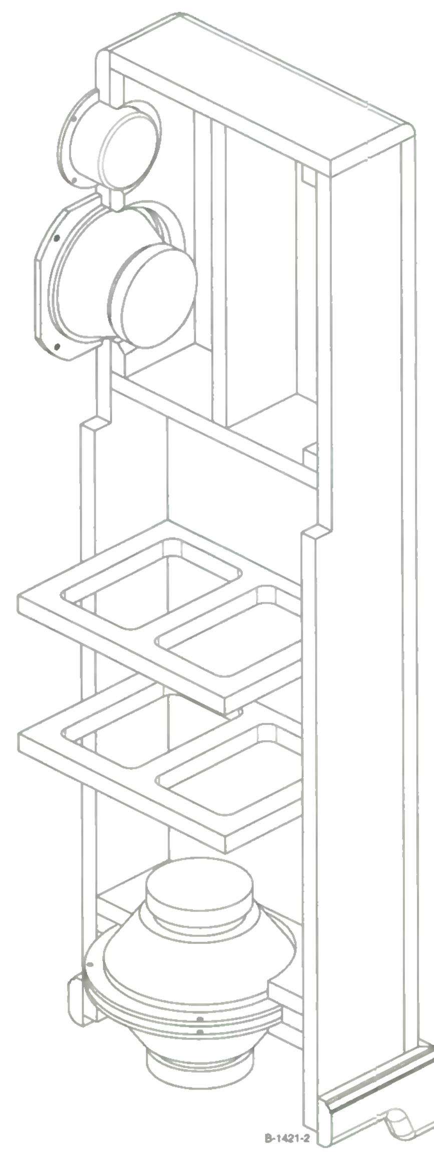
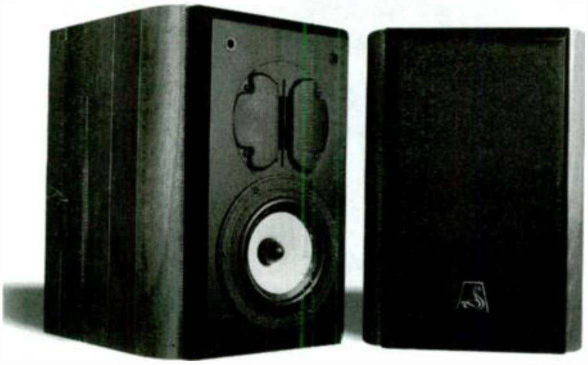


FIGURE 2: Broken out view to show the construction details and driver placement.

Swans M1 kit



Great news from Swans!

New beautifully cabinets for Swans M1 kits are available in three finishes: piano black, solid walnut and rosewood veneer. Totally irresistible!

The Swans M1 speaker system is a two-way bass-reflex design. The front baffle is very narrow with rounded edges to reduce cabinet diffraction for better clarity and imaging. The internal panel and corner reinforcement substantially reduce unwanted cabinet vibrations. A flared port is mounted on the rear baffle for smooth transition from the port to cabinet boundaries. This provides linear bass performance and absence of port noise. The heavy-duty gold plated binding posts are mounted directly on the rear panel to enable easy cable connection.

The 5-inch paper/Kevlar cone woofer 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. These key features greatly contribute to the M1's clear transparent sound and effortless dynamic performance.

The tweeter is a high-tech planar isodynamic design that employs Neodymium magnets and extremely light Kapton®film, with flat aluminum conductors.

This unit provides an immediate and precise response to any transients in original signal, and gives the M1 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 M1 kit includes:
- 2x F5 paper/Kevlar bass-midrange drivers,
- 2x RT1C isodynamic tweeters with sealing gaskets,
- 2x dedicated tweeter crossovers.
- 2x dedicated bass-midrange crossovers.
- two flared ports.
- two pairs of heavy duty gold plated terminals.

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.

Price: $410 delivered without cabinets.
$660 delivered with cabinets.
Warranty 3 years. We accept VISA.

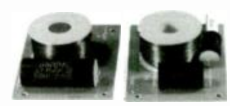
High sonic resolution Loudspeaker with room friendly performance

"...explicit, easy to listen to, effortless, seamless and stunning."
Ernie Fisher
Swans M1 Speaker Systems Review
INNER EAR REPORT
Volume10, #3 1998

SWANS
SPEAKER SYSTEMS
The step beyond the limits


RT1C Tweeter


F5 Bass-midrange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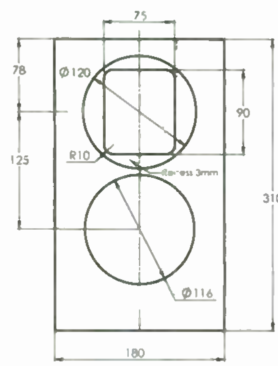
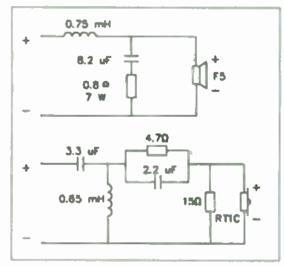
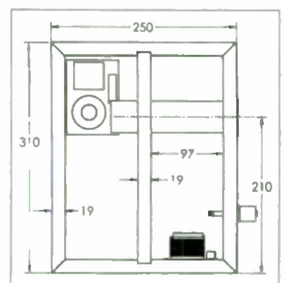
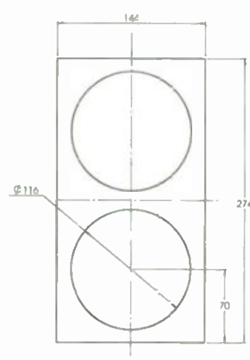


Front view

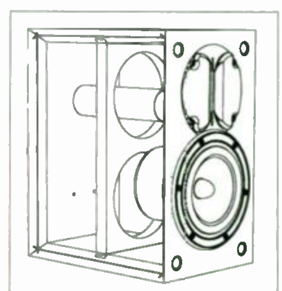




Right view of the cabinet with accessories(right side panel removed)



Internal panel



SPECIFICATIONS

Frequency response	60Hz-35kHz,±2dB
(1m,half space)	55Hz-40kHz,-3dB
Sensitivity,1W/1m	86 dB
(100Hz-8kHz averaged)	
Nominal impedance	8 ohms
(7.2 ohms minimum at 250 Hz)	
Power handling	50W nominal, 90W music
Dimensions,HxWxD	310x180x250 mm

Amplifier requirements:
30W recommended minimum.

for more info please
Call: (905)-889-7876

ACOUSTIC TECHNOLOGY INTERNATIONAL INC.
15 WEST PEARCE STREET UNIT 2&3,
RICHMOND HILL
ONTARIO L4B 1H6 CANADA
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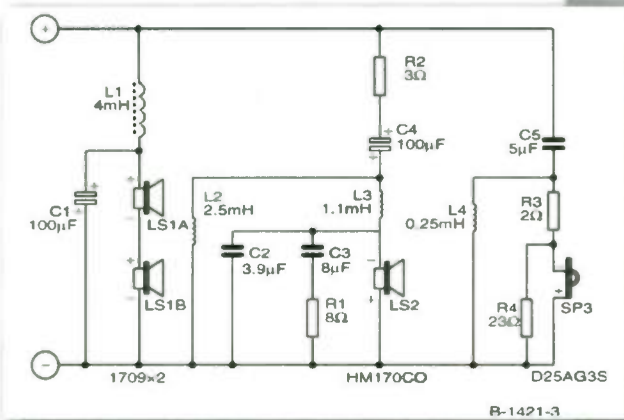


FIGURE 3: Crossover schematic.

PHOTO 6: The speakers in the author's living room.

ers mount, the spacer to separate them, and the back panel. I needed access to the inside of the cabinet, so I decided to use closed-cell foam weather stripping and screw the back panel onto the assembled cabinet. If you do this, make sure the screws are on the outside of the weather-stripping; otherwise, you would no longer have an airtight seal.

Both sub-cabinets are sealed with silicone caulking and filled with polyester. Each speaker cabinet has about ½ pound of fill for the woofers, and the midrange/tweeter sub cabinet has about a ¼ pound (*Photo 4*).

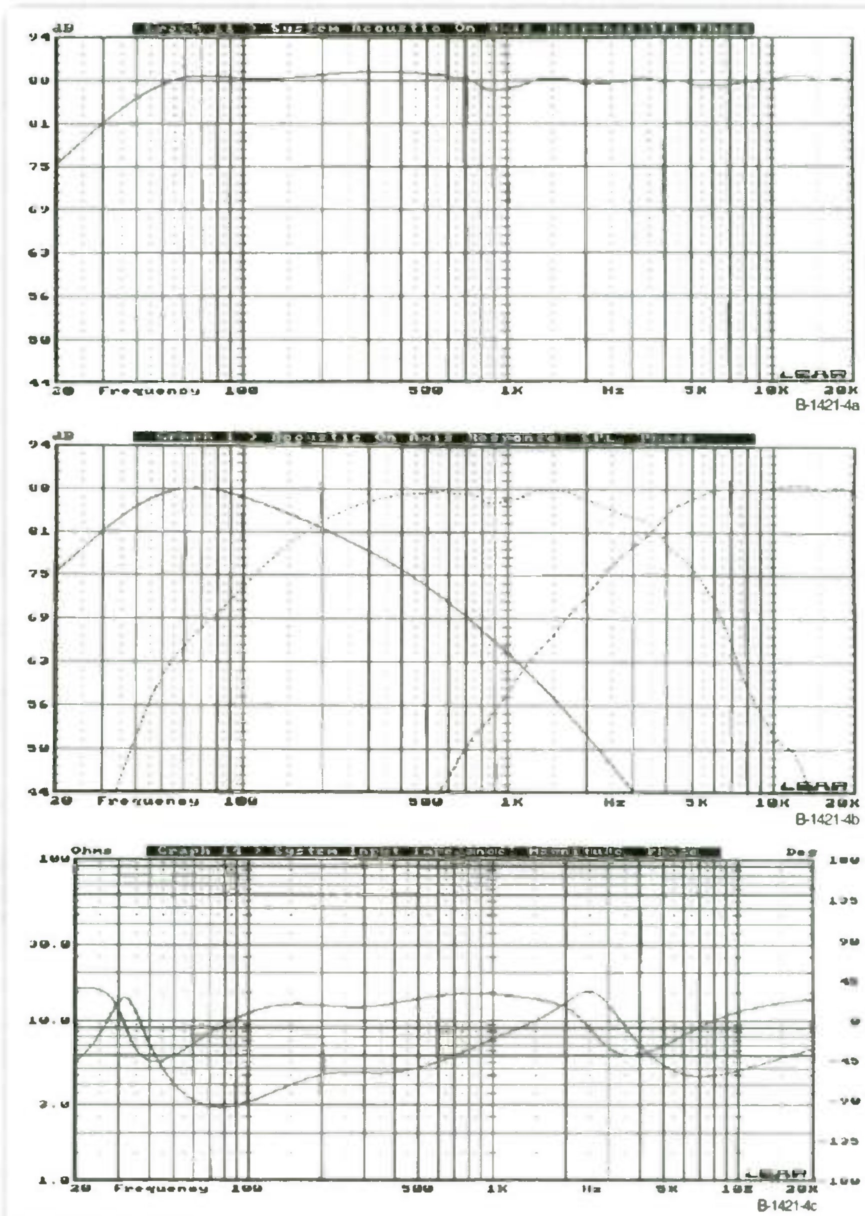
I decided to make the bottom trim pieces out of solid oak, forming them to match some of the other furniture in the room, but this has another purpose. The shape allows the air to flow from the bottom of the woofers, and having the speakers on carpet filters out a little more noise that the isobaric configuration normally hushes.

I sanded and stained the cabinets, and then added three coats of varnish to give them a shine. They blend in well with the other wood colors in the living room (*Photo 5*).

DRIVERS AND CROSSOVER

I knew that the Panasonic Leaf tweeters I had chosen to use six years earlier were out, because I tried to get more, but found out they had not been manufactured for over three years. After looking at current designs on the market, I decided I liked the sound of the metal-dome tweeters over the soft-dome versions. So I decided to use the Vifa D25AG-35, a 1″ aluminum dome, based on the recommendation of a friend.

I also liked the quick sound of cones made from lightweight materials such as Kevlar and carbon fiber for the mid-



FIGURES 4–6: Predicted LEAP measurements.

range. Since I had wished to replace the midranges on my current speakers before I even got into the new design, I chose the Audax HM170C0 6.5″ so I could swap it with the old Driver Designs 6.5″. I immediately noticed a marked improvement in sound image and quality with the more expensive, lightweight Audax. I decided that for my new design the 93Hz I could get from the Audax drivers in a sealed box would work fine with the woofers, so I chose that instead of the 60Hz or lower I could get in a ported configuration with a larger compartment.

I knew I wished to use the 8″ Peerless drivers I would take out of the old design, and since I had two for each side, I decided to use them in an isobaric configuration with a sealed box, giving me a respectable 39Hz at the lower F_3. I found that at a Q_{tc} of .707, the box size was just over $1ft^3$. I decided I could do quite a bit with this in a small footprint. I was trying to figure out how to use the isobaric design and not have a really strange looking cabinet. I didn't wish to have a magnet structure hanging out of the cabinet, and I thought it would be great if I could hide the woofer altogether.

I gave Madisound all the specifications for my design and the drivers, and they designed a crossover for me (*Fig. 3*). Since I am not good at soldering, I let them make the crossovers as well. *Table 2* is the parts list. I was very happy with the crossovers' appearance. They were mounted on a large circuit board and were very heavy, especially when compared to those taken out of my original speakers. Going from a first-order to a third-order crossover requires the addition of many more components than I thought. *Figures 4–6* show the predicted LEAP measurements Madisound sent me for this crossover design.

CONCLUSION

I am very happy with the project as a whole. The sound quality and the fit and finish in the room meet my criteria (*Photo 6*). The first time I hooked them up and started cranking the volume, my wife said she really noticed the difference in sound quality from the old design. The bass is much tighter and does not have a tendency to resonate through the house as much as before. The midrange is cleaned up by the use of the third-order crossover, so it does not jump all over the place, distorting and bottoming-out, and the tweeters are nice and smooth.

I do not have test equipment, so I cannot tell you what the actual frequency response is or produce waterfall plots. I am now working on the design of a powered subwoofer and a shielded center channel with the same drivers as the sides. For the future when I move into a house, I have several ideas for making dipole surrounds for the back, using the same drivers. For now, the in-wall Radio Shack speakers will work just fine.

This author designs a cabinet to meet the special needs of a fellow musician. Besides addressing weight and size matters, the resulting PA system produces just the right sound.

The Mid Ranger

By Bill Fitzmaurice

I recently received a most unusual request. A bass playing acquaintance, Tim, wished to have a new cabinet. He was satisfied with the tone of his current rig, but it had three shortcomings: too big, too heavy, and not loud enough. A 4 × 10″ T/S box, it was somewhat over 6ft^3, weighed 72 lbs, and had an average SPL per watt of 98dB.

I let him take my Snail (*SB* 6/97) out on a gig. His response: "Nice size, but too heavy, and too much bottom end." I figured that he didn't really desire less bass, but needed more midrange and top end, so I let him try my Siamese Snail (*SB* 2/99). His reaction was, "Good pop, and the weight's not bad, but it's too big and still has too much bottom end."

BITING MIDRANGE

Complaints from bass players about having too much bottom are rare, so I went to see his band. They turned out to be a funk act; his style was almost all "slap and pop"; his sound had very little first-octave fundamental content, but lots of biting midrange. I then took his cabinet home to test its response.

Like most cabinets using MI 10s (low Q, high F_s), its response died below 100Hz, with practically no capability below 60Hz. Moreover, to achieve his preferred tone, Tim would run his amp's bass tone control flat, but boost both his midrange and treble pots to full. It was no wonder he didn't care for the round bass tones my Snails gave him. What he wished for was a super-efficient midrange box.

The logical choice would have been a straight horn cabinet, with an F_h over 100Hz, using a 10″ or 12″ MI driver, perhaps with a tweeter for the high end. The problem with a straight horn would be that even a fairly short horn two feet long would require a box at least 30″ deep. That problem could be solved with a folded horn, but the folding configuration would kill the high end, right?

Wrong! If you've been reading my Snail series you know that folded horns can give good mid- and high-end response. For Tim's dream cabinet I pulled out all the stops, using every trick I'd learned in building the various Snails to give him maximum midrange and high end (*Photo 1*). First, I chose a 12″ EVM model 12L for the woofer, since its nominal range of 80Hz–6kHz with 100dB sensitivity and 200W rating fits the requirements (you may substitute another 12″ or 10″ MI driver with specs close to Q_{ts} of .25, V_{as} of 2ft^3, F_s of 55Hz, and high frequency rolloff F_3 of 5kHz).

Around this driver I designed a cabinet using the dual path configuration of the Siamese Snail. Splitting the horn into two halves minimizes cross-sectional dimensions, limiting phase-cancellation effects. To keep the cross-sectional size even smaller, two braces divide each horn in half, right to the mouth openings. At the throat, separate paths for the front wave and the duct outputs shrink throat cross sections even further. A rapid flare on the front-wave throats gives better loading of highs; conversely, a slow flare on the duct's throats provides better low-frequency loading. Having only two 90° bends in the horn path minimizes high-frequency losses and phase cancellations, as do the curved surfaces of the throat choke and corner reflectors.

Finally, since all these measures still give only a bandwith up to about 4kHz, I incorporated a Motorola Twin-Bullet piezo tweeter (model KSN 1177),

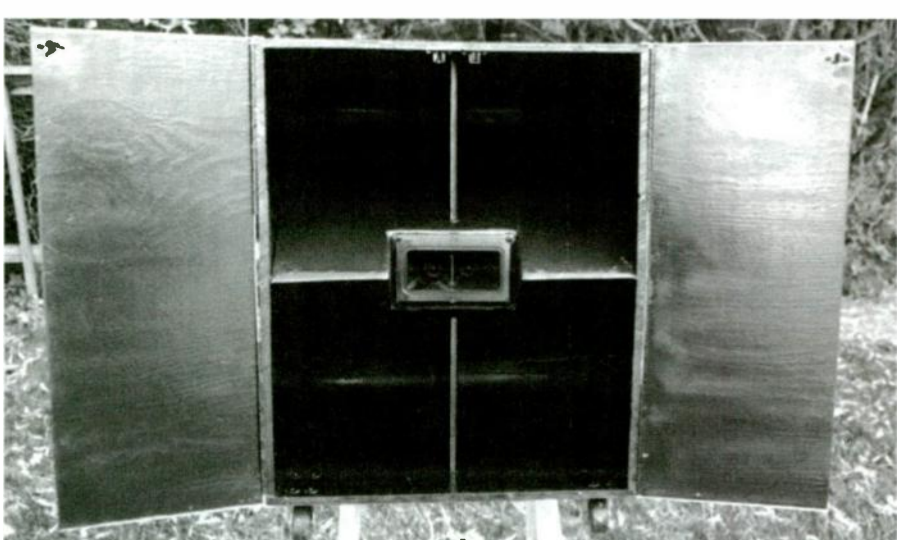


PHOTO 1: The completed Mid Ranger.

mounted coaxially, as well as swing-away doors on the cabinet front. Think of the effect of these doors as similar to that of the books on either side of a true bookshelf speaker: the panels create a reflective surface that minimizes diffraction and phase-cancellation effects as the wave leaves the horn mouth, both smoothing overall response and, at many frequencies, improving sensitivity. As a plus, these doors, when closed, protect the cabinet innards, especially the tweeter, from the elements during transit to and from the gig.

TABLE 1
PARTS LIST (REFERENCED TO DRAWINGS)

All sizes approximate, all parts except as noted ½" plywood.

1. Top, bottom	18" × 19"
2. Sides (2)	22" × 18"
3. Baffle	18" × 14¾"
4. Horn braces	see text
5. Driver spacer	13" × 13" (¼" plywood)
6. Throat choke	9" (4" PVC pipe, halved lengthwise)
7. Horn plates	18¼" × 17¹⁵⁄₁₆" (⅜" plywood)
8. Corner reflectors	17 ¹⁵⁄₁₆" (4" PVC pipe, quartered)
9. Tweeter baffle	6½" × 4"
10. Throat reflector, long (2)	2" × 12"
11. Throat reflector, short (2)	2" × 4"
12. Horn dividers	see text
Café doors	23" × 9 ⁷⁄₁₆" (not shown in diagrams)

SUPPLIES:
EVM-12L driver (or equivalent); Motorola KSN1177 driver; drywall screws; construction adhesive; 2" PVC pipe (ducts, 2" × 5"); ³⁄₁₆" T-nuts with Allen-head bolts; convoluted acoustic foam and spray adhesive; hot-melt glue; 14 or 16ga zip cord; paint, carpet, vinyl, or laminate exterior finish material; protective corners or edging; piano hinges; cabinet catches; castors; handles; input jack with mounting hardware.

Cost of cabinet built as described, with paint finish: $300.

PHOTO 2: Forming the horn-brace and divider patterns.

INITIAL CONSTRUCTION STEPS

I achieved light weight by constructing the cabinet primarily of ½" plywood (all parts dimensions depend on the actual measured thickness of the material used—see *Table 1* for parts list). You may use thicker materials if you wish, at a penalty for weight, adjusting parts dimensions accordingly.

Secure all joints with drywall screws at least every 6", along with construction adhesive applied liberally to ensure airtight joints. Use screws of both 1" and 1¼" length, using the longer screws wherever possible without penetrating outer walls. All screw holes should be pilot drilled and deeply countersunk. You will achieve the most accurate joints if you first glue up the parts, clamp them, and then screw them into place.

The first step is to create the pattern for the horn braces and dividers. Cut a piece of plywood 17" × 11½"; draw on it a vertical line ½" from its left edge, followed by five lines at 3" intervals, and a final line 16" from the first, ½" from the right edge of the board (*Fig. 1*). Mark a point on the first line down 11" from the top edge, and points on each succeeding line at, respectively, 8½", 6¾", 5⅜", 4⁵⁄₁₆", 3½", and 3¼". Into each point drive a finish nail, leaving at least ½" of the nail exposed.

Cut a ½"-wide sliver of ⅜" plywood about two feet long, and bend it into place along the nails, securing its bottom edge with more nails; trace both the top and bottom curves of the sliver onto the plywood (*Photo 2*). Remove the sliver and the nails, and cut along both traced lines. Trim off the ½" of selvage from both edges of the patterns; trim ½" of selvage from the lower edge of the lower pattern. Make a copy of the upper pattern, which is for the horn dividers. Now trim the lower pattern (for the horn braces) to a 1½" width, and then duplicate it seven times, for a total of eight braces. You may cut these from ½" plywood, or from thicker lumber if desired.

Cut the two sides, each measuring 22" × 18". Draw on them the location of the baffle, and then use the pattern to trace the locations of the horn braces. Trim the ends of the horn braces where they intersect the baffle to accommodate the baffle thickness. In one side, cut a triangular access hole, the cut lines for which are curving lines bisecting the tracings of the horn braces and a straight line ¾" inside the baffle, with the intersections of the lines rounded to a smooth curve (*Photo 3*). Cut this panel out with a sabre saw, starting with a plunge cut.

THE BAFFLE

Cut the baffle to size, the ends cut at a 10° angle to match the taper of the horn plate. Draw on the baffle vertical and horizontal bisecting reference lines, fol-

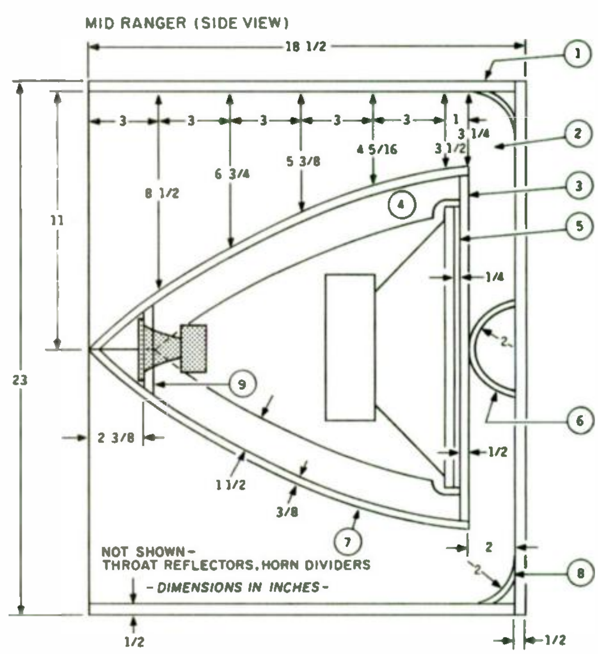


FIGURE 1: Dimensions and placement of parts related to one side.

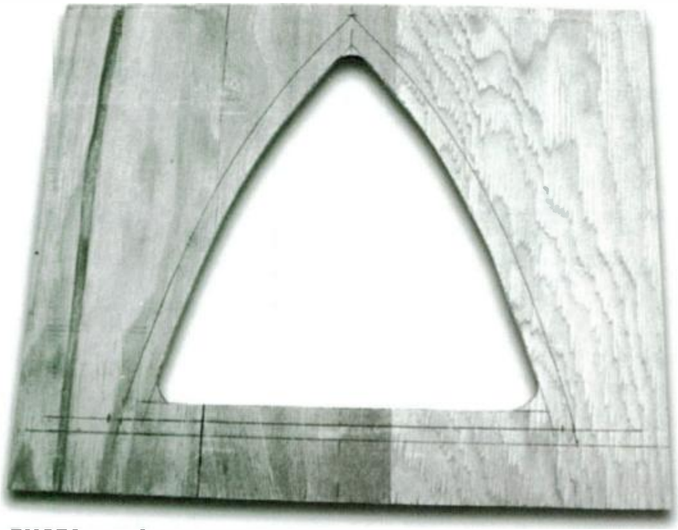


PHOTO 3: Driver-access hole cut into one side.

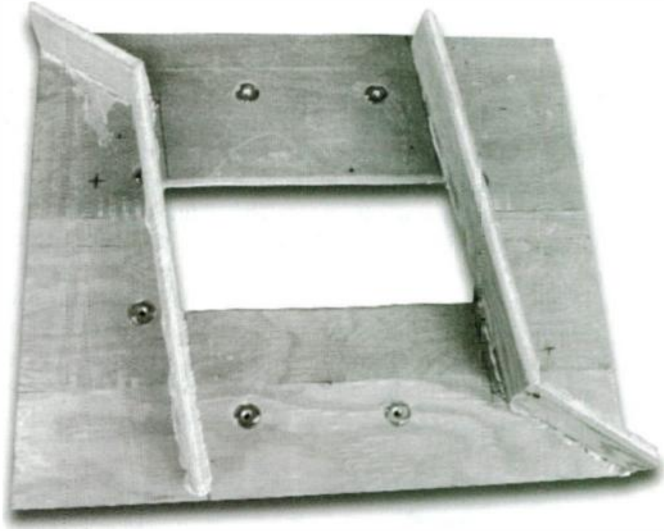


PHOTO 4: Baffle subassembly.

lowed by the rest of the parts and hole locations (*Fig. 2*). Center the driver on the panel, marking the hole locations for the driver mounting bolts. Drill the holes and install T-nuts, countersinking the heads so that they lie flush with the panel. Cut the driver hole, using a ¼″-radius router bit to round over all edges not mated with reflectors, inside and out, and cut the holes for the ducts.

The mating ends of the throat reflectors are both cut at a 23° angle. Round over the exposed ends of the longer pieces, and cut the ends of the shorter pieces that mate the cabinet sides at 34° angles (*Photo 4*). Install these parts, filling any voids in the joints with extra adhesive. To prevent the cone edge from hitting the baffle in long excursions, you may rout a circular channel into the baffle, ⅛″ deep (*Fig. 3*). Alternatively, you may cut a spacer from ¼″ plywood attaching it to the baffle prior to drilling the driver bolt holes (*Photo 5*). A spacer must be used should you decide to substitute a 10″ driver for the 12″.

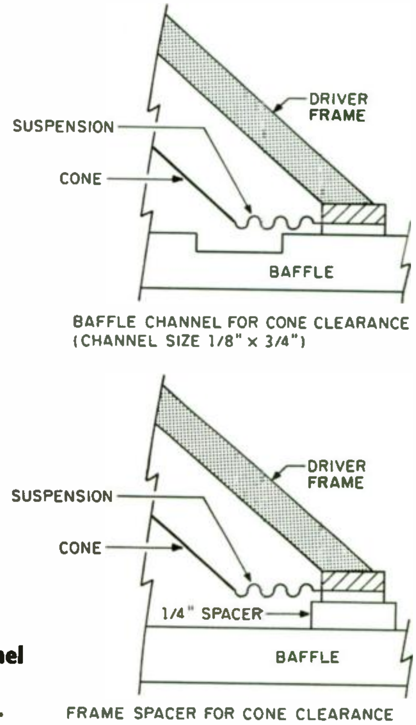


FIGURE 3: Baffle channel and frame spacer to ensure cone clearance.

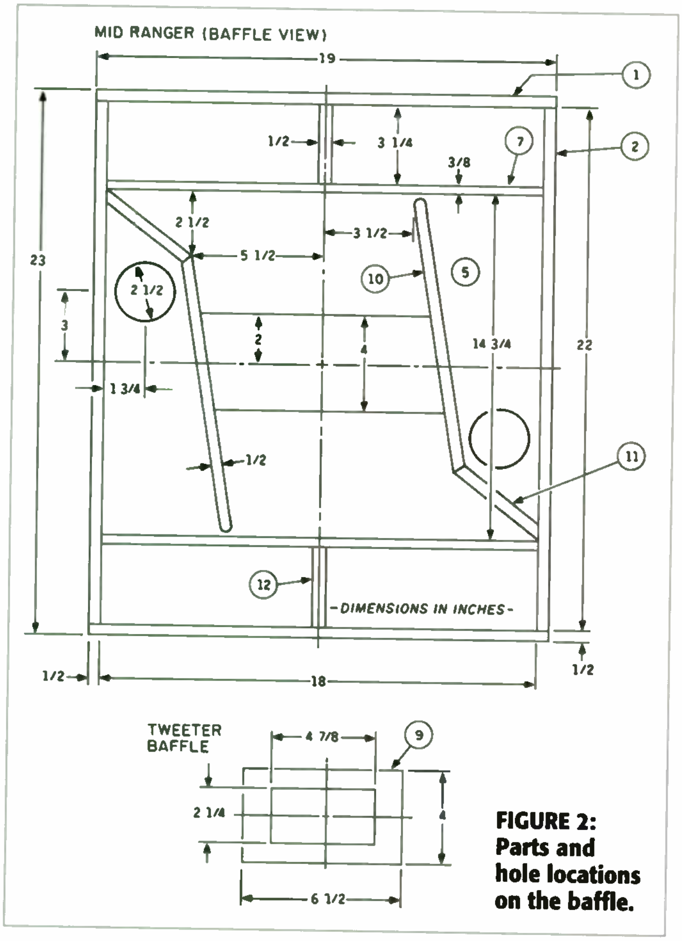


FIGURE 2: Parts and hole locations on the baffle.

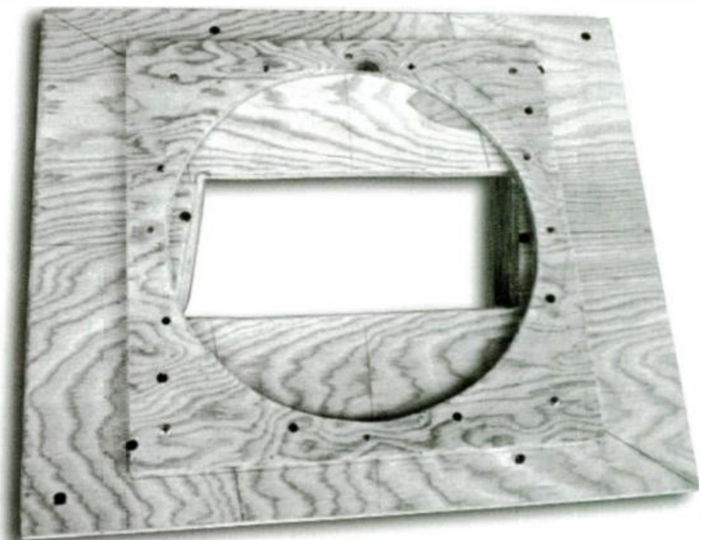


PHOTO 5: Baffle with drive spacer.

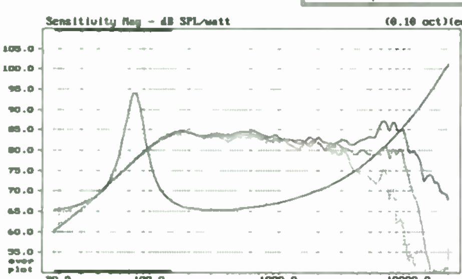
AP100G0

Shielded 4" coated paper cone

The AP100GO is designed for uses where a magnetically shielded speaker is needed. This driver is a good choice for any A/V application. Use it in a center channel or perhaps a computer speaker.

- 84.5 dB efficiency
- Coated paper cone
- Rubber surround
- Good response to 4kHz
- Polymer chassis
- Price Each $24.75

Technical Data	Symbol	Value	Unit
Nominal Impedance	Z	6	Ω
Resonance Frequency	Fs	75.7	Hz
Power Handling (IEC)	P	30	W
Sensitivity (1W/1m)	E	84.5	dB
Voice coil Diameter	Ø	25	mm
Minimum Impedance	Zmin	6.2	Ω
DC Resistance	Re	5.7	Ω
Voice Coil Inductance	Lbm	0.49	mH
Voice Coil Length	h	9.4	mm
Former	-	Alum.	-
Number of Layers	n	2	-
Magnet Weight	m	0.205	kg
Flux Density	B	1	T
Force Factor	BL	3.92	NA⁻¹
Height of Magnet Gap	He	4	mm
Linear Excursion peak	Xmax	2.7	mm
Suspension Compliance	Cms	949	µm/N
Mechanical Q Factor	Qms	2.53	-
Electrical Q Factor	Qes	0.78	-
Total Q Factor	Qts	0.60	-
Moving Mass	Mms	4.66	g
Effective Piston Area	S	50.27	cm²
Equivalent Air Volume	Vas	3.37	ltrs
Mass of Speaker	M	0.5	kg



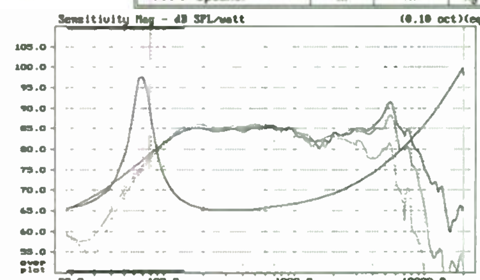
AP100Z0

Shielded 4" HDA Aerogel cone

The AP100Z0 is a shielded magnet speaker for use in audio video applications. The small size of this driver makes it an ideal choice for a center channel speaker or computer speaker.

- 84.7 dB efficiency
- HDA Aerogel cone
- Polymer chassis
- Rubber surround
- Decorative flange
- Good vented or sealed
- Price Each $27.00

Technical Data	Symbol	Value	Unit
Nominal Impedance	Z	6	Ω
Resonance Frequency	Fs	64	Hz
Power Handling (IEC)	P	30	W
Sensitivity (1W/1m)	E	84.7	dB
Voice coil Diameter	Ø	25	mm
Minimum Impedance	Zmin	6.1	Ω
DC Resistance	Re	5.7	Ω
Voice Coil Inductance	Lbm	0.45	mH
Voice Coil Length	h	9.4	mm
Former	-	Alum.	-
Number of Layers	n	2	-
Magnet Weight	m	0.205	kg
Flux Density	B	1	T
Force Factor	BL	3.99	NA⁻¹
Height of Magnet Gap	He	4	mm
Linear Excursion peak	Xmax	2.7	mm
Suspension Compliance	Cms	1329	µm/N
Mechanical Q Factor	Qms	2.16	-
Electrical Q Factor	Qes	0.63	-
Total Q Factor	Qts	0.49	-
Moving Mass	Mms	4.65	g
Effective Piston Area	S	50.27	cm²
Equivalent Air Volume	Vas	4.72	ltrs
Mass of Speaker	M	1.7	kg



>> NEW <<
Polymer Chassis
Shielded Magnet
Woofers

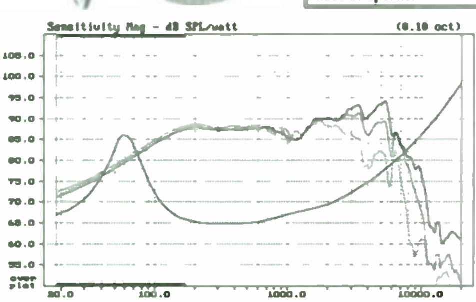
AP130Z0

Shielded 5 ¼" HDA Aerogel cone

The AP130Z0 is a shielded magnet speaker for use in audio video applications. F3 of 100Hz in a sealed enclosure or 60Hz vented. Frequency response to 3kHz.

- 87.4 dB efficiency
- HDA Aerogel cone
- Polymer chassis
- Rubber surround
- Decorative flange
- Good bass in small vented enclosure
- Price Each $28.90

Technical Data	Symbol	Value	Unit
Nominal Impedance	Z	6	Ω
Resonance Frequency	Fs	57.6	Hz
Power Handling (IEC)	P	40	W
Sensitivity (1W/1m)	E	87.4	dB
Voice coil Diameter	Ø	25	mm
Minimum Impedance	Zmin	5.7	Ω
DC Resistance	Re	5.2	Ω
Voice Coil Inductance	Lbm	0.4	mH
Voice Coil Length	h	10	mm
Former	-	alum.	-
Number of Layers	n	2	-
Magnet Weight	m	0.35	kg
Flux Density	B	1	T
Force Factor	BL	4.72	NA⁻¹
Height of Magnet Gap	He	5	mm
Linear Excursion peak	Xmax	2.5	mm
Suspension Compliance	Cms	1113	µm/N
Mechanical Q Factor	Qms	1.48	-
Electrical Q Factor	Qes	0.57	-
Total Q Factor	Qts	0.41	-
Moving Mass	Mms	6.86	g
Effective Piston Area	S	83.32	cm²
Equivalent Air Volume	Vas	10.85	ltrs
Mass of Speaker	M	1.18	kg



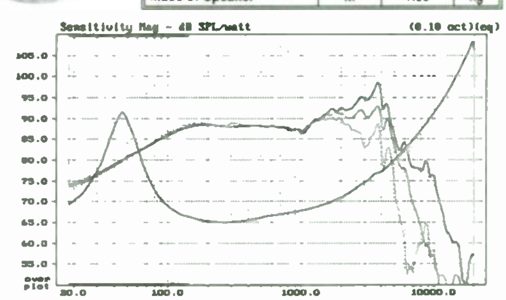
AP170Z0

Shielded 6 ½" HDA Aerogel cone

The AP170Z0 woofer is designed for use in any audio /video application. The frequency range is from 55Hz (vented) to 3kHz. This woofer can also be used sealed for an F3 of 90Hz.

- 87.4 dB efficiency
- HDA Aerogel cone
- Polymer chassis
- Rubber surround
- Decorative flange
- Price Each $31.50

Technical Data	Symbol	Value	Unit
Nominal Impedance	Z	6	Ω
Resonance Frequency	Fs	48.5	Hz
Power Handling (IEC)	P	60	W
Sensitivity (1W/1m)	E	89.3	dB
Voice coil Diameter	Ø	30	mm
Minimum Impedance	Zmin	6	Ω
DC Resistance	Re	5.3	Ω
Voice Coil Inductance	Lbm	0.74	µH
Voice Coil Length	h	12	mm
Former	-	Alum.	-
Number of Layers	n	2	-
Magnet Weight	m	0.555	kg
Flux Density	B	1	T
Force Factor	BL	5.76	NA⁻¹
Height of Magnet Gap	He	6	mm
Linear Excursion peak	Xmax	3	mm
Suspension Compliance	Cms	996	µm/N
Mechanical Q Factor	Qms	1.61	-
Electrical Q Factor	Qes	0.5	-
Total Q Factor	Qts	0.38	-
Moving Mass	Mms	10.82	g
Effective Piston Area	S	132.73	cm²
Equivalent Air Volume	Vas	24.65	ltrs
Mass of Speaker	M	1.05	kg



LA PASSION DU HAUT-PARLEUR

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Attach the baffle to the cabinet side containing the access hole, along with two horn braces and a piece of plywood 1½″ by about 12″, which forms the flange for attaching the access panel. Fitting the driver through the access hole is a tight squeeze, so you must trim the flange somewhat with a sabre saw to allow the driver frame to go through (*Photo 6*).

Now fasten the second side to the assembly, along with two 18″ lengths of scrap wood that act as temporary braces to keep the cabinet square. Cut the tweeter baffle to size, including the mounting hole. Install two horn braces on the second side, and fasten four braces to the baffle and the tweeter baffle, spacing them 6½″ apart (3¼″ off the baffle center). It is very difficult to secure the tweeter baffle with screws, so glue it, clamp it, and let the adhesive set overnight (*Photo 7*).

ATTACHING THE HORN PLATES

Cut two pieces of ¾″ stock into 1″ × 1″ blocks to fill the area of the point of the horn on either side of the tweeter. Secure them with adhesive and screws, sanding them and the tweeter baffle to match the contour of the horn braces (*Photo 8*). Use ⅜″ plywood for the horn plates, but before cutting them out, flex the plywood sheet to determine the more flexible axis for bending to shape.

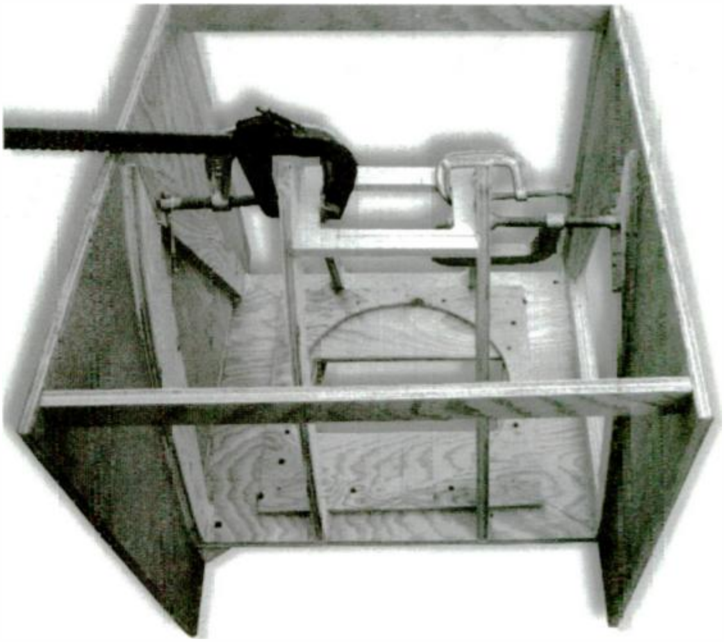


PHOTO 7: Gluing the tweeter baffle; note temporary 18″ squaring braces attached to sides.

PHOTO 8: 1″ × 1″ blocks at the horn point.

PHOTO 6: Baffle assembly attached to side with access-hole flange installed.

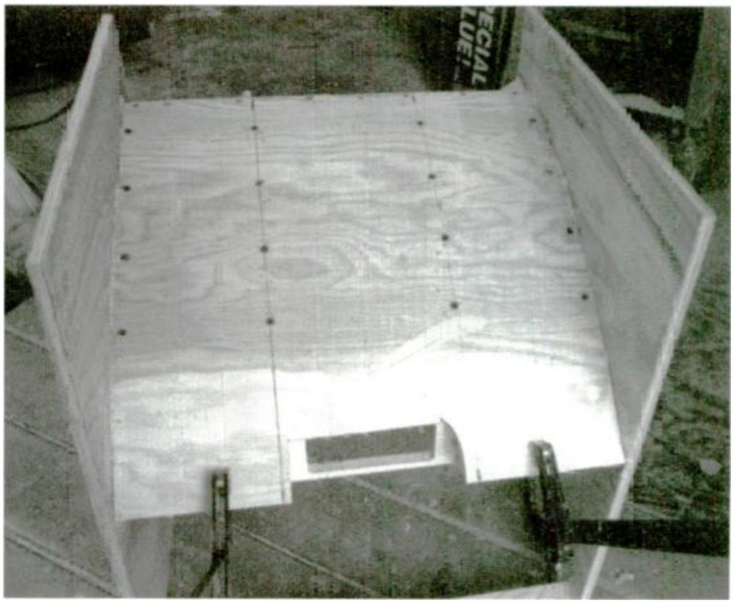


PHOTO 9: Installing the first horn plate.

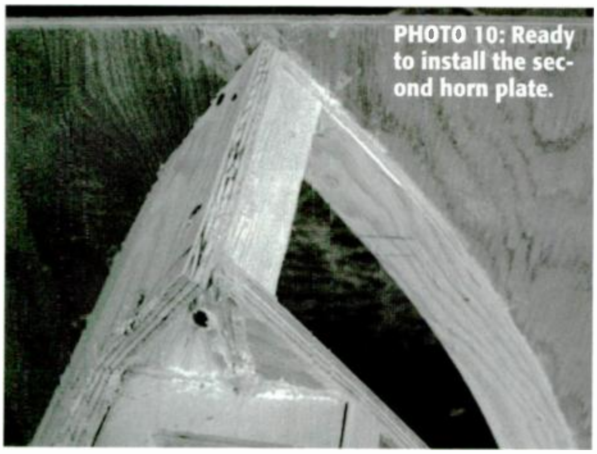


PHOTO 10: Ready to install the second horn plate.

Cut away just enough of the plywood from where the tweeter will be located to make screw positions easy to determine, and install the first plate, attaching it first to the baffle. Pull the plate gradually into shape against the braces, while driving rows of screws across it every three inches (*Photo 9*). Sand the plate's leading edge to match the contours of the remaining exposed braces, and install the second horn plate (*Photo 10*).

Sand—first flush, and then to a slight radius—the joints of the plates where they meet each other, the baffle, the tweeter baffle, and the exposed braces next to the tweeter baffle (*Photo 11*). Remove the temporary squaring braces, and install the top and bottom panels (*Photo 12*).

You must trim the horn dividers lengthwise a few inches so they will not extend past the tweeter opening; also, round over their leading and trailing edges. Attach the dividers to the assembly, driving screws from the inside of the driver chamber and from the outside of the top and bottom, using extra adhesive to fill all gaps in the joints with the horn plates (*Photo 13*).

PVC-PIPE PARTS

Four-inch PVC (schedule 40) pipe is used for the curved parts, quartered for the corner reflectors, halved for the throat choke. You can easily cut it on a table saw, provided you first screw it to a piece of plywood, which prevents it from rolling around (*Photo 14*). You can eliminate its tendency to close down on the saw blade by setting the blade height to cut not quite all the way through the pipe, finishing the job with a utility knife.

To achieve a perfectly quartered piece with chamfered edges, first run a halved piece of pipe, inverted, over the saw table, again using a stabilizing piece of plywood to set the distance to the rip fence (*Photo 15*). In similar fashion, complete the quartering process, this time with the PVC half-moon screwed to the plywood stabilizer on its newly cut flat edge (*Photo 16*).

Glue the corner reflectors and throat choke in place with hot-melt, holding them in proper alignment until the glue has set. Cut the choke on both ends at 10° to match the angle of the throat reflectors across the baffle. In both cases, cut the PVC slightly (3/16") shorter than the opening size, filling the void with hot-melt.

Drill a ¼" hole through the baffle into one of the duct throats. Line the driver chamber with acoustic foam, and install both the woofer and the tweeter. The woofer clearance is extremely tight, and you can drive the mounting bolts only by feel, with a short-shafted tool. To facilitate this, use Allen-style socket-head bolts and an Allen wrench. The tweeter is simply screwed in place, using weatherstrip on its flange for an airtight seal. Feed about 18" of 14 or 16ga wire through the hole in the baffle to wire the woofer, sealing the hole over on both sides with hot-melt (*Photo 17*). Wire the tweeter in parallel, but out of phase (negative-to-positive and vice versa), to the woofer.

Cut two 5"-long ducts from 2" PVC pipe and glue them in place on the baffle, using hot-melt. Mount the jack of your choice to the cabinet back, and wire the jack, but do not yet attach the back to the cabinet (*Photo 18*). Using ¼" × ¾" neoprene weatherstripping, rim the

PHOTO 12: The cabinet after attaching the top and bottom.

PHOTO 11: The completed horn assembly.

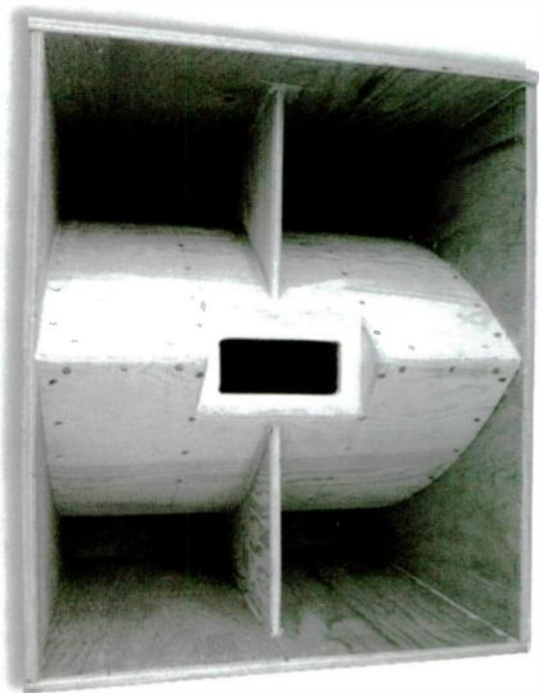
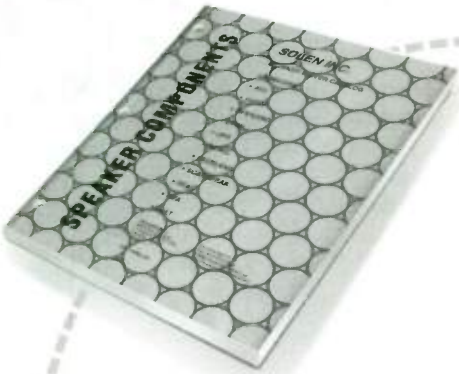


PHOTO 13: The horn dividers in place.

The Process of Design.



DRIVERS:

- ➤ AIRBORNE
- ➤ ATC
- ➤ AUDAX
- ➤ DYNAUDIO
- ➤ ETON
- ➤ LPG
- ➤ MOREL
- ➤ PEERLESS
- ➤ SCAN-SPEAK
- ➤ SEAS
- ➤ VIFA
- ➤ VOLT

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Reader Service #24

flange of the access hole (*Photo 19*), and screw the access panel in place, with screws placed at least every 4″. Hook the cabinet up to an amp, and test it with a 30Hz tone from either a generator or test CD, listening and feeling for any leaks in the chamber, and sealing any you find with hot-melt. Once it's verified tight, attach the back, using plenty of adhesive, especially on the PVC parts, which cannot be screwed.

Either sand or rout all exterior joints flush, rounding them if desired. Apply your finish of choice, casters and handles, and either protective corners or aluminum edging (*Photo 20*). If you wish to add café doors, cut them from ½″ plywood and attach them to the cabinet with piano-style hinges. Use kitchen-cabinet catches (*Photo 21*), the type that have no moving parts that might vibrate, to lock the doors shut for transport (*Photo 22*).

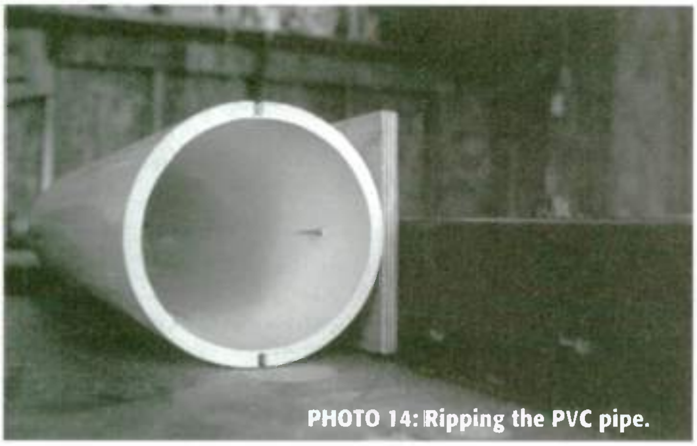


PHOTO 14: Ripping the PVC pipe.

PHOTO 15: Cutting a flat side on the PVC.

PHOTO 16: Quartering PVC.

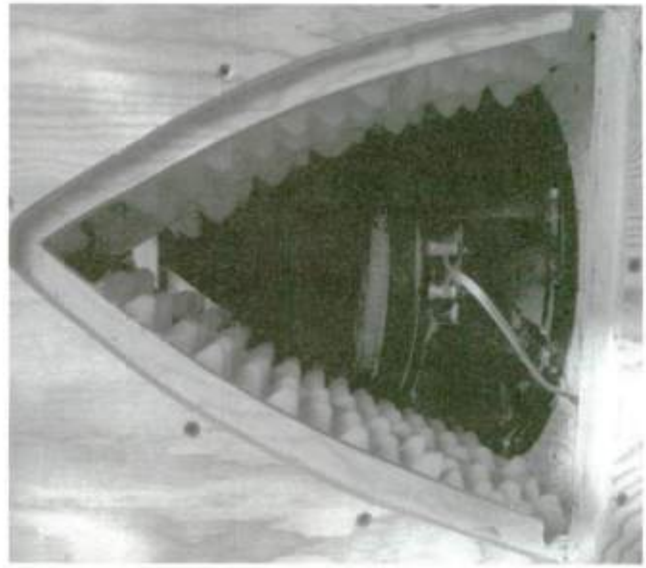


PHOTO 17: Woofer in place.

PHOTO 18: Ready to attach the back.

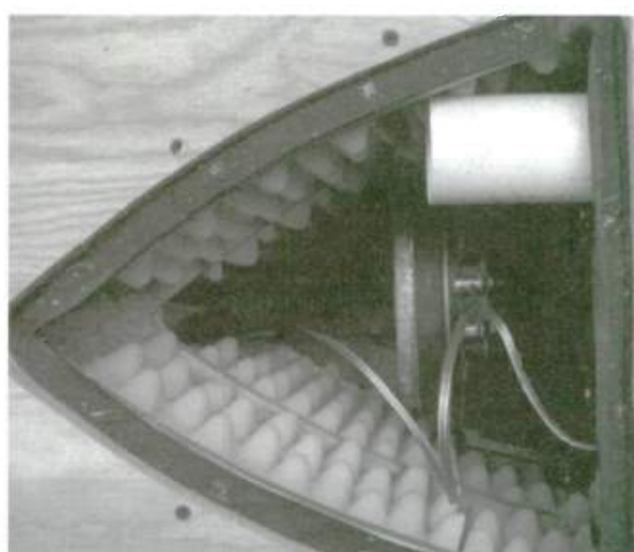


PHOTO 19: Ready to install the access panel.

SATISFACTORY CONCLUSION

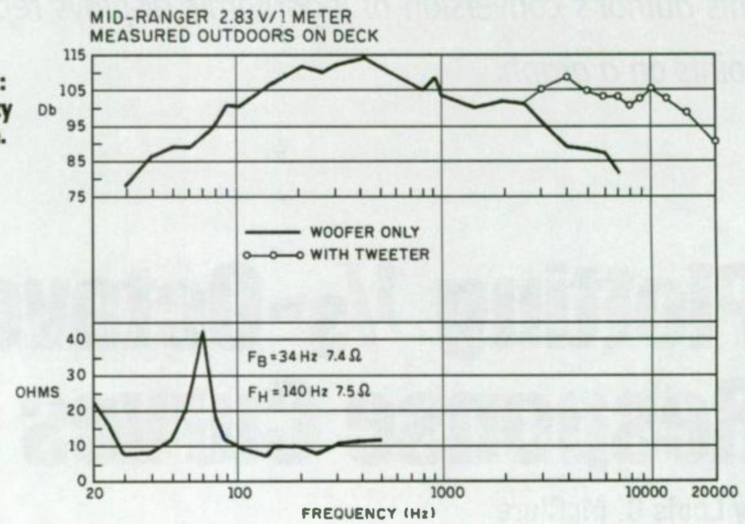
When I delivered the finished Mid Ranger to Tim, he was thrilled, both by the completely unique look of the cabinet and its penetrating tone. At less than 5ft^3 and 58 lbs, it's easier to lug around than his old cabinet, while its average sensitivity (100Hz-6kHz) of 106dB/W gives him the power he craves. In fact, the box is so powerful from 150Hz to 1kHz (109dB average) that he no longer needs to boost his amp's midrange beyond flat to get his desired tone (*Fig. 4*). With the extended range given by the tweeter, he now cuts—instead of boosting—his treble tone control by 10dB; hence, his amp's direct out to a PA no longer has a shrill top end that would need to be padded down at the board's EQ.

Beyond slap and pop bass, this cabinet also performs well in a more traditional style of playing if amp EQ is cut at 250Hz and boosted at 60Hz. It also makes a fine high-power PA mid-bass when constructed only with the woofer, having an output capability (132dB/200W/150Hz-1kHz) unmatched by any commercial unit of which I am aware.

For a two-way system, coupled with a sub, you can achieve reasonably flat response all the way to 20kHz by substituting for the single twin-bullet four Motorola KSN-1165A tweeters, which work down to 1.8kHz, lengthening the tweeter baffle as needed. This configuration would also require a 4Ω 20W resistor wired in series between the tweeters and the woofer to maintain a minimum 4Ω load; also, you would need to rotate the cabinet orientation 90° so that the multiple tweeters would form a vertical array.

Finally, for home stereo—forget about it! Unless, that is, you're Mark McGwire, and the home you want to fill with midrange is Busch Stadium.

FIGURE 4: Frequency response.



A patent application has been submitted by the author for Vented Throat Horn Loaded Speaker cabinets. Designs using this concept are offered to readers for their personal use only. Any commercial use of said designs or of said concept without licensing agreement with the author may constitute an infringement upon the author's patent protection rights.

PHOTO 21: A café-door catch.

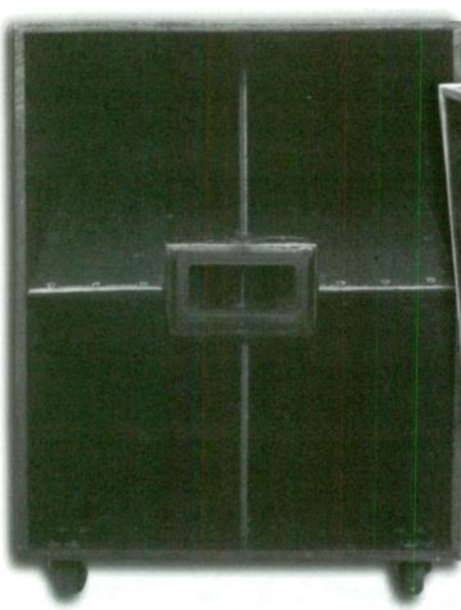


PHOTO 20: Almost finished.

PHOTO 22: Ready for travel, come rain or shine.

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This author's conversion of logarithmic displays represents an easier way to plot response points on a graph.

Plotting 1/3-Octave Frequency-Response Curves

By Louis C. McClure

This article shows you a fast and easy way to plot ⅓-octave frequency response curves. Of course, everyone is familiar with the traditional semilogarithmic ruled paper that is normally used to plot response curves. It usually has four logarithmic cycles on the horizontal, or x-axis, and is ruled linearly on the vertical, or y-axis. (If you have difficulty finding this paper, look in the larger office-supply or stationery stores.)

However, when you try to plot ⅓-octave frequency-response curves on such paper, you quickly see that many of the frequencies do not fall exactly or even approximately on the vertical lines of the paper. Therefore, you must do a lot of interpolating.

THE LOGARITHMIC-SCALE PROBLEM

Recently I constructed a homemade semilogarithmic graph form to see if I could find an easier way to graph frequency-response curves for my horn. I began by listing the whole numbers from 2 to 10 with their respective logarithms, rounding the mantissas to three decimal places (*Table 1*). (If your memory of high-school math is dim, see the sidebar, "More About Logarithms.")

Using a sheet of square-ruled paper, with ten divisions per inch, I drew a rectangular grid 7″ long (x-axis), and 2½″ high (y-axis). This made each logarithmic cycle 2″ long—much easier to plot, since each square represents 0.05″ on the x-axis.

I placed points on the x-axis representing the mantissas of the logarithms of the numbers from 2 to 10, and duplicated this scale a little more than three times to cover the logs of numbers from 1 to 1,000. I then drew vertical lines upward from each point, and horizontal lines at ¼″ intervals from the base line to the top of the grid, thus completing a usable 3½-cycle semilogarithmic graph (*Fig. 1*).

The fun began when I started to plot the ⅓-octave frequency responses on the graph. As mentioned previously, the ⅓-octave frequencies do not correlate very well with the logarithmically ruled paper, so it was necessary to do a lot of interpolating. In fact, about half of the ⅓-octave frequencies do not even closely coincide with the vertical lines on the logarithmic graph.

TABLE 1
LOGARITHMS OF WHOLE NUMBERS

NUMBER	LOGARITHM	PLOT AS:
2	0.30103	0.3
3	0.47712	0.477
4	0.60205	0.6
5	0.69897	0.7
6	0.77815	0.778
7	0.84509	0.845
8	0.90308	0.9
9	0.95424	0.954
10	1.00000	1.000

A BETTER WAY

At this point, I got the idea of examining the logarithms of the ⅓-octave frequencies. I listed these (*Table 2*), again rounding off the mantissas to three places, and then saw that I could round all the mantissas throughout the entire ⅓-octave frequency spectrum to the nearest tenth with a maximum error of only 0.004, or 0.4%!

Since the maximum deviation of the actual mantissas from the nearest 0.1, 0.2, 0.3, and so on, was so insignificant, it was obvious that I could lay out a graph with *equally-spaced* horizontal divisions and label each successive vertical line with the actual ⅓-octave frequency. I therefore constructed another grid, this time using ¼″ × ¼″ square-ruled paper (often called "quadrille-ruled"). I made this graph 33 divisions long (x-axis), since there are 31 frequencies in the ⅓-

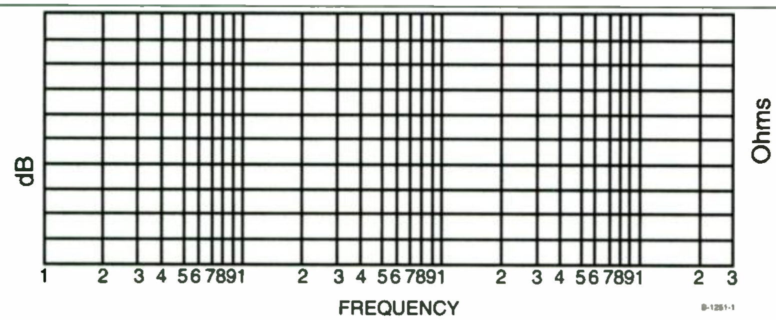


FIGURE 1: Standard semilogarithmic graph for plotting frequency response.

ABOUT THE AUTHOR

Louis McClure, after WWII service in the US Army Air Corps and graduation in 1949 from Central Technical Institute in Kansas City, enjoyed a long career as an electrical engineer with RCA, Hughes Aircraft, North American Aviation, and US Borax and Chemical Co. Developing an interest in audio in the early '50s, he has built many horn-type loudspeakers, and continues to do so in retirement. Out of an avocational interest in mobile homes, Mr. McClure pursued research that resulted in his being awarded two patents, and he has written extensively about mobile homes, including magazine articles and a book, *How to Build Low-Cost Motorhomes*.

octave frequency list, and ten divisions high on the y-axis (*Fig. 2*).

Beginning at the left end of the x-axis, I labeled each successive vertical line with the successive ⅓-octave frequencies. I saw I could also label the right vertical y-axis scale as ohms for plotting impedance.

The next logical step was to plot the ⅓-octave response of my horn on my new graph. Believe me, it was a breeze! Each ⅓-octave frequency corresponded almost exactly with the vertical line representing the logarithm of that frequency. I doubt that anyone could plot a logarithmically ruled frequency-response curve more accurately. Also, how much accuracy is really required?

Please don't let all this talk about logarithms and such discourage you from using this method. Many people enjoy knowing the logic behind the method, but it will work just as well for you whether you understand logarithms or not.

THE ADVANTAGES

This approach has several advantages over the conventional semilogarithmic method. First, it is much faster; second, it is much easier; third, it is probably more accurate; fourth, ¼″ square-ruled paper is more readily available than semilog paper; fifth, it is easier to interpret accurately; and sixth, it is more economical.

Now, when I wish to make a ⅓-octave frequency-response plot or an impedance plot of a speaker system, I use this method exclusively. However, I wish to caution you that it will work only for full-octave and ⅓-octave response plots, not for ½-octave plots.

This is no great disadvantage, however, since when you plot the frequency response of a speaker system in ⅓-octave increments, you obtain more points. This in turn gives a higher resolution of the speaker response, and the resulting curve is more realistic. Please feel free to make copies of this full-octave and ⅓-octave response graph for your own use if you so desire.

It is my sincere hope that this method will be helpful to you for use in your own projects, as it has been for me. Believe me, it works. Try it—you'll like it!

TABLE 2
LOGARITHMS OF ⅓-OCTAVE FREQUENCIES

⅓-OCTAVE FREQUENCY	LOGARITHM	PLOT AS:
16	1.204	1.2
20	1.301	1.3
25	1.398	1.4
31.5	1.498	1.5
40	1.602	1.6
50	1.699	1.7
63	1.799	1.8
80	1.903	1.9
100	2.000	2.0
125	2.097	2.1
160	2.204	2.2
200	2.301	2.3
250	2.398	2.4
315	2.498	2.5
400	2.602	2.6
500	2.699	2.7
630	2.799	2.8
800	2.903	2.9
1,000	3.000	3.0
1,250	3.097	3.1
1,600	3.204	3.2
2,000	3.301	3.3
2,500	3.398	3.4
3,150	3.498	3.5
4,000	3.602	3.6
5,000	3.699	3.7
6,300	3.799	3.8
8,000	3.903	3.9
10,000	4.000	4.0
12,500	4.097	4.1
16,000	4.204	4.2
20,000	4.301	4.3

MORE ABOUT LOGARITHMS

The common logarithm of a given number is actually the exponent of the power of 10 that corresponds to that number. Quite obviously, then, to provide equivalent powers of 10 for *all* numbers, almost all logarithms will be decimal fractions. In fact, all the numbers you find in the body of a table of common logs are just the fractional parts of the exponents. These are called the mantissas (derived in higher mathematics by means of infinite series). The whole-number part of the log (called the characteristic) *you* must supply according to where the number you are working with lies on the scale of the powers of the base 10. A table of some integral powers of 10 should make this clear:

$10^4 = 10{,}000$
$10^3 = 1{,}000$
$10^2 = 100$
$10^1 = 10$
$10^0 = 1$
$10^{-1} = 0.1$
$10^{-2} = 0.01$
$10^{-3} = 0.001$
$10^{-4} = 0.0001$, and so on.

Take the number 5040 as an example. If you look this up in a table of four-place logarithms, you find the mantissa is 7024. But to this fractional part of the log, you must add the integral part by seeing that 5040 lies between 1,000 and 10,000, or between 10^3 and 10^4. Therefore, the characteristic is 3, and the full logarithm is 3.7024. This is normally written as log 5040 = 3.7024. In exponent form, the equivalent notation is $10^{3.7024} = 5040$.

Now, suppose your number is 5.04. In looking this up in the table, you pay no attention to the location of the decimal point, but only the sequence of digits 5-0-4. You will find exactly the same mantissa, 7024. You then supply the characteristic, which is 0, since the number is greater than 1 (10^0) but less than 10 (10^1). You write log 5.04 = 0.7024.

As a final example, if your number is 0.00504, you again enter the table with the digit sequence 5-0-4, find the same mantissa, 7024, and add the characteristic, this time −3. But this does not mean the logarithm is the negative number −3.7024 (logarithms are never negative). It really means −3 + .7024, since your number is *greater* than 10^{-3} but less than 10^{-2}. When you have a negative characteristic, remember that it simply means a negative exponent, indicating a fraction between 0 and 1. Normally, you would write this characteristic as 7 − 10 (= −3), sandwiching the mantissa in between: log 0.00504 = 7.7024 − 10. (The −3 characteristic could equally well be expressed as 17 − 20, or 27 − 30, and so on.) If your calculation involves negative numbers, you simply affix the correct sign to the answer according to the rules for multiplication or division of signed numbers.

The way you determine the characteristic according to the powers of 10, coupled with the fact that the mantissa is always identical for the same sequence of digits, should help to clarify the cycles of the logarithmic scale on the x-axis in *Fig. 1*. The spacing (the scale of mantissas) is always the same within each cycle, whether from 1 to 10, 10 to 100, 100 to 1,000, and so on. A careful examination of the log table of mantissas also explains the "squeezing" that appears within each cycle of the log scale.

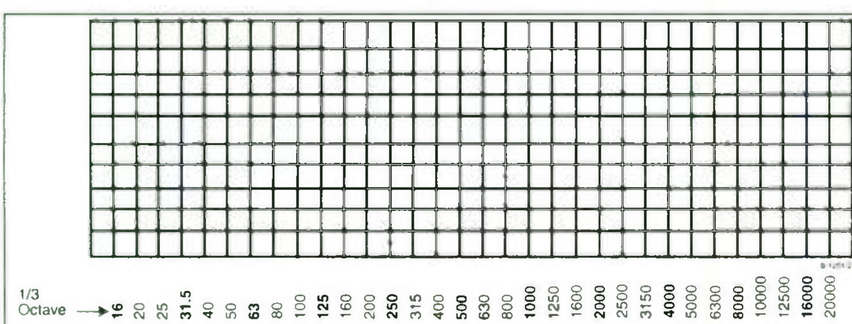


FIGURE 2: Full- and ⅓-octave frequency-response linear graph form on ¼″ × ¼″ square-ruled paper.

Life is too short to spend countless hours glued to your computer monitor without music. If you want low level, listenable sound, with a holographic soundstage on your desk, this design will not disappoint.

The Sammy Six Monitor

By Philip E. Abbate

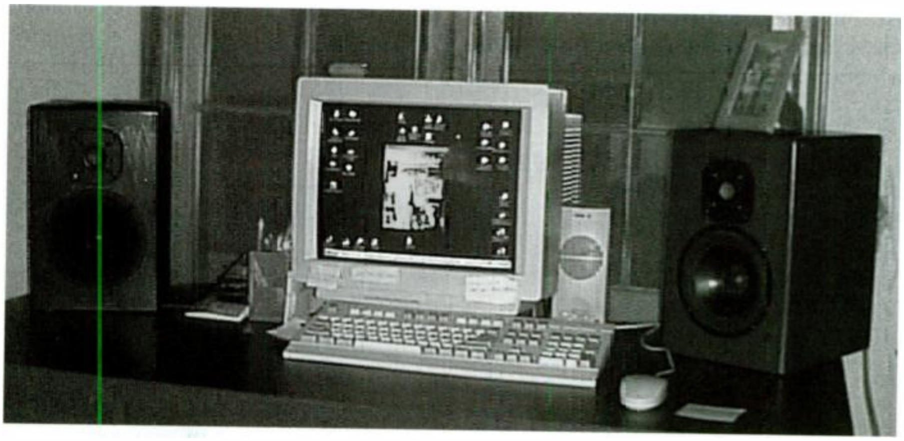


PHOTO 1: Completed speakers on author's desk.

I could not figure why my audio buddy Sam Papadas was so interested in the Focal tweeters in my home-theater speakers. I knew he was a soft-dome dude, but he interrogated me as though he were considering using the old-style rubber-surround Focal T90s himself. This was very clear when he bequeathed me two pairs of Focal T90ti-02 tweeters and one pair of Vifa P17WJ-00-08 midbass drivers that were collecting dust under a dresser at his house. Were there any strings attached? Oh yeah—I must build a box and crossover, and then subject them to his scrutiny. I accepted the challenge.

I wished to build another set of small near-field monitors to listen to during my increasingly long hours at work. I had some minor concerns about this driver complement. First and foremost were the nonshielded drivers affecting the monitor. That turned out not to be a problem with my 17″ Hitachi monitor at home (*Photo 1*) or the LCD on my laptop at work. My next concern was the sensitivity mismatch, the tweeter being much more sensitive than the midbass. That's what they make resistors for, right?

DESIGN BEFORE YOU CUT

After many sleepless nights of playing with BoxModel, I froze the design for a 12-ltr sealed box with an f_c of 72.9Hz. I could have squeezed more low bass out of those drivers with a ported design, but my crystal ball had a faint image of a bandpass passive sub supplying the bass foundation for this project. The sealed box would protect the midbass driver from overexcursion at the low frequencies without a detail-robbing series crossover capacitor. An added benefit of no bass was that my office mates would not be bothered much. The factory-specified Thiele/Small (T/S) parameters differed significantly from the T/S parameters I manually measured using the voltage-divider method. Neither set of measurements would take me far from my goal, as *Fig. 1* shows.

PUTTING THE PIECES TOGETHER

I was happy to get more use from my

I would like to thank Sam Papadas and Ed Scruggs of Audio Solutions for the raw drivers and use of the AudioControl analyzer. I'd also like to thank Bill Waslo for LAUD, and G.R. Koonce for sharing his knowledge on how to use it.

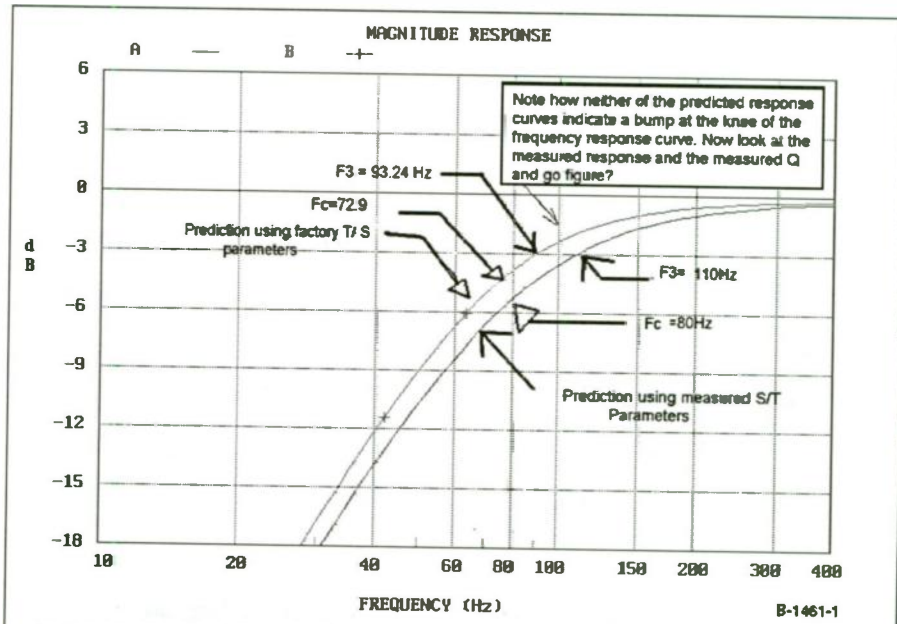


FIGURE 1: BoxModel predictions.

T90 router template. I recess the drivers into the front baffle before cutting it out from the uncut piece of ¾″ MDF stock. It's easier to clamp the uncut stock to the bench, and I have ample room to clamp the router over the place where I wish to make the recess. What's more, if I make a mistake, I can just redo the recess in another place and then cut the stock differently. I can use the spoiled spot on the inside of the box, or just hack it off. Hey, this isn't mass production; we are craftsmen, right?

The Sammy Six 13¾″H × 8¾″W × 11″D boxes are butt-jointed and glued. I

PHOTO 2: Stuffed box and drivers ready to assemble.

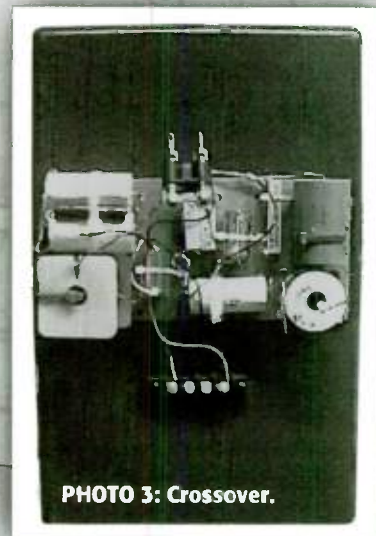


PHOTO 3: Crossover.

routed a ¾″ round-over on all but the bottom edges and used 3M® spray adhesive and staples to attach ½″ carpet pad to the back top and sides inside the cabinet (*Photo 2*). The carpet pad damps cabinet-panel vibration. I also stapled batting, obtained from Wal-Mart's sewing department, to the back of the cabinet for absorption.

Before I painted the box, I rubbed a diluted coat of water-based wood putty into the rounded-over and rough MDF edges. I found that after a light sanding, the wood putty keeps the end cuts from soaking up the paint faster than the mill-finished parts. After two brush coats of acrylic OOP's paint dried, I finished it off with a clear coat of water-based polyurethane for protection. Three stick-on rubber feet keep this small speaker from walking off the desk.

I used a four-terminal barrier strip on the rear of the box to connect the tweeter and woofer to the outside of the sealed box. This configuration (*Photo 3*) makes it easy to connect the computer or the crossover to the drivers during measurement and tweaking sessions. It is also easy to disconnect the tweeter and woofer for individual driver measurements. I used tie-wraps to fasten the final crossover components to a piece of pegboard, which is fastened to the back of the box with two drywall screws. I can then easily tweak away without having to open the box. When I give the speakers away, I will put the crossover inside.

NEW TOOLS OR NEW TOYS

This project was my first using LAUD and LspCAD. Both are available from Bill Waslo at Liberty Instruments (PO Box 1454, West Chester, OH 45071, Tel/Fax 513-755-0252, E-mail bwaslo@one.net), and both installed and ran perfectly on my 486/120 Windows 95 machine.

I bought LAUD primarily to be able to home in on problems by measuring what I'm doing. I also bought it to make professional graphs like *Fig. 2*, the spliced frequency-response graph. LAUD is just a toy unless you use it correctly. With skill and discipline, it can become your most valuable tool except for your ears.

But how do you identify measurement problems? Correlation, or the lack thereof, is a good starting place. I found that LAUD could make some pretty nice graphs, even when there is no sound coming from the speaker. A little correlation with the ear in this case can go a long way to keep you from fooling yourself. I was suspicious of what I actually measured in *Fig. 2* when I calculated

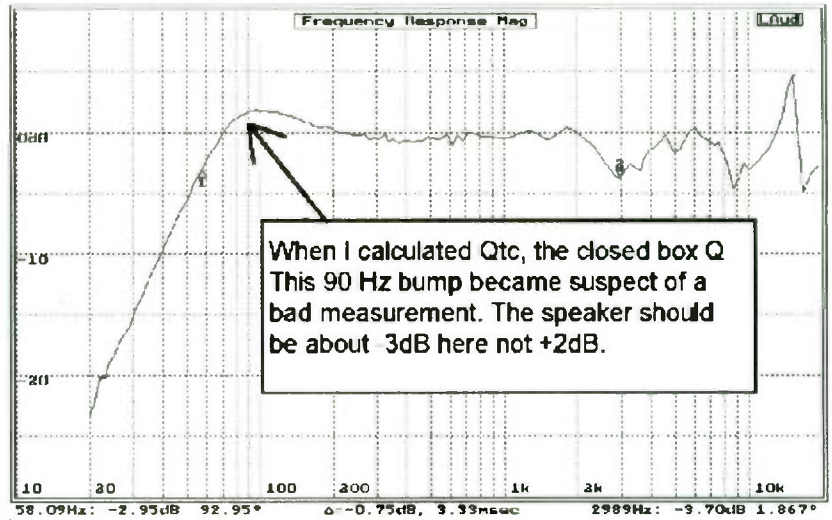


FIGURE 2: Spliced nearfield and 1m measurements. B-1461-2

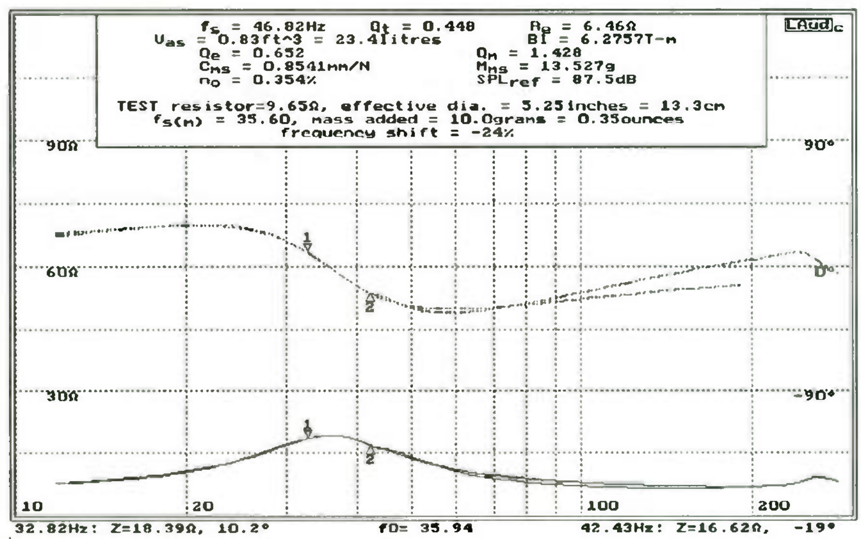
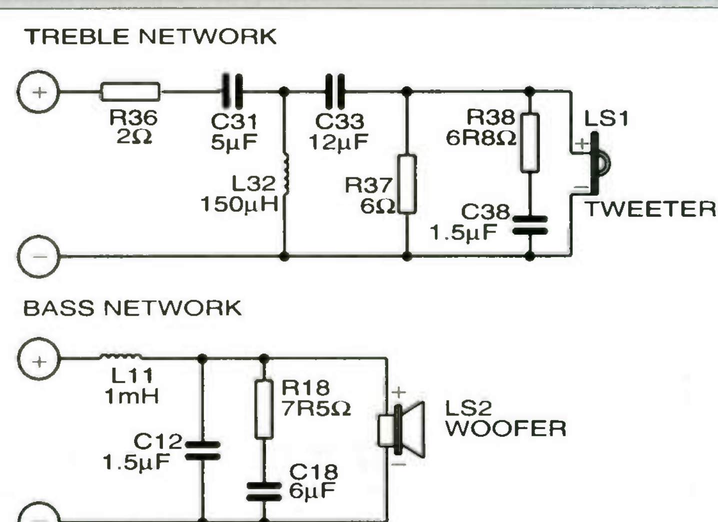


FIGURE 3: T/S parameters extracted with LAUD. B-1461-3



B-1461-4

FIGURE 4: Schematic for the Sammy Six two-way nearfield monitor.

the Q_{TC} (the Q of the closed box). (See sidebar.)

PRELIMINARY DRIVER MEASUREMENTS

I used LAUD to measure impedance and frequency/phase response of the tweeter and woofer while they were mounted in the enclosure. My fear that LAUD's maximum-length sequence (MLS) signal would blow the tweeter did not undermine my eagerness to measure it. I just hooked the amp across the tweeter and let 'er rip. If you are more paranoid about obliterating a tweeter than I am, you could put a 10µF cap in series with it, which limits the low frequencies going to the tweeter. Placing the CAL probe on the tweeter's hot lead will zero out the 10µF first-order filter.

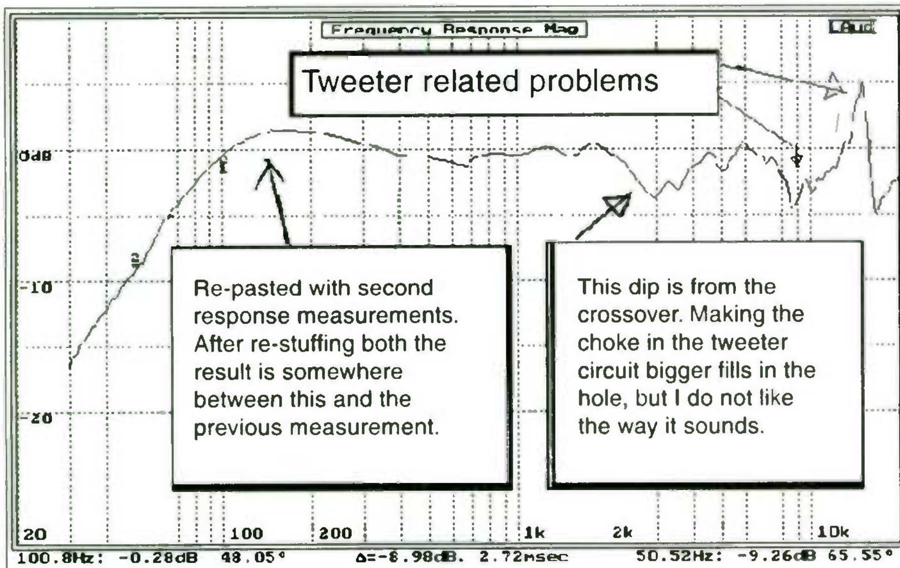


FIGURE 5: Blemishes revealed and explained. B-1461-5

I used LAUD to measure the (T/S) parameters of the free-air (*Fig. 3*) and closed-box woofer systems. No more tedious measurements and calculations required. These were closer to the manufacturer's specs, but many parameters still varied more than 20%. Proper discipline in setting up the tests is mandatory if you wish consistent results.

This was tricky, since I did not expect little things such as how I was holding the speaker to change the results as wildly as they did. I finally suspended the driver in the middle of the room and used the added-mass method to extract V_{AS}. Since it took only a minute or so to measure the T/S parameters with LAUD, I used it a lot. The specs were pretty consistent from minute to minute, but they varied somewhat from day to day. I finally discovered the cure: measure R_e with a multimeter and enter it manually into LAUD.

I was having a devil of a time making the LspCAD crossover-modeling program give me reasonable results until I read G.R. Koonce's "An 'IMP'ortant

Question" ("Ask *SB*," *SB* 6/98). It seems that the frequency/phase files work much better in LspCAD if I first use the Hilbert phase-shift transform in LAUD. I loaded the T/S parameters into LspCAD's crossover program, then linked LAUD's Hilbert-transformed, ASCII impedance and frequency/phase response files for both tweeter and midbass drivers into the program. I came up with the crossover in *Fig. 4* after much real and computer tweaking.

HEARING IS BELIEVING

The LAUD frequency-response graph in *Fig. 5* is the composite of a nearfield bass measurement spliced to a 1m on-axis measurement at about 700Hz. Declaring the 0dB line as the reference point, several anomalies are obvious. First and foremost is the nasty 5dB peak around 15kHz. It is a resonance in the tweeter, as is the 8kHz dip. They are obvious on the raw tweeter measurements and the waterfall plot in *Fig. 6*. Response evens out as you move off axis, but the dip at 3kHz is a crossover artifact.

I can practically flatten out the –3dB valley by raising the value of L32 to .4mH, or in steps, assigning values of .2mH, .22mH, and .27mH. I prefer the sound of the .15mH and .2mH chokes. This inductor need not be anything fancy. It only shorts out the residual low end that made it through the first capacitor, C31. A 22-AWG air-core will work just fine. Use all the money you save to buy CFAC inductors for the midrange.

The final departure from zero is the 150Hz, 2dB bump and gradual 12dB per octave acoustic rolloff at the bottom end of the graph. The bump looks like a high-Q ripple caused by a box that is on the small side. It is not evident in free-air driver measurement. The 6″ actually has a rising response above 1kHz in free air. The cause is a subject of heated debate on audio night. My favorite theory is that the bump results from the LP crossover on the top end of the 6″ combined with its acoustical rolloff.

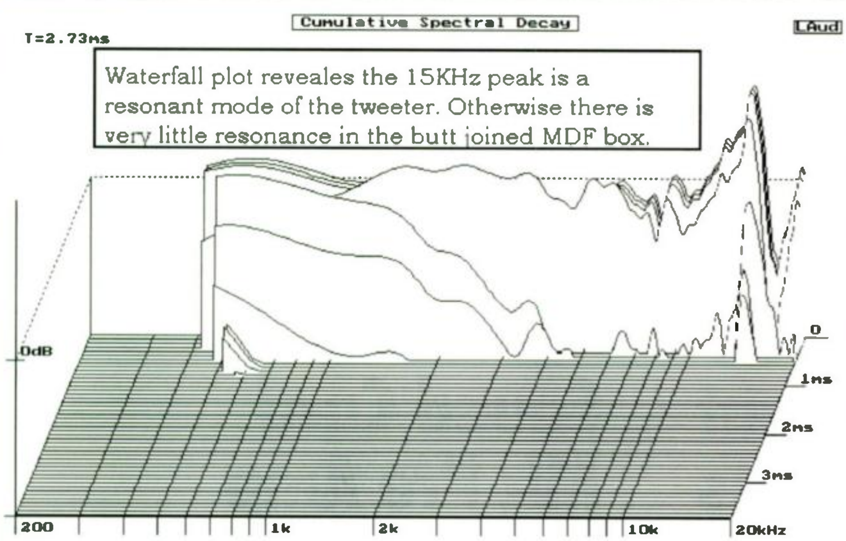


FIGURE 6: Waterfall plot of the Sammy Six.

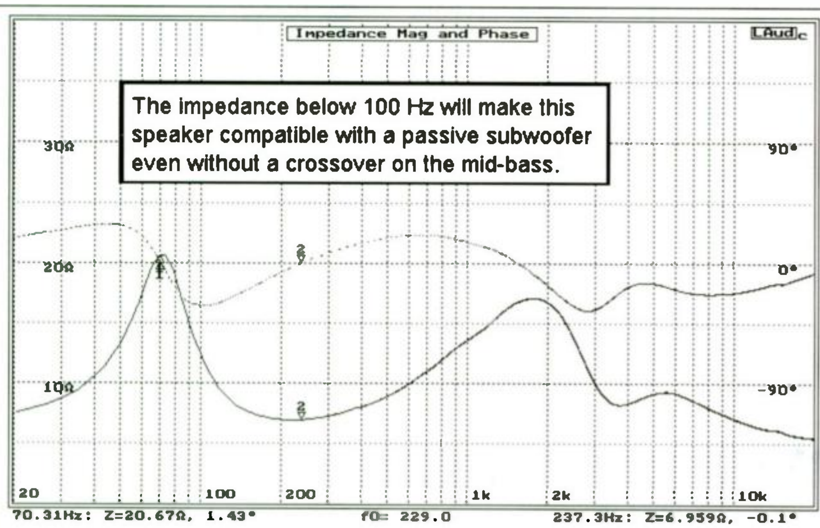


FIGURE 7: Impedance of midbass, tweeter, and crossover.

LAST MEASUREMENTS

LAUD makes easy work of generating an impedance graph. What I like best about *Fig. 7* is the low point at nearly 7Ω. This means that most amps will not have much trouble driving it in parallel with a passive subwoofer. Close examination of the region below 100Hz, where the subwoofer would operate, shows that the impedance is mostly between 10–20Ω. These small speakers will be happy mated with an 8Ω sub. And it needs it if you like bass.

I find the bass anemic, yet listenable. You get the overtones of all of the bass when running a CD player directly into a power amp. If you are using an amp with bass shelving control, a little boost brings the low end to life without a subwoofer. Either way, they play plenty loud for nearfield listening. They can fill my 12′ × 12′ office to a satisfying level with my active subwoofer, but they are beginning to show signs of strain when I push them. If you like to party with two turntables and a microphone, the Sammy Six ain't where it's at!

LISTENING TEST

Golden Palominos' *This Is How It Feels* album (Restless 7 72735-2) was one of my reference CDs at *Stereophile*'s Hi-Fi '97 and '98 shows. It was played on some of the industry's most highly rated equipment. It is deeply textured and rich, with many sounds and voices. I was playing track 5 on this system while sitting at my computer when I heard the telephone call-progress tone. I thought that my modem was dialing my internet-service provider (ISP). I could not believe that the subtle sound was in the music that I must have listened to a couple of hundred times. Track 6 is a favorite. Lori Carson is multitracking her voice in a low, sexy, almost pornographic way. This speaker in the nearfield-monitor mode lets her voice cut through the clutter like a siren's call cuts through the fog. I understood more words than ever before.

My wife Monica gave me a Walkman to take on the road with me, and I have become seduced by the sound of the open-air headphones playing at a low level. It is so easy to hear the detail, while the low SPL draws you into the music. These speakers mounted on my desk come pretty close to the sound of my AKG k-240 headphones. The character of the sound does not change as much when I switch from the speakers to headphones as does the perspective. The speakers are a little more laid back, and of course you get the full effect of the soundstage.

THE DILEMMA

What about that 90Hz bump at the knee of the HP filter in *Fig. A*? At first glance, I would assume it was related. It looks like Q_{TC} of 1 to 1.1. That does not correlate with the measured Q_{TC} or the Q_{TC} calculated from measured and factory T/S parameters. All those Qs are much lower. With LAUD, I measured Q_{TC} directly—it was in the .6 range. I measured f_s, Q_{TS} (from the LAUD T/S-extraction utility), and F_c (from the LAUD system-impedance utility) to solve for Q_{TS} using the formula $F_c/f_s = Q_{TC}/Q_{TS}$. With measured parameters, Q_{TC} is in the .55 range, and with factory parameters, it is less than .707.

The bumps shown in *Fig. A* theoretically should have been −3dB. I could not get the measured low-end frequency response to match the BoxModel predictions—even when using improbable combinations of measured and factory T/S parameters in a 12-ltr box, or severely undersized boxes! What was wrong?

I instantly suspected LAUD. I double-checked the nearfield measurement with Sam's AudioControl 3050 ⅓-octave real-time analyzer. There was still a bump (*Fig. B*), but now it was at 150Hz. (By the way, the 160Hz LED is off-scale in the figure.) I went back to LAUD again. This time LAUD was not the same as last time. What could be wrong? Had I tried to measure frequency response with the 10Ω series-resistor configuration used for impedance measurements? No.

It took an entire weekend of familiarizing myself with LAUD and some old-fashioned discipline to figure out what was going on. Seems I was fooling myself mixing up two dissimilar drivers in two dissimilar boxes! One thing for certain, LAUD tracks the AudioControl 3050 dead on. After removing some stuffing from one cabinet and adding it to the other, and keeping track of which driver is in which box, the end result was somewhere between the two sets of plots. Both cabinets' f_ss are now within 2Hz, and the Q_{TC}s are within 10%.—**PEA**

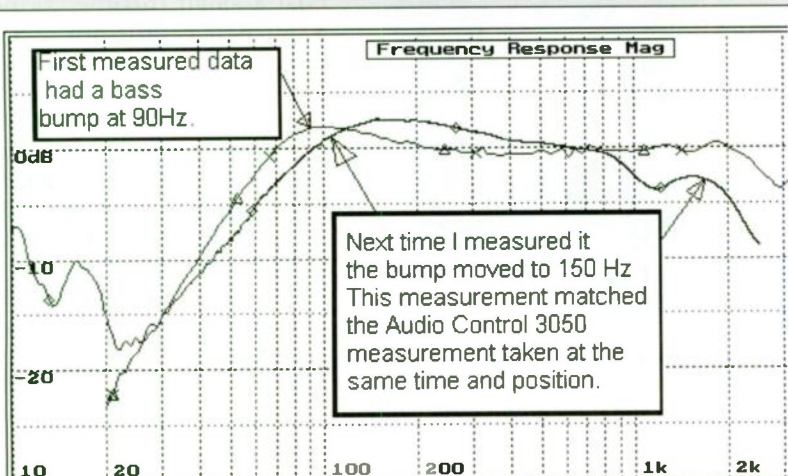


FIGURE A: The dilemma of the bass.

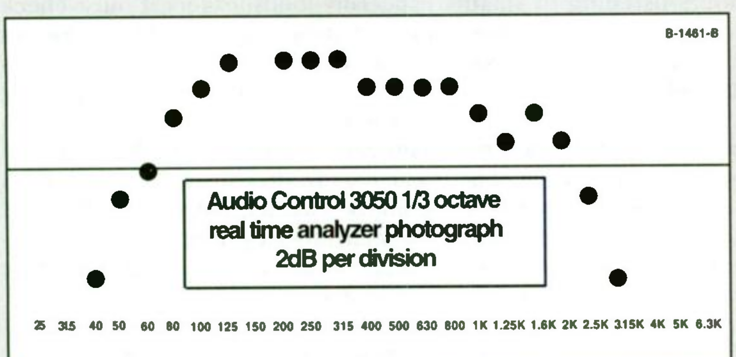


FIGURE B: AudioControl analyzer confirms LAUD—the bump is there.

This author's plan (replacing the shell, damping material, and some electronic components) for modifying a pair of small commercial speakers—B&W's DM302s—resulted in improved appearance and performance.

An Improved Mini-Monitor

By Fred Janosky

One day many months ago I was shopping for a small pair of loudspeakers to use in my office with my old, but rebuilt and modified, Advent Model 300 receiver. While I'm a speaker builder at heart, on this occasion I did not have time to design and build from scratch. While cost was also a factor, it makes no sense to listen to music all day on speakers that aren't pleasing.

LIKE AN OLD FRIEND

The Advent Model 300, with me since the 1970s and now born again, is still a pretty decent audio component even though it's not in the same league as my serious audio gear. In its lifetime, it spent time with me at college, at home, and even with my then future wife, not to mention all the traveling we did together (both my wife and Advent!).

It did duty as a preamp and later as a phono preamp in ever-growing audio systems. Once, for a short time, it even drove a set of the renowned LS3/5a BBC monitors and even high-output "party" speakers—extreme ends of the speaker spectrum. As a long-time, go-anywhere-music-is-needed unit, it is no wonder that this versatile little receiver outlived so many of my costlier higher-end audio components traded for the elusive ultimate audio system.

The author's modified DM302 with grille removed.

But now I simply needed a reasonable set of small speakers for my little Model 300. By this time, I had spent more than a few lunch hours listening to small speakers under favorable or not-so-favorable conditions in both mass-merchandise and specialty audio stores.

Frequently, one common problem emerged: an aberration that can best be described as "boxy" sound. Having constructed many small speaker systems, I am aware of the difficulty in eliminating such coloration. Because of the problem of controlling a driver's rear energy in a small space, small boxes are especially susceptible. There simply may not be enough volume to accommodate sufficient damping material to absorb the rear wave.

One particular lunch hour while visiting a friend's audio shop, I noticed something new: the B&W DM302. Let me admit that I've always had a fondness for B&W's designs. Before listening, my first thought was that the DM302s would probably cost a small fortune. Nope—$250/pair retail. But at that price, were they merely capitalizing on the fine B&W name?

It took but a few seconds of listening for me to realize that I was onto something special. I listened some more. Are these really that good, or am I dreaming? A quick comparison to another small, favorably-reviewed loudspeaker system quickly revealed the DM302's general lack of "boxiness," fine imaging, and definition, as well as extended, dynamic response. I took a pair home.

A LOOK UNDER THE HOOD

As with any new piece of equipment and especially loudspeakers, I must check everything out. The DM302's enclosures are disassembled by removing six screws located deep in the rear panel. (A long #1 Phillips-head screwdriver is required.) You can then pull away the front and rear panels after disconnecting wires from the tweeter and woofer drivers. I recommend that you note the wires' colors and terminal connections for future reassembly.

Upon close inspection, what B&W provides for the money is exceptional. Probably the most interesting and unique

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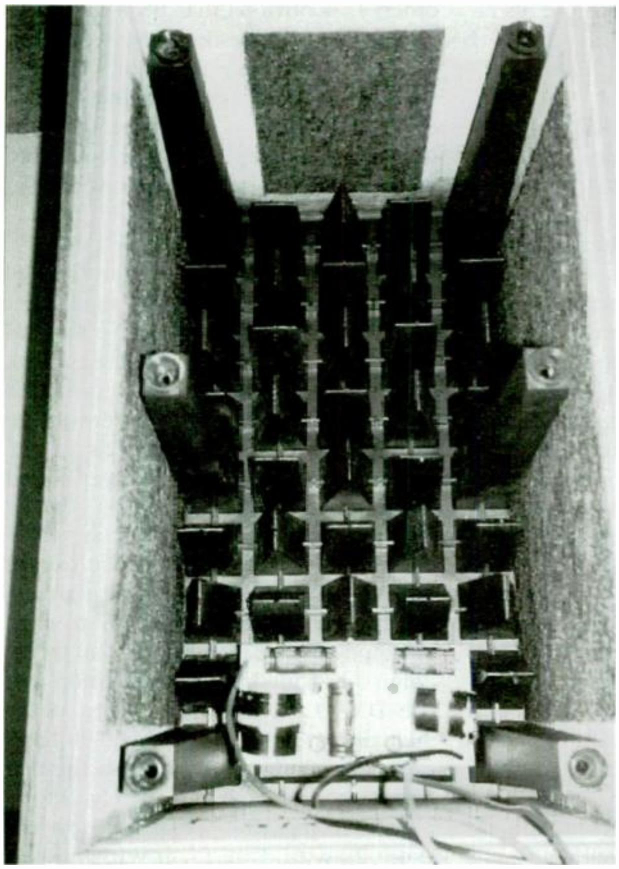
Fred Janosky is Product Manager at Wireless Technologies for GPU Telecom Services in Reading, Pennsylvania. Trained as an electrical engineer, his past includes ownership of an audio shop, work at a nuclear power plant, and later various engineering positions for GPU Energy. Fred enjoys music, biking, computers, hiking and traveling with his wife Mary and son Thomas.



part is the cast-molded one-piece rear panel that B&W calls "Prism." Made of strong plastic, it features internally spaced wedges, resembling those of an anechoic chamber, to break up standing waves. This panel has six "arms" that connect to the front panel so that the top, bottom, and sides—a unit made of 7⁄16″ particleboard—fit between the front and rear panels. The crossover is located on the rear panel along with the input binding posts (*Photo 1*).

The front panel, also cast-molded, is cleverly designed as well. Made of similar strong plastic, the baffle is tapered for minimized diffraction. The grille is designed to complement the baffle, maintaining the smooth, tapered antidiffraction characteristic. Included in the molded baffle is a rectangular port. The front panel with its clamped rear-mounted drivers makes for a stiff, solid baffle assembly (*Photo 2*).

Having built speaker systems for a number of years, I admire the elegant, well-engineered enclosure system and overall synergy of the entire implementation. The molded plastic front and rear panels simultaneously lower cost and greatly contribute to system performance while being elegant in form and function.

The particleboard "shell" (top, bottom, and sides), covered with the now common black embossed vinyl veneer, is accurately premachined with grooves to grip and position the front and rear panels. A precision V-groove machining process allowed the original enclosure to be manufactured from a single piece of material and then folded together to form

PHOTO 1: View into the new MDF enclosure with baffle removed. Note the matrix rear panel and stock crossover assembly. Damping panels were added, and electrolytics were changed to polypropylene. The Zobel network was mounted on the tweeter.

the enclosure shell. Almost all mid- and lower-priced speaker enclosures are now manufactured with this economical and efficient process.

I have only a minor gripe about the DM302 implementation: the use of relatively thin particleboard and vinyl finish. Most speaker builders I know would opt for a real wood finish and thicker panels. At this price and with the resulting fine performance, however, I shouldn't complain.

DRIVERS AND CROSSOVERS

The DM302 uses fine drivers. A 1″ soft-dome tweeter with a slightly flared faceplate fits precisely into the baffle, eliminating steps and edges that cause response ripples. A 5″ woofer with doped-paper cone, rubber surround, heavy-gauge stamped steel basket, large magnet, and long-throw motor makes for a really fine small woofer (*Photo 3*).

PHOTO 2: Front baffle with drivers removed.

The crossover, working at 3kHz, has higher-order slope rates, another design aspect that is rather unusual for a low-cost speaker system. While I did not measure acoustic rolloff rates, judging by the circuit configuration, I'd expect it achieves a 24dB/octave acoustical rate. Most important, the drivers audibly integrate very well with each other. It is obvious that B&W took the time to properly design the crossover, a critical component.

The capacitors are very tight-tolerance electrolytics. Air-core and iron-core inductors and a cement-cast resistor constitute the rest of the crossover components.

PHOTO 3: DM302 drivers.

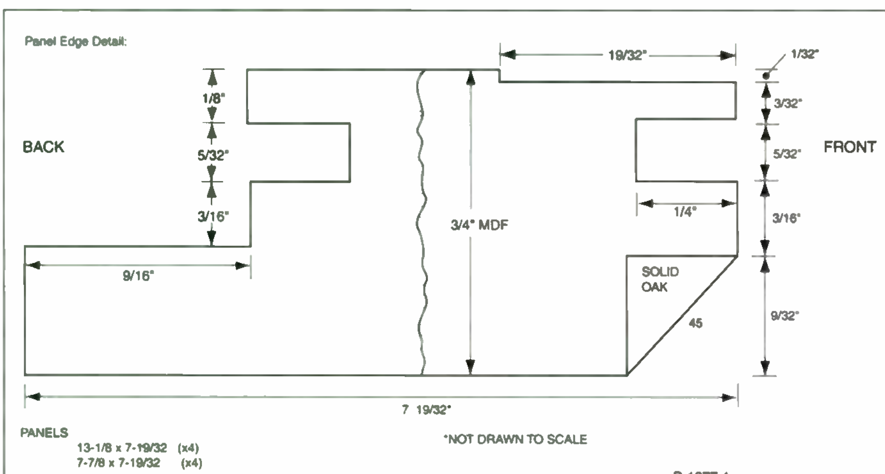


FIGURE 1: Enclosure panel detail.

GREAT EXPECTATIONS

Setting up the DM302s with my Model 300 in a spare bedroom produced rather amazing results. I listened to several recordings and was always pleased with the overall presentation. It seemed that the receiver and speakers were a fine match, especially as the DM302's high efficiency made the small receiver sound more powerful.

Considering the cost of the system, I could not fault the performance except possibly for the highest frequencies, which had a slight tendency toward brightness. A small tweak of the treble control provided the cure. I noted that the DM302's response accentuates midrange presence. My Model 300 has a laid-back-sounding midrange, so the pair complemented each other nicely.

As time passed, I wondered how the DM302s would perform with newer, more refined electronics. I moved the pair to my living room, a much larger space, connected them to more serious electronics, and played some favorite CDs.

The DM302s again provided a fine performance. Their ability to play loudly without break-up is impressive, as is their wide dynamic range. As small speakers, they do have limitations, which you can find if you try. But under most listening conditions, you'd think they were much larger in size.

It takes a while to become really familiar with any new piece of audio equipment. While they are fine performers, going beyond what you'd normally expect at their price, I came to realize that the DM302s do have room for improvement. Although diminished at lower levels, I noticed an aberration in the upper-bass/lower-mid area: a bit too "full" sounding, with a slight bit of a "glare." The highs were good, but not quite as pristine and detailed as I've heard in my listening room. Again, brightness in the topmost octave was evident; switching in my preamp's tone controls with treble control at the 11 o'clock position provided some cure. Midrange balance remained forward.

I was not overly impressed with the results of performing the "knuckle test" (knocking on the sides of an enclosure) on the particleboard side panels. The re-

TABLE 1
PARTS LIST

Felt Tweeter Rings (2) (from Madisound)—for experimenting; not required
Fiberglass insulation (as necessary)—use 1½″ on rear, top, and side panels
¾″ preveneered MDF, 9″ × 8′ machined and assembled to specifications
Polypropylene film capacitors, 2 each: 4.7µF and 10µF, 2%
Mylar film 2µF capacitor and series 5Ω 10W resistor across tweeter
#1 Phillips-head extra long screw driver, Husky #90044 (from Home Depot)
Yellow wood glue
Strip caulking (optional, but recommended)
Strap clamps to hold panels while glue sets up
⅛″ latex-backed carpet and adhesive (optional for side-panel damping)
Your choice of wood stain and finish

sulting "knock" impulse sounded as though it might be related to the same frequency range in which I heard the "fullness" noted earlier. This made me wonder if performance would improve if I substituted a more rigid shell for the existing thin particleboard unit. An improved shell could also provide a fine real wood finish instead of the stock black vinyl.

Although it was some time later that I read *Stereophile's* review (Vol. 20, nos. 10 and 12) of the DM302, I learned of its selection of the DM302 for a special Editor's Choice Award. The review provided measurements, subjective and objective evaluations, and useful input, while encouraging ideas for a modification plan.

COMMITMENT

With more passing of time, and after some mental wrangling, I decided to make a new enclosure shell for the DM302s. The DM302s appeared to be ideally suited for such an undertaking, and my curiosity was getting the better of me.

Increasing the shell thickness meant having an exposed front edge, since the front and rear panels were designed to completely cover the original particleboard shell. A wider front edge should maintain the taper of the cast baffle so as to destroy neither antidiffraction properties nor appearance. If I chose preveneered ¾″ MDF for its acoustical properties, the tapered edge

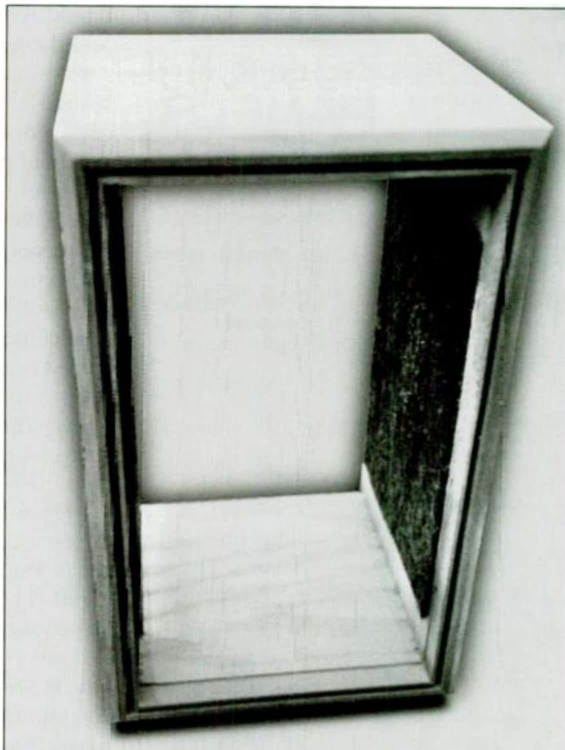


PHOTO 4: New MDF enclosure shell.

would require a method to hide the exposed edge.

Considering the rear Prism panel, I would make the new shell to cover the exposed side portion for better appearance and precise fit. Hence the shell panels would need to be about ⅝″ deeper externally while maintaining the internal dimensions (*Photo 4*).

Producing the factory shells required precision machining techniques. Thicker replacement shells with real wood finish are even more involved, considering the requirements. Precise measurements, finely adjusted power equipment with sharp blades, and patience and care are absolute musts.

Figure 1 shows front- and rear-panel edge-machining detail for the enclosure shells. Since the new enclosure has an external depth of 7¹⁹⁄₃₂″, you can initially machine one long panel of 8′. The top and bottom panels are 7⅛″, while the side panels are 13⅛″. With joints cut at 45°, you can glue together and align the new panels squarely by inserting the front and rear plastic panels and using two strap clamps until the glue dries.

CLEAR IMPROVEMENT

With the new MDF shells completed, the "knuckle test" produced better results than the first time. To further improve panel damping, I bonded ⅛″-thick latex-backed carpet (approximately 6″ by 9″) to the side panels. This gave still better results. (Now is an appropriate time to stain and finish the shells.)

The original shells use a rubber gasket, placed in channels cut in the edges, to provide an air-tight seal with the plastic baffle and rear panels. You can easily remove this gasket material from the original shells and use it again with the new ones. As an alternative, and I recommend this, you can place strip caulking in the edge channels to provide a seal and bonding.

After reassembly, I conducted more listening tests. To my ears, performance had improved. The bass had more depth and extension. Yet, some areas remained requiring attention. I made several trips carrying the speakers, now noticeably heavier, between my workshop and listening room to perform and then validate incremental modifications.

I next focused on improving HF performance. I substituted polypropylene capacitors for the two electrolytics (4.7 and 10µF) in the tweeter crossover, and these required break-in time. Transient detail audibly improved. I placed a felt tweeter ring around each tweeter. To my surprise, HF performance seemed to improve somewhat, but the off-axis response seemed less desirable—the sound was too "dead." Eventually I removed the felt rings. In time, I realized that the rising response in the last octave did not suit me. I added a series network of 2µF and 5Ω across the tweeter. This RC network not only flattens the tweeter's rising impedance, but reduced power to the tweeter at higher frequencies to help level its rising response. The upper-end response became more pleasing, with no loss of detail.

DAMPING EXPERIMENTS

I spent time experimenting with damping material, eventually replacing the original poly-fill batting with fiberglass, and later adding more fiberglass, 1½″ thick, along the inner surfaces of both sides. This almost entirely eliminated the upper-bass "over-fullness" as well as the "glare" noted earlier.

This is an area where experimentation is required. Many small monitors seem to be designed with a slight rise in upper bass to produce a "large" sound. While I prefer a flatter upper bass, you may prefer the "warmer" sound resulting from some upper bass boost. The additional fiberglass also helped prevent mid frequencies from escaping from the front-mounted port, while low bass remained quite robust for a small system.

During the modification process, as one area improved, others needing improvement seemed to stand out all the more. This makes the process time-consuming and sometimes tedious, but interesting and necessary. You may be tempted to go further and replace the remaining crossover components with costlier devices, but I'd generally discourage doing that without evaluating the results achieved thus far.

Changing inductors might change series resistance, affecting the Q factor and overall system performance. Physically larger inductors would also pose greater placement problems if electrical interaction is to be minimized. Yet, I would still encourage you to experiment appropriately in tweaking any design for best results in your own application, especially if advanced measurement and analysis tools are available.

One potential improvement dealing with rear panel damping remains. I'd opt for a better-damped rear panel. What's needed, however, is a form of dense rubberized material for filling the rear panel's prism wedges from the outside of the cabinet. Ideally, this material would pour into the wedges and then set itself up to remain in place, yielding improved knuckle test results. I'm still searching for such a material. Let me know if you've found a material that meets these requirements.

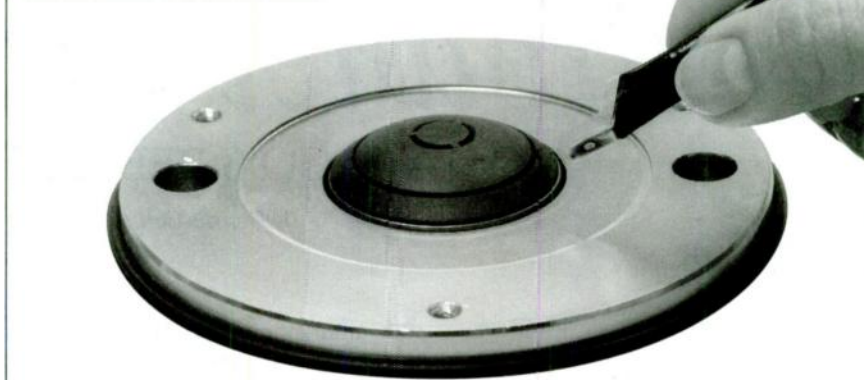
THE FINAL RESULT

By now, I was pleased with the modified B&W DM302s. Listening tests were fading into pure musical enjoyment. Voices took on a higher level of realism, clarity, and detail; imaging and spaciousness were awesome, and the sound had a better spectral balance. When I used the system with various components, differences in electronics were very noticeable. The bass seemed to go deeper than before, often making listeners think much larger speakers were playing. Considering bass response and overall performance, I found that the use of very sturdy, well-anchored stands is imperative if the DM302s are to perform at their best.

Do they have a music preference? I've long held to the belief that reasonably accurate speakers with flat response are likely to sound good with the widest variety of music. Yet I admit that many of the speakers I've used, including some highly respected expensive commercial models and some I've constructed, have sometimes favored one musical genre over another in my listening room. This is true of my modified DM302s. While they give a pleasing performance on almost all material, they really come alive with complex, well-recorded classical music, as well as recordings made in intimate acoustical venues.

The modified DM302s are a great find whether you're on a budget or not. Possibly their greatest achievement, like many costlier high-end speakers, is their ability to convey exceptional imaging and sense of space. As a bonus, the "little boxes" now look and feel like more expensive speakers, with their real wood finish and additional heft. While I'm obviously pleased with the modified DM302s and probably somewhat biased, they provide musical enjoyment far beyond the money invested.

Interested readers may contact Audio Arts concerning availability of precision-machined, ¾″ preveneered unfinished oak MDF panels with tapered, hardwood front edges. Panels have lock-miter joints for easy and accurate assembly. Eight panels are provided to make a pair of shells for the DM302 speakers. E-mail audioarts@enter.net or write Audio Arts, RD2, Wernersville, PA 19565.



Product Review

TOM YEAGO'S REBUILT AR-3*a*

By Dennis Colin

TEST DRIVE

This classic three-way with 12″ (or so) sealed-box woofer, dome mid, and dome tweeter needs no introduction; neither does the massive rebuilding effort by Tom Yeago, presented in great detail (*SB* 6/97–3/98). The cabinets look beautiful—massive and well constructed, a nostalgic delight to these eyes.

LISTENING TEST SETUP

My equipment includes a Nakamichi AV-1 receiver (100/ch), Yamaha CDC755 CD changer, Yamaha KX-W592 cassette player, and Miracord turntable with Shure R700E cartridge.

The listening room is approximately 20′ × 18′ × 8½′ (≈3000ft^3), and is moderately damped with large stuffed chairs and couch, 10′ front-wall drapes, and full carpet. Rear and side walls are reflective, but dispersed by doorways and a stairwell. The wood floor is rigidly supported. The room sounds very good with speakers, including the two-way Linaeum with 360° ribbon tweeter (Radio Shack Optimus Pro-LX5), the classic A/D/S 300C mini-monitor, and my home-built bipolars with 10″ Focal woofer and coincident mid/tweeters.

I placed the modified AR-3*as* on 9″ stands, as Mr. Yeago recommended. They were about 3′ from their rear-facing (front to the listener) wall and 5′ from the side walls.

TABLE 1
SOURCE MATERIAL

LPs

- *The Blue Danube*, Ormandy, Philadelphia Symphony Orchestra—Columbia MS6217
- *Mozart Symphony No. 36*, Istvan Kertesz, Vienna Philharmonic Orchestra—Super Analogue Disc, KIJC 9128
- *Blues, Ballads, and Jumpin' Jazz*, Lonnie Johnson and Elmer Snowden—Analogue Product APR 3001

CDs

- *Ocean Front Property*, George Strait, MCA MCAD-5913
- *Natural High*, The Commodores—Motown MCD 08014 MD
- *Rhapsody in Blue*, Gershwin—Mercury 434341-2
- *Tango*, Julio Iglesias—Columbia/Sony CK67899
- *Marches in Hi-Fi*, Fiedler, Boston Pops Orchestra—RCA 09026-61249-2
- *Two Fisted Mama*, Katie Webster—Alligator ALCD4777
- *Stradivarius on Gold*—Cisco GCD 8001

CASSETTES

- *Blue*, LeAnn Rimes—Curb D4-77821
- *Toccata and Fugue in D Minor*, Bach, Virgil Fox

FIRST IMPRESSIONS

- Very good sound on the strings and horns of *The Blue Danube*, excellent violin sound. (See *Table 1* for recordings used.)
- A frequency imbalance or resonance that imparts a somewhat hollow, megaphone-like quality to voices; also a colored upper bass effect.
- Very good deep bass, both clean and powerful.
- Very good on pipe organ.
- Excellent dispersion; the sound is remarkably consistent all around the room.
- Nice, full, natural stereo imaging, due to the foregoing.
- Good power handling; one woofer bottomed out only once when I clipped the 100W/ch amp on an 18Hz organ tone—but the room shook long before that volume level! By the way, I heard no 18Hz distortion except for the overload.

SPECIFIC RECORDING IMPRESSIONS

1. *The Blue Danube*—very good except mid-bass; excellent imaging.
2. *Rhapsody in Blue*—good reproduction of midrange and treble, somewhat "tubby" with bass instruments.
3. LeAnn Rimes, whose voice is hauntingly musical and naturally recorded, sounded "hollow" on the AR-3*as*.
4. Lonnie Johnson's acoustic guitar had less natural "snap" compared to the other speakers.
5. George Strait (very clean country band recording)—very nice guitars and violin, bass and drum detail somewhat lacking, voice somewhat hollow.
6. *Toccata and Fugue in D Minor*—very nice, full, deep, clean pipe-organ reproduction.
7. *Marches in Hi-Fi*—excellent strings and horns, outstanding imaging.
8. *Stradivarius on Gold*—I heard a buzz on one fairly high-pitched violin note, played moderately loud. I think it came from the midrange driver on one speaker (the same one sent for measurement). Prior to the buzz, I heard a resonant emphasis at this note's frequency.

COMMENT

My memory of the original AR sound dates back to 40 years ago, when my father owned a pair of AR-2s. But, I think the sound of Tom Yeago's redesigned AR-3*as* compared fairly well with the originals, but with much more power-handling ability, and better ultra-low frequency accuracy (the latter, I think, due to F3 and Q of 35Hz and 0.5, as compared to the original 42Hz and 0.9).

I experimented with the mid and tweeter level pots; they didn't change the basic sound quality much. Overall balance sounded best with them up full, so that's where I left them. Note that the original AR-3*as* were flat (on-axis, ±2dB or so from 42Hz–20kHz) with the pots up full. AR recommended a mid setting, with gently falling high-frequency response, to "simulate the absorption of a concert hall," but this is contrary to their own (correct) assertion that you judge instrument tonality based on first-arrival (direct on-axis) speaker sound and about the first 50ms of reverberant decay (the "Haas effect fusion time").

I believe these speakers can benefit significantly from a crossover redesign and real-time analyzer. Since these units were designed for consistent reproduction on- and off-axis, a single mike position, say 5′ on-axis, should yield measurements that correlate well with sound. I think that the modified drivers have different enough relative sensitivities (and possibly impedances) to cause crossover anomalies. Or, particularly considering the violin note-resonance and buzz, the midrange driver may need more mechanical damping.

SUMMARY

These speakers are rock-solid rugged, handle high power without noticeable distortion down to at least 18Hz, and have very good deep bass response, and smooth, extended highs.

I think some crossover or midrange driver work can change these good-old AR-3*a*s into state-of-the-art units, even by today's standards. This speaks well for a product originally designed 40 years ago, and for Mr. Yeago, who meticulously rebuilt these drivers with today's materials.

TESTING THE AR-3*a* REBUILD

By Joseph D'Appolito

I ran a series of impedance, frequency response, and distortion tests on the AR-3*a* rebuild by Mr. Yeago. *Figure 1* is a plot of the system impedance magnitude and phase. The impedance magnitude peak at 33.1Hz indicates the system's closed-box resonant frequency. In the low-frequency range, an impedance minimum of 5.9Ω occurs at 90Hz.

The peak of 12.4Ω at 300Hz is due to a parallel resonance formed by the interaction of the low- and high-frequency crossover networks. Impedance magnitude falls below 3Ω above 5kHz. Impedance phase lies between +46° to −52° over the full-frequency range. This may be a difficult load for some tube amps.

Before making frequency-response tests, I needed to determine an appropriate reference axis for those tests. It is common practice today to align all drivers vertically for the most uniform horizontal coverage. The tweeter is usually placed at ear height for a seated listener. In this case, the tweeter axis is the appropriate test axis. The three AR-3*a* drivers are arranged on the baffle to fill the available space. There is no obvious design axis. I chose the midrange driver

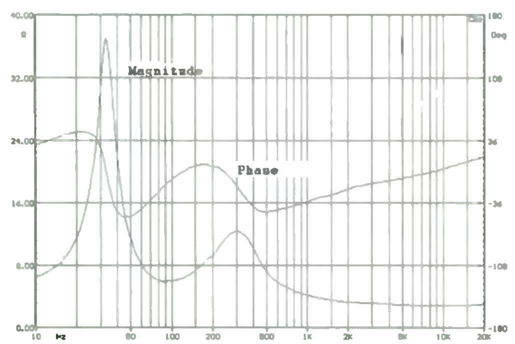


FIGURE 1: System impedance.

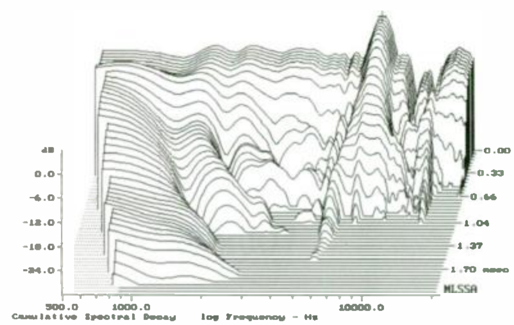


FIGURE 3: Cumulative spectral decay.

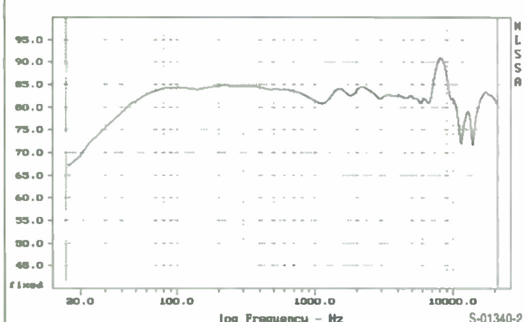


FIGURE 2: Frequency response on midrange axis at 50″. Enclosure vertical.

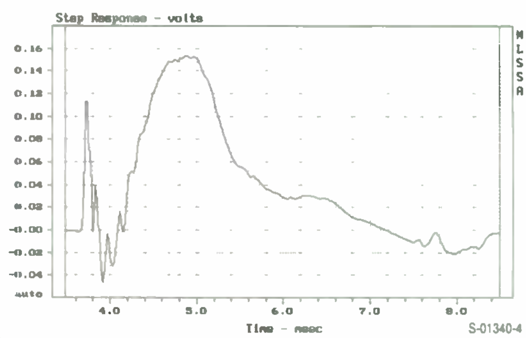


FIGURE 4: Step response.

axis as the reference axis for the frequency-response tests.

FREQUENCY RESPONSE

Figure 2 displays the on-axis frequency response of the AR-3*a* rebuild. This curve is a composite of the quasianechoic response data above 200Hz taken with the microphone placed on the midrange axis at 50″, combined with near-field woofer data below 200Hz to get the complete curve. The plot is normalized to 1m distance to get system sensitivity.

I left the midrange and tweeter level controls set to the levels selected by Mr. Colin in his review. Sensitivity averages 82.7dB SPL/2.83V/1m in the two octaves around 1kHz. This is quite low. More typical values for closed-box systems are in the range of 85–88dB.

The low-frequency −3dB point is 51Hz. Frequency response is relatively smooth out to 7kHz. Beyond that point, however, there is an 8dB peak in tweeter response at 8kHz followed by severe breakup modes in the 10–15kHz region. Another view of this behavior is seen in the cumulative spectral-decay response (*Fig. 3*).

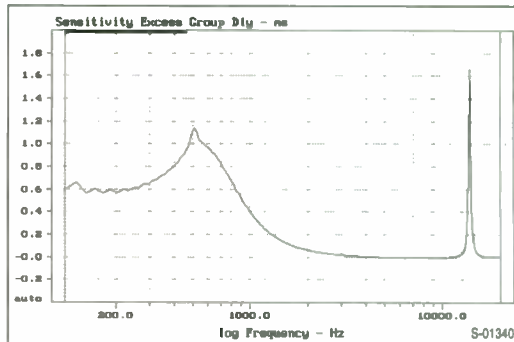


FIGURE 5: Excess group delay referenced to the tweeter.

The cumulative spectral decay (CSD) measures the frequency content of a system's decay response following an impulsive input at time zero. Ideally, a loudspeaker's impulse response should die away instantly. Real drivers, however, have inertia and stored energy that take a finite time to dissipate.

In *Fig. 3* the first 2.5ms of the CSD are shown with a total dynamic range of 33dB. On this plot, frequency increases from left to right, and time moves forward from the rear. The first slice at 0.00ms is the system frequency response shown in *Fig. 2*.

The response peak at 8kHz is the start of a long resonant decay mode in the tweeter, lasting about 1.5ms. This probably accounts for the etched hardness heard by Mr. Colin when listening at higher volume levels.

Figure 4 is a plot of system step response. The initial sharp positive peak indicates tweeter arrival, followed by the more broadly peaking woofer arrival, about 1ms later. Midrange arrival time is not obvious from this plot. The woofer and tweeter are connected with positive polarity, but the system is not time coherent.

Driver time offset is examined with greater precision in *Fig. 5*, which is a plot of excess group delay versus frequency referenced to the tweeter's acoustic-phase center.[1] In a time-coherent system this plot would be a flat line. Above 10kHz excess group delay is essentially zero, as it should be, since it is referenced to the tweeter in this frequency range. The curve rises below 2kHz to a peak of 1.1ms at 500Hz and then falls to a level of 0.6ms below 200Hz.

The relatively flat region between 2–10kHz indicates that the tweeter and midrange acoustic phase centers are aligned. This is a direct consequence of the 6dB/octave crossover used between the tweeter and midrange, and it is also why you see no distinct midrange arrival peak in *Fig. 4*. The B2 500Hz crossover causes the peak at 500Hz. Below 200Hz the woofer is delayed relative to the tweeter/midrange pair by 0.6ms. The sharp peak in excess group delay at 14kHz is caused by the previously discussed tweeter breakup, which produces a rapid build-up in tweeter phase, as in the excess phase plot (*Fig. 6*).

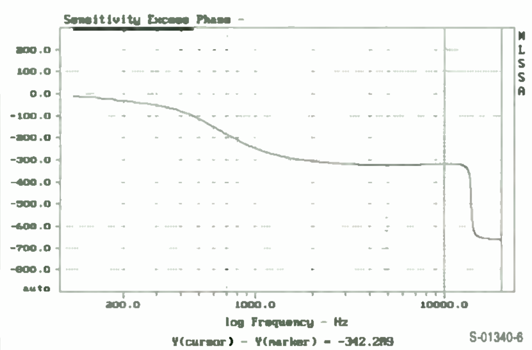


FIGURE 6: Excess phase.

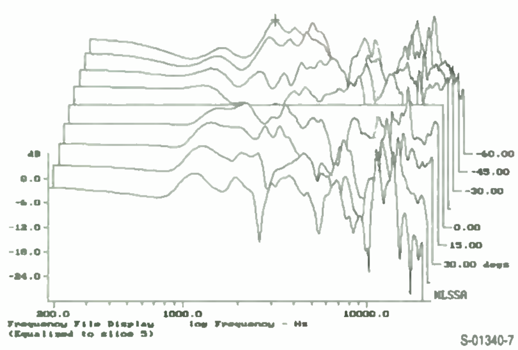


FIGURE 7: Polar response–horizontal position.

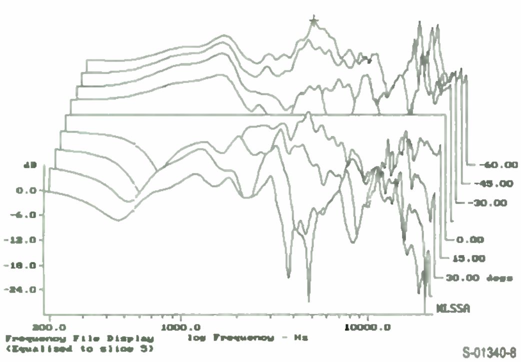


FIGURE 8: Polar response–vertical position.

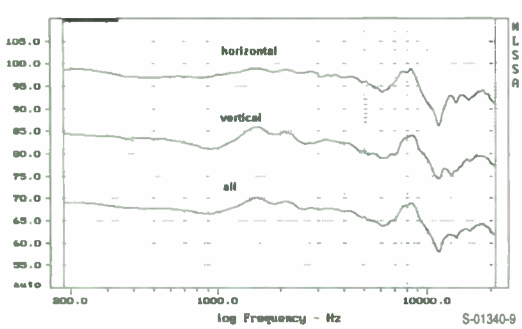


FIGURE 9: Power responses.

SYSTEM POLAR RESPONSE

In use, you can place the AR-3*a* horizontally on a bookshelf or vertically on a stand. For this reason, horizontal polar response data was taken over ±60° in both orientations. I placed the microphone on the midrange axis at a distance of 50″. All off-axis plots are referenced to the on-axis response that appears as a straight line at 0.00°. Thus, the curves show the *change* in response as one moves off-axis.

Figure 7 is a waterfall plot of polar response in horizontal orientation taken in 15° increments from 60° left to 60° right when facing the speaker. Frankly, these curves are a nightmare! The odd placement of drivers coupled with the deeply recessed baffle causes all kinds of diffraction and interference problems. Direct-field spectral balance will change markedly as one moves off-axis.

Figure 8 is the waterfall plot of polar response taken in the vertical position. These curves also show extreme off-axis variations in response.

The poor off-axis response will degrade imaging, but not necessarily perceived frequency response. The polar response data measures only the direct-field response. However, the perceived spectral balance of a loudspeaker is a function of both direct and reflected sound. All sound arriving at the listener's ears within the Haas fusion zone (5–40ms) will go into the subjective assessment of a loudspeaker's frequency response.

In this regard, *Figs. 7* and *8* may present an unfair view of the rebuilt AR-3*a*'s performance. The original AR-3 was designed for uniform power response. In semireverberant rooms, power response is a good measure of perceived spectral balance and is determined by averaging the polar response data over the full range of 120°.

Figure 9 shows three different averages. The "horizontal" and "vertical" curves are averages of the data shown in *Figs. 7* and *8*, respectively. The "all" curve averages both. All averages fall within a ±2.5dB envelope out to 9kHz. In this range, power response is quite acceptable. Above 10kHz response shelves down about 5dB.

DISTORTION TESTS

I ran harmonic distortion tests at an average SPL of 90dB at 1m. *Figs. 10* and *11* show second- and third-harmonic distortion levels in dB SPL versus frequency in ⅙-octave steps.

I also plotted system frequency response on these figures, with worst-case distortion levels shown in the upper left-hand corner of the graphs. This distortion level occurred at 70Hz. Above 100Hz distortion fell below 1% on average, although there were occasional blips of second harmonics into the 2–3% range. Above 2kHz, harmonic distortion tends to be higher than you have seen in most of my earlier test reports.

In the intermodulation distortion test

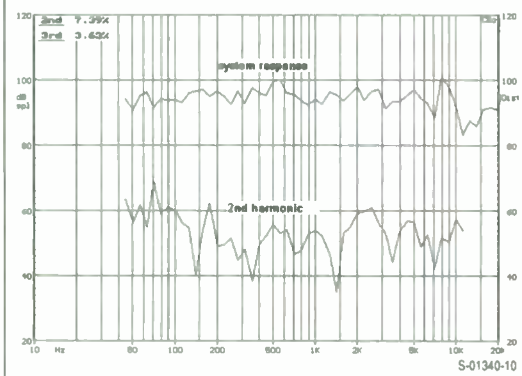


FIGURE 10: Second-harmonic distortion at 90dB SPL/1m.

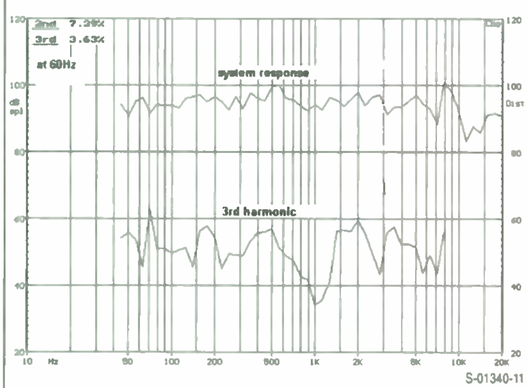


FIGURE 11: Third-harmonic distortion.

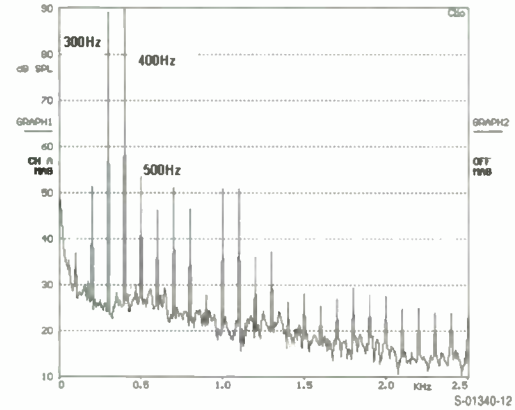


FIGURE 12: Woofer intermodulation distortion.

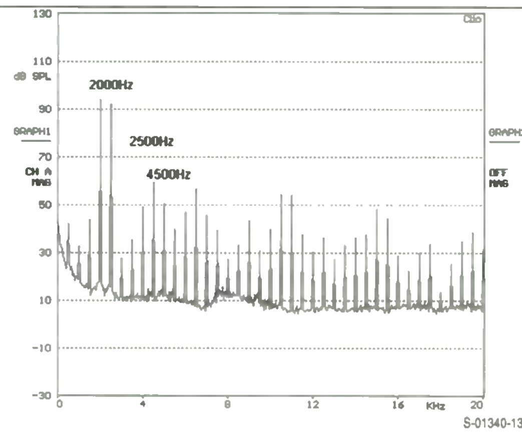


FIGURE 13: Midrange intermodulation distortion.

results (*Figs. 12–14*), two nearby frequencies are input to the speaker. Intermodulation distortion creates output frequencies that are not harmonically related to the input and are much more audible and annoying than harmonic distortion. Let the symbols f_1 and f_2 represent the two frequencies used in the test. Then a second-order nonlinearity will produce intermods at frequencies of $f_1 \pm f_2$. A third-order nonlinearity generates intermods at $2f_1 \pm f_2$ and $f_1 \pm 2f_2$.

I examined woofer intermods first by inputting 300 and 400Hz signals at equal levels. I adjusted SPL with the two signals to 90dB at 1m. The two longest lines in the rebuilt AR-3*a* output spectrum (*Fig. 12*) represent the input signals. The primary distortion products and where they come from are:

200Hz = 2 × 300 – 400 (third-order)
500Hz = 2 × 400 – 300 (third-order)
700Hz = 300 + 400 (second-order)
1000Hz = 2 × 300 + 400 (third-order)
1100Hz = 300 + 2 × 400 (third-order)
1300Hz = 3 × 300 + 400 (fourth-order)

Total intermodulation distortion at 90dB SPL is approximately 1.4%. This level is higher than most other system tests reported in *SB*. The spectrum also shows many harmonics of the 300 and 400Hz signals.

I evaluated midrange intermods with 2 and 2.5kHz signals at an SPL of 90dB at 1m (*Fig. 13*). The largest intermod was 1.5% at 4.5kHz. However, the entire spectrum is rich in both intermods and harmonics. Again, distortion performance is poor relative to other system tests reported in *SB*.

For the tweeter intermods (*Fig. 14*) I set the test signals to 9 and 10kHz and the adjusted level to 90dB SPL at 1m. Tweeter intermods averaged 1%. Still another poor figure.

WRAP-UP

I conducted all of the above tests with the grille off. *Figure 15* shows the response of the rebuilt AR-3*a* with the grille on, but referenced to the response with the grille off. That is, it plots the *difference* in response under the two conditions. Below 1kHz the grille has no significant effect. Above 1kHz, however, the grille causes response deviations of up to 5dB.

In addition to uniform power response, the AR-3*a* was also designed to be placed against a wall. *Figure 16* shows the ⅓ octave RTA response of the rebuilt AR-3*a* placed against the middle of the larger wall of a semireverberant listening room. Room modes and floor reflections cause significant response variations below 500Hz, but note that bass response at 20Hz is at the same level as the 1kHz response. This is much better bass response than the anechoic response plot of *Fig. 2* would lead you to believe.

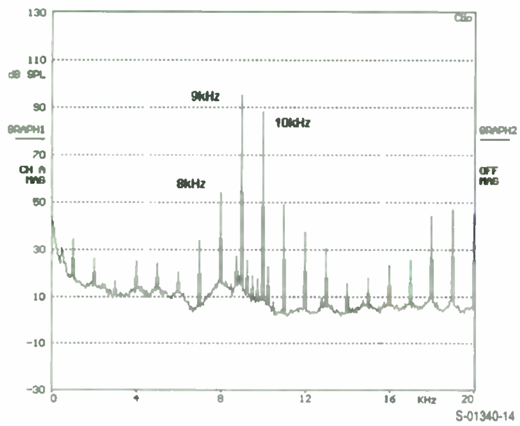


FIGURE 14: Tweeter intermodulation distortion.

REVIEWER'S COMMENTS ON MEASUREMENTS

1. Most of the coloration I heard is not evident on the axial response (*Fig. 1*). But that resonant and distorted violin note agrees with the 8kHz peak, the long resonance at 8kHz on the CSD (*Fig. 3*), and possibly *Figs. 13* and *14* (midrange and tweeter IMD).

2. The "less than snappy" acoustic guitar transients I heard seem to correlate with the step response (*Fig. 4*), in which the speaker takes about 2ms to begin a smooth decay.

3. I believe the strong response variations off-axis (*Figs. 7* and *8*) are responsible for the "megaphone-like" tubbiness and blurring I heard. Regarding *Fig. 9*, the integrated power responses, these are good except for the 8kHz—and up—region. However, I believe the ear is discriminatory enough to sense the various off-axis anomalies (*Figs. 7* and *8*) arriving from different reflected directions, even though they may result in a smooth response when integrated in the measurement.

After all, the ear is roughly analogous to a massive spectrum analyzer with 4000 parallel frequency-filter channels, each with fast response and most with over 120dB dynamic range—not to mention the brain's computing power!

4. *Figure 15* shows about a 3dB p-p variation due to the grille. I did most of my listening with

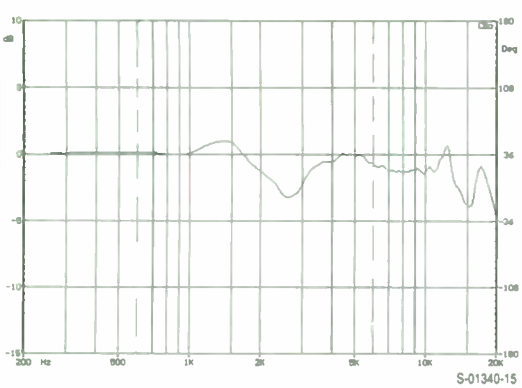


FIGURE 15: Effect of grille on rebuilt AR-3*a* system response.

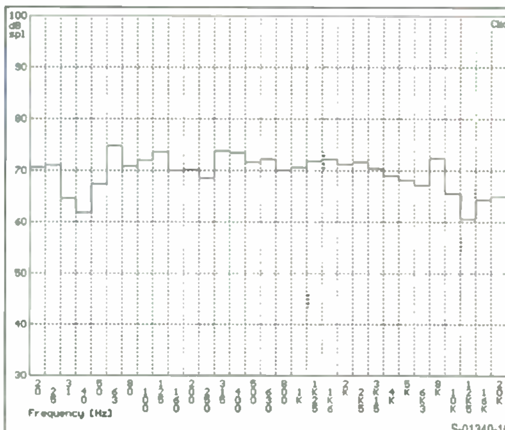


FIGURE 16: In-room RTA response.

the grilles off, but noted only a slight worsening of coloration with them on.

5. Regarding *Fig. 16*, even though my review was not with the speakers against the wall, the deep bass I heard sounded flat right down to 20Hz. Joe measured the RTA response in my review room (not shown) prior to taking the speakers, and, indeed, the bass response was not even down 2dB at 20Hz.

6. I conclude that truly comprehensive measurements such as Joe performs (now even including two-tone IMD) do correlate well with the sound.

Tom Yeago responds:

Well, my course is clear. Public decency demands that I take those poor, misguided tweeters out behind the barn and humanely put them out of their misery. It goes against my frugal nature, but this looks like a job for a pair of Dynaudio D-21s.

And those distortion figures! Disaster. Calamity. Woe. I feel as though I've presided over a train wreck. First, there's depression, then acceptance, and finally a strange fascination at how I could have accomplished this. But, there's some good news amongst the wreckage. Best to take it figure by figure.

Figure 1: System resonance is slightly lower than predicted, but where did that hump at 300Hz come from? I make no claim to understand network theory, but 300Hz? I could see 640Hz. As for the top end, it looks as if 20Ω off the bottom of each pot should fix things.

Figure 2: Not too bad, except for that execrable tweeter. My crossover doesn't look too bad here. I half expected to declare the crossover a disaster area. The textbook solution seems not too bad, for a change. Now, on the sensitivity issue, if I understand Mr. D'Appolito, quasianechoic simulates a boundaryless environment. So if we add a boundary (i.e., assume the device is radiating into half-space) we'll get SPLs of 6dB higher, right? Doesn't this bring the results in line with predictions? Not so fast. This might work for the woofer, but I expected the baffle to force the domes to see a half-space environment above 500Hz (the "baffle step"), which means I would expect the response to gradually shelve up 6dB in the treble, which it doesn't.

Figure 3: Actually, this spectral-decay plot is very encouraging. First, let's kill off the tweeter. What's left looks pretty darn good. The decay plots previously published (*SB* 8/97, 1/98, and 4/98) are spun out to last 3.7–4.0ms; this one stops at 2ms. The mid dome has dropped below the resolution floor at 1.27ms, only 0.94ms after the chirp stopped. The woofer decay drops from sight at 1.93ms, only 1.6ms after signal cessation. Not too shabby for a 12″ woofer with 1/8kg of moving mass. Also, if we ignore the tweeter, decay is fairly orderly, without resonance-flagging ridges. So the woofer cone and dome seem to hold up structurally.

Figure 4: Again, a better-behaved tweeter would improve this by cleaning up the extraneous (approximately 8kHz) junk. This looks like a pretty good midrange-tweeter integration to me.

Figure 5: I don't know enough to comment intelligently on this, but I wonder about the cause and significance of that little blip on top of the general trend at 500Hz.

Figure 6: Again, cannot make an intelligent comment.

Figures 7 and *8*: What a mess! But that's what you get with a recessed baffle, sharp corners, and so on. And, presumably, why the response curves of the drivers AR published didn't come from the domes installed in the box, but in a big baffle, and why AR made a point of power response. I await another hideous set of curves when a stock AR-3*a* is tested.

Figure 9: No comment.

Figure 10: Trouble in driver city. Gobs of distortion—about ten times what I'd like. What's the root? The spectral-decay plot suggests the diaphragms themselves are okay, which leaves the motors. Could it have something to do with the vent holes in the motor forms? Is something rubbing? Could it be the crossover inductors?

(Although I neglected to mention it in the text, I wound the 1.7mH and 2.7mH coils myself and brought them up to spec by adding transformer iron to form a core. I hope I bungled the job, because the alternative is horrible to contemplate.) One observation: on both second- and third-harmonic plots, there is a spike at system resonance plus one octave (approximately 70Hz) and a dip an octave higher at 140Hz.

Figures 11-14: Gloom, despair, and agony.

Figure 15: Okay, there are better things than AR's linen for the job. Let's just call them dust covers, and leave it at that.

Figure 16: I consider it a personal kindness that Mr. D'Appolito included this figure. There's some vindication for the chosen bass response alignment here. I've seen better, but I've seen worse, too.

With all this data and Mr. Colin's remarks on listening to the beasts, I've much food for thought, speculation, and eventual revision. I note Mr. Colin used a country-music singer as one of his vocal references. I've noticed that the Nashville cats are unsurpassed at getting terrific-sounding voices on tape. I pumped some Reba through the speakers just before sending them to Joe D'Appolito, and they sounded pretty good. But I'm completely prepared to attribute that to the well-known effect of speaker builders' self-delusion. Something does seem amiss with the mid domes, so I must do some troubleshooting. Thanks to Mr. Colin for putting in the hours and recording the results.

Well, enough for this thirty-year-old design and my sometimes misguided renovations. I've had fun and, with this reply, had the opportunity to exercise a colorful sector of the vocabulary. I wish to thank Mr. D'Appolito for his labors, and to marvel at the restraint he displayed in his report.

A NOTE ON TESTING

The rebuilt AR-3a was tested in the laboratories of Audio and Acoustics, Ltd. using the MLSSA and CLIO PC-based acoustic data-acquisition and analysis systems with an ACO 7012 ½" laboratory-grade condenser microphone and a custom-designed wideband, low-noise preamp. Polar response tests were conducted with the aid of a computer-controlled OUTLINE turntable on loan from the Old Colony Division of Audio Amateur Press.

REFERENCES

1. J.A. D'Appolito, *Testing Loudspeakers*, Audio Amateur Press, Peterborough, NH, 1998.

SB Mailbox

CORRECTED SCHEMATICS

The capacitor values of C1–C4 in "Afterburner for Aftershock" (*SB* 3/99) should be listed in microfarads, not millifarads, as shown in Fig. 1. So, the values of C1 and C2 are 4700µF, while the values of C3 and C4 are 330µF.

Also, the capacitor and resistor values for Fig. 1 in "Tools, Tips, & Techniques" (p. 59) are incomplete, but are published correctly in *Fig. 1*.

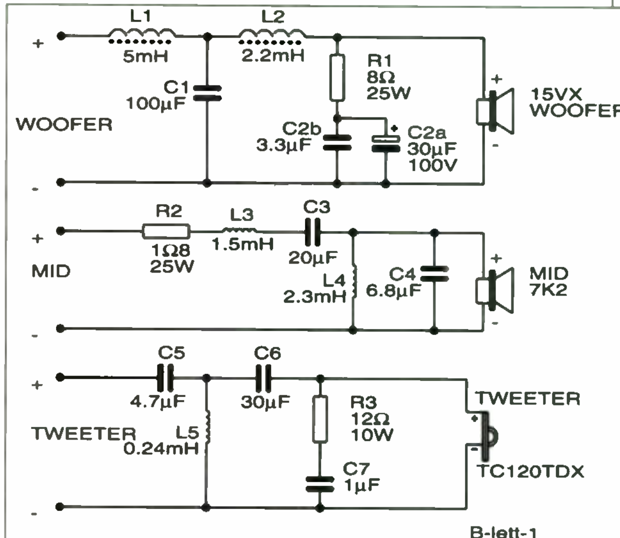


FIGURE 1: Corrected crossover network.

MEASUREMENT FEEDBACK

I have a comment on two excellent articles that appeared in *SB* 2/99. First, with regard to Bruce Carpman's "Frankenstein's Speakers," p. 8, a driver with half the cone area of some reference will produce 6dB less output, not 3dB as stated, assuming equal excursion and frequencies low enough so cone diameter is much smaller than wavelength. In such a case, doubling cone area radiates twice the air volume displacement, which also doubles acoustic pressure. This is analogous to a current source feeding a resistance (here the speaker radiation resistance, which is very low compared to that of the cone). Since power is proportional to i^2R, doubling i (analogous to air volume velocity) quadruples power, a 6dB increase.

Second, Louis C. McClure's bridge circuit in "A Handy-Dandy Impedance Measurement Device" (p. 22) is very accurate if you're measuring a purely resistive load. However, there will be significant error with reactive loads, such as a driver near (but not at) its resonance frequency, or at its high-frequency limit where voice-coil inductance is significant. For example, consider measuring a capacitor (*Fig. 2*).

$$V_O = V_I \frac{-jX}{R - jX} \text{ If } X = R, V_O = V_I \frac{-jV_I}{1 - j} = \frac{V_I}{\sqrt{2}} < -45°$$

Thus, if the capacitor's impedance X = R, the output voltage is *not* half the input, but 0.707 V_I with a phase shift of –45°. So adjusting R for an output of:

$$\frac{V_I}{2}$$

will not result in R equaling X. Rather, R must be set to $\sqrt{3}$ X = 1.732 X to produce an output of

$$\frac{V_I}{2}$$

thus the reading will be 73% too high.

There are at least two ways around this: with Mr. McClure's circuit, when R is set to equal X, or the magnitude of any load (Z), the voltage drops across R and Z are equal since equal current flows through both. So in the previous example (R = X), both have a voltage drop of 0.707 V_I. Of course, the reason these two voltages add up to V_I is that the capacitor voltage is shifted –45° with regard to V_I, while the resistor voltage has a +45° phase shift. So the two voltages are 90° shifted with reference to one another. But by setting R for equal voltage measurements across R and across Z, accuracy is ensured. Using two voltmeters would greatly facilitate this.

Another way to measure complex impedances easily and accurately is to simulate an AC current source (*Fig. 3*). If R is 100 times, for example, the highest Z to be measured, then 1% accuracy is ensured regardless of phase angle. For example, R = 10kΩ allows ±1% accuracy for impedances up to 100Ω magnitude.

$$V_O = V_I \frac{Z}{R + Z}; \text{if } R \geq 100|Z|, \text{ then}$$

$$V_O = V_I \frac{|Z|}{R} \text{ to within 1\%, so } |Z| = R\frac{V_O}{V_I} \text{ to 1\%.}$$

The disadvantage of this method is low output. For example, if V_I = 10V and R = 10k, the output will be 1mV per ohm of measured Z. But even an inexpensive Radio Shack DVM can measure to within 1mV, giving 1Ω resolution. Of course, the meter should be referenced to the input V_I (or some fraction thereof), as Mr. McClure does, to "cal out" the meter's frequency response or other errors.

But I think the most practical method is to use the Handy-Dandy circuit, but with two voltmeters–one across the load and the other across the variable R–and adjust R for equal readings. If the two meters are identical, no input reference is needed.

Dennis Colin
Barnstead, NH
dcolin@wordpath.net

Bruce Carpman responds:

Thank you for taking the time to read my article in enough detail to catch this error. Doubling the cone area will indeed produce a 6dB increase in output. I will not bother trying to explain my reasoning for this initial mistake, except to say it made sense to me at the time.

My corrected chart (*Fig. 4*) does remove some of the differences between the three drivers, but does not negate the final conclusions. The DV12 is still capable of playing significantly cleaner and louder. Too bad the original DV12 is no longer available.

Louis McClure responds:

First, I would like to thank Dennis Colin for his kind and gracious remarks concerning the device. It is obvious that Mr. Colin, who gave an

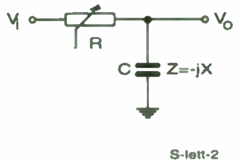


FIGURE 2: Sample circuit to measure capacitance.

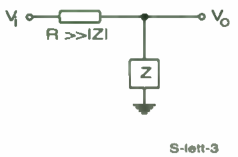


FIGURE 3: Measuring complex impedances.

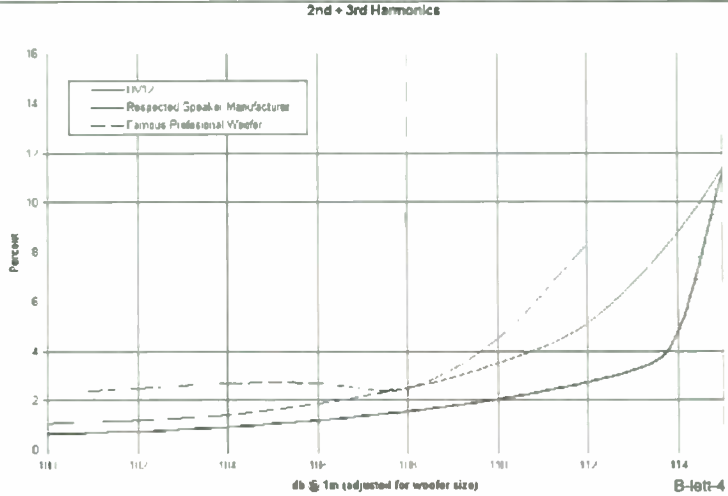


FIGURE 4: Author Carpman's corrected DV12 chart.

excellent dissertation on measuring compound impedance (resistance and reactance), is very knowledgeable on the subject.

In all honesty, I cannot take credit for the principle or the theory behind the device. I have often used the method as described by Mr. Howard Tremaine (*Audio Cyclopedia*, 1978 edition, p. 1513, Fig. 23:140A). However, for convenience, I added a few features which made it much easier for me to use.

Mr. Tremaine shows a simple method to switch the VTVM between each side of the variable resistor to obtain equal voltages across the speaker and the variable resistor. This was cumbersome and time-consuming for me. By using a switch to simply change the meter input from the voltage across the speaker to the voltage across the variable resistor, I could work faster and easier.

Also, I was using the same meter for both applications, which ruled out differences in meter readings due to frequency response of the meter. The same meter would have the same reading for the voltage across the speaker and the variable resistance. Also, by switching the meter between the voltage across the speaker and the voltage across the variable resistance as a final check, I ruled out possible errors in measurement.

Another feature I incorporated was a selector switch with 30, 60, and 90Ω readings. I could insert this switch in series with the input to increase the maximum value of the variable resistance (actually, the L-pad) and be able to read the peak value of impedance at resonance (in most cases). This would be useful in determining (approximately) the resonant frequency of the speaker.

The device was not intended to be a precision laboratory instrument. However, I believe that it is entirely adequate for the amateur speaker builder who may have limited equipment and limited funds. The impedance plot (Fig. 4 in my article) includes the actual plot points of a 6½″ driver mounted in a test box. The plot points were not smoothed out as much as they could have been. However, "What you see is what you get!"

MORE WORDS

My personal thanks to Ed Dell for clarifying terms we should use for electrical quantities ("Words, Words, Words," *SB* 2/99). Volts, amperes, farads, and hertz can easily be further quantified with the standard "multiplier" prefixes: kilo, milli, nano, mega, and so forth.

My question is, why not the bel? What's wrong with a CD having a dynamic range just over 9 bels (9B)? Why not a phono preamp which conforms to the RIAA curve within a centibel (cB), or a millibel (mB) for purists? Being restricted to tenths of the root quantity—as is current practice with decibels—is as cumbersome as saying, "I just spent fifteen dimes for a gallon of gas" or "I worked a ham in Burma on the 4000-centimeter band?"

Jim Wood
Brea, CA

A hearty thanks for this wonderful editorial! Every time someone talks about "dampening" his speakers, I can't help but wonder why he'd care to leave his loudspeaker systems out in the rain? Such misuse of technical terminology is like fingernails on a chalkboard. There have been many times I've wanted to correct someone but chose not to, so you have spoken for me. Thanks!

John Levreault
Boxford, MA

I concur completely with your belief that we could eliminate confusion by being more precise in expressing our thoughts and agree with most of what you propose. It might be useful to give further consideration to two of the words you discussed.

We use the word "speaker" when we mean "loudspeaker," either out of laziness or an aversion to sesquipedalian expression. I suspect the former motive is the stronger. Using the word speaker causes confusion when the topic, such as public address systems, includes reference to talking humans as well as loudspeakers.

One possible solution is to use "speaker system" whenever referring to an assembly that consists of an electroacoustic transducer and (a) another such transducer, (b) an enclosure, (c) crossover elements, or (d) built-in amplification. "Driver" is acceptable when referring to the transducer, but over the decades that term has most frequently referred specifically to a compression driver designed to be mounted on a horn.

You are to be applauded for pointing out the misuse and overuse of the word "incredible." But I would hesitate to substitute another misused and overused term, "awesome." Correctly used, awesome means inspiring an emotion combining dread, veneration, and wonder that is caused by authority or the sacred. I have experienced that emotion in the presence of loudspeaker systems, but it was the Faure' Requiem and not the engineering that induced it. Thank you for starting us down the path of elucidation.

Mike Lamm
Fenton, MO

SOUND OFF

I would like to make a couple of comments on the *SB* 7/98 article by Dennis Colin ("Real Backseat Bass," p. 22). The first is a word of warning to those who would attempt to imitate Mr. Colin's subwoofer setup. His description of "great sounding bass" may mean different things to different people. Since most people have only been exposed to reproduced (exaggerated) music, Mr. Colin's bass system will not sound as "good" as some other reproduced (exaggerated) bass that they might have heard before.

The second comment addresses those who truly enjoy music as natural as can be. The subsystem he describes is by far a major step toward very pleasant bass reproduction inside a vehicle. His setup, mixed with great electronics and great drivers (such as the ones he uses), rivals the best of home setups. The results are wonderful and soothing bass, lots of depth and ambience, low coloration, very little resonances, and (best of all) the type of bass that doesn't call attention to itself and allows instruments to glow.

For the record, I have been installing in-car audio systems for about nine years, and I soon began to compete in literally all of the sound-off formats in the States and then in the UK. The vehicles I have built have collected over 500 trophies, many of which for best-of-show. Also, many of these vehicles have been recognized for their sound-reproduction abilities, rather than for their installation qualities.

Many of my most recent systems have included woofer systems that I consider to offer very realistic sound reproductions. I attributed the quality of the bass response to the fact that I allowed for a larger direct-to-reflected (loaded) sound ratio than what is common with bass drivers placed in the trunks of the vehicles. Of course, you are limited to the lowest possible frequency at which this ratio can be maintained, since the car offers a very small cavity. This ratio, I thought, allowed for a better impulse and time response. The same sort of thing you experience when comparing low-reflection/high-absorption halls with very live ones with respect to the intelligibility of the human voice.

My first experience with great bass came when I mounted a pair of 8" Madisound woofers in sealed boxes in the doors of a '93 Honda Civic. Then I was hooked. My own competition car, an '89 Nissan Sentra, started with a pair of Dynaudio 11" woofers mounted in an aperiodic enclosure in the trunk and ended with a pair of Morel 9" units in sealed boxes inside the doors. Although the aperiodic box system sounded very smooth tonally and had very little box-induced coloration and an almost flat impedance response, it didn't sound as good as the door-mounted woofers, which, on top of everything, enhanced the stage depth and ambiance.

When '96 rolled around, I went to work for an autosound distributor in Great Britain and had the opportunity to build a system inside of an imported '90 Chevrolet Astrovan. I placed two 8" Eton woofers in a three aperiodically connected chambers box on the floor in between the front seats. Of all the cars I had worked on, this was my best work so far, and the first vehicle that could truly reproduce the sense of "being there" when playing orchestral music.

Unfortunately, in the autosound competition circuit, many sound judges have very questionable music references to evaluate against. For this reason and in order to win, I was forced to display large woofer layouts to affect their subjective psychoacoustic impression. For example, the Civic had ten 15" woofers, and the Astrovan contained 16

15″ woofers. But even with all these woofers in sight, sound judges commented on the lack of "extension" (resonant 45Hz response) as soon as they realized that the bass was coming only from the front woofers.

Contrary to these impressions, all of the vehicles displayed a very smooth frequency response at the front listeners' ear level that sloped upwards to an average of +9dB at 20Hz referenced to the midbass level (the response was kept at an average of ±3 from midbass sloping down toward the highs). In other words, extension was not the problem at all. I cannot stress enough the fact that this type of bass is not for everyone.

Alberto A. Lopez
Jalisco, Mexico

Dennis Colin responds:

Thank you, Mr. Lopez, not only for your supportive comments about my work toward natural autosound bass, but also for sharing your experiences. I especially appreciate your insight regarding the distorted view of naturalness held by those who haven't heard, or have forgotten, the sound of live unamplified music. Too bad this includes many autosound "judges"!

I have a theory about some people's preference for boomy, resonant bass: most electric music, and much acoustic music, is recorded very dryly with little or no natural acoustic ambience, and often with insufficient deep bass. Of course, well-recorded music doesn't need this artificial "enhancement," but as you pointed out, many sound judges have a very questionable music reference. Indeed, consider the type of (non) music often played by car stereo owners!

A WOOLLY AFFAIR

A few years back, a bumper sticker that read "Question Authority" was popular. Apart from healthy skepticism, such an attitude forced you to learn more than what appeared on the surface of a concept. Thus I admire Don Jenkins for taking on the question of the change of speed of sound in a fiber mass ("What's Really Happening in a Stuffed Line?," *SB* 7/98, p. 32).

In my previous letter ("*SB* Mailbox," p. 64), I avoided this central theme of Mr. Jenkins' article and simply pointed out some inconsistencies in the data that was used to buttress the argument that there is no change in the speed of sound in a fiber mass. I hoped that Mr. Jenkins would draw the conclusion that the data presented did not prove his argument. However, in his reply, he states, "As an aside, the test results from Figs. 2 and 3 also confirm that there is no reduction in sonic velocity due to wool stuffing." This statement is wrong.

The proof of this can be made as a general and a specific to the TL case. For the general case: Velocity is medium dependent. The speed of light in a vacuum is defined as a constant, but it changes in a medium such as glass, resulting in refraction. In the quantum scale it can be slowed down to a "crawl" by chilling the medium in which it propagates. Thus it would be very strange indeed if the velocity of sound would not be medium dependent. Bradbury derives and quantifies such dependency as a function of frequency for fiberglass and wool stuffing mass in an open line.

In the specific case, as applicable to speaker design, two types of proofs are possible. The direct case would be to use a differential measurement with an accuracy of microseconds, which would be sufficient for a limited frequency range of about 50–200Hz. Such a measurement was actually done by an amateur, L. DeMartin, for Miraflex and AcoustaStuff fibers, in the sub-100Hz range to complement Bradbury's data that stops at about 50Hz. The data is graphic in format and can't be presented here. My citation of it is that it can be done by an amateur.

The indirect case considers the closed-box response, where V_b undergoes an apparent volume increase with fiber stuffing. This is the adiabatic/isothermal conversion, which is fiber-density-dependent and thus also dependent on change of velocity in the medium and attenuation.

The more graphic and easily grasped case is the asymptotic attenuation of the harmonic structure in an unstuffed TL line. Here the calculated harmonics are frequency shifted and attenuated in such a pattern that it would not be understandable without the concept of the change of velocity of sound in a medium. Note that air has a density, 0.075kg/m^3, and thus is frequency and attenuation dependent, just as any fiber mass.

The data that Mr. Jenkins presented in his article is compromised by two limitations: 1) an insufficient understanding of the TL line response, and 2) by the type of experiment chosen and instrumentation inadequacies. The specific case is the reliance on a single 50Hz frequency signal. The problem here is that the low frequency of the line resonance for a 57.5″

long tube will be about 59Hz and will propagate in the fiber medium as well as in the side wall of the tube.

Thus the pickup at the end of the tube will be excited by both the impulse travelling through the fiber medium which will be slowed and by the signal transmitted through the side wall which will be delayed but little. The differentiation of these signals at low frequencies is a difficult task. In 1976 Bradbury was not able to obtain reliable data for frequencies below 50Hz. This is possible today with a differential high-speed oscilloscope, though the case resonance problems persist.

I admire Mr. Jenkins for tackling this problem, since many speaker-design parameters are gross simplifications adequate for a classroom but seriously flawed when applied to a real-world problem. Also, I believe that the only ones who do not fail are those who don't try. Failure in an experiment is a very good teacher.

E. Jakulis
Avon, MA

Don Jenkins responds:

One of the benefits of writing articles is receiving comments from readers. The most interesting commentary comes from readers who 1) don't for a moment believe that your data is any good, and 2) don't believe that you have a clue as to what you are doing. The second proposition is always debatable. In this case, however, the first proposition deserves some additional development.

Mr. Jakulis seems convinced that wool stuffing in an open-ended tube, stuffed to a density of about 0.5 lb/ft^3, will cause the velocity of sound transmission through the stuffed tube to be significantly reduced for sinusoidal frequencies below about 100Hz.

To determine where we are in this discussion, it is appropriate to review where we have been, and what started this ongoing debate. In 1965, and again in 1972, A.R. Bailey, in *Wireless World*, reported his experience with transmission line enclosures. In the 1972 article, in an unsupported statement, and as an almost passing comment, he wrote, "The effect of the filling in the pipe is to slow down the wave relative to its velocity in free air. This reduction factor is between 0.7 and 0.8 for the recommended packing density." The recommended density was given as 0.5 lb/ft^3.

In April 1976, the much-quoted article by L.J.S. Bradbury appeared in the *JAES* and presented his theory of why fibrous materials in transmission lines reduce the velocity of sound in the line. He made reference to not only Bailey but also to a series of tests at MIT in 1953 with fiberglass-filled ducts.

My original interest was in questioning Bradbury's theory. My efforts were an attempt to prove that a two-phase, heterogeneous medium of air and fiber would behave as a homogeneous medium when evaluated by sound transmission theory for a gas at low pressure. These tests were all negative.

I was unable to show any reduction of sound velocity, relative to free air, due to the transmission through the two-phase heterogeneous medium—in this case air at normal pressure with either wool or a synthetic polymer—by direct time of transit measurement. I found that the filler modified the resonant modes of excited tubes, an effect that has been reported many times and used successfully in many transmission line enclosures. This led to the direct measurement of velocity which Mr. Jakulis now questions.

The test setup is simple, yet direct. A pulse is fed to a free air driver, with a microphone placed at various distances from the driver (for these tests, between 1.2 and 4.5ft). I measured time delay between the driver pulse and the microphone response and recorded ten sets of free air times. The calculated velocity, at the ambient conditions in my laboratory, was 1132.06ft/sec. The one sigma velocity dispersion for these ten values was 0.7%. This result not only proves the correctness of the technique, but the accuracy and repeatability of the measurements.

Now for the wool filling. First, Bailey used wool of long fiber length. His specification was, "The wool should be of long fiber length and packed fairly loosely, about one pound to every two or three cubic feet..." After several false starts I was able to obtain long fiber wool. I combed and pulled until I had a filled density in the 3″ pipe of 0.48 lb/ft^3.

Figure 1 in my letter response (*SB* 2/99, p. 64) is the time record for a single pulse transmission through the filled pipe. Regardless of what Mr. Jakulis thinks, ***there is no delay in the pulse transmission time due to the wool filling.*** After over 100 tests with line lengths up to 117″ (some with two 90° elbows), the maximum velocity variation was ±1%.

Some will say that the pulse shown in Fig. 1 is too "sharp" and that Bradbury's theory only holds for low frequency transmission. Figure 2 in the same letter response is a single 50Hz sine pulse sent down the tube. The response curve starts to receive the forcing wave front at 4.4ms for a velocity the same as free air. As with the sharp pulse tests, I made about 50 or 60 sine pulse tests using this open, wool-filled line, at frequencies between 20 and 200Hz. None of these tests showed a reduction in wave front transmission time.

An objection to the single pulse test is that it does not allow the wool to "get in phase" with the forcing function. Bradbury's theory supposes that the wool fibers oscillate in phase with the compressive wave that moves through the air in the tube, thus simulating a homogeneous, compressible fluid of increased density and undefined gamma. This is where my doubts originated. Is it possible for a two-phase system, in this case air and wool, to have the properties of a homogeneous medium for the transmission of a compressible wave front through the heterogeneous mixture?

Figure 5 shows ten cycles at 40Hz slowly increasing in amplitude. This should allow the wool enough time to accelerate and "phase lock" with the free air wave front. The fact is that each peak, forcing to response, has the same displacement and is equal to the free air transmission time.

If Mr. Jakulis has a problem with the experiment not producing the result he wishes, he can well question the accuracy of the instrumentation used and the competence of the person making the analysis. The questionable variable, however, is the wool filling the line. I will readily admit that the wool used in the experiments may not be up to the specific quality required to provide the answer Mr. Jakulis expects.

In personal correspondence with Mr. Jakulis in December 1998, I sent him a comprehensive report of all my tests up to that date. This document contained a complete description of the wool used and its provenance. The wool Bailey used in his 1965 tests is no longer available, at least not in the United States.

In continuing tests and modeling since December 1998, I have about reached the conclu-

to page 60

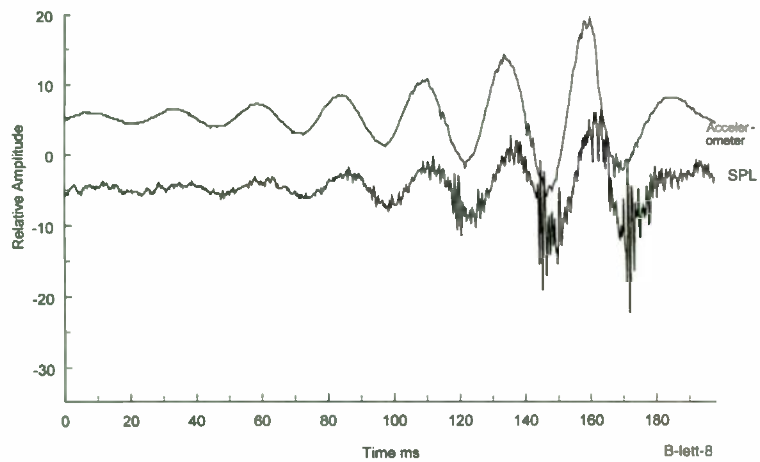


FIGURE 5: Ten cycles exponential sine at 40Hz; 50" tube open wool at 0.49 lb/ft³. Accelerometer mounted to center of driver cone; SPL from microphone at the end of tube.

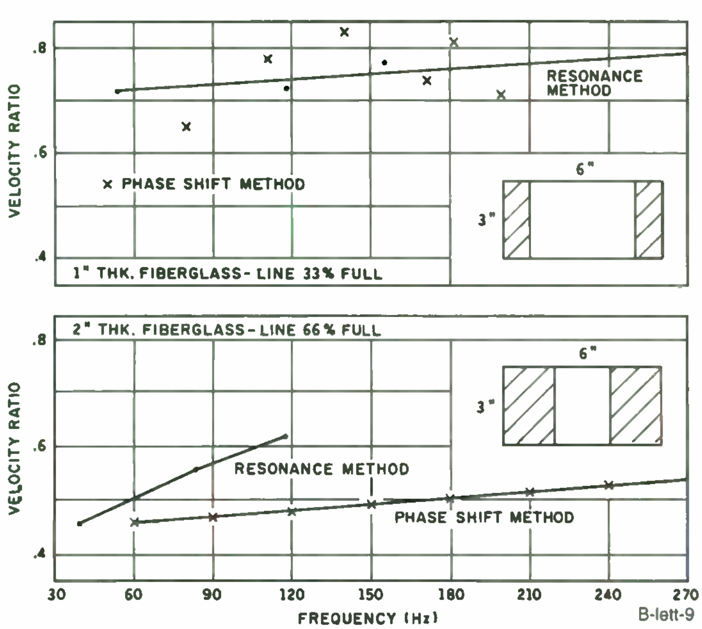


FIGURE 6: Mattern's measurements for a stuffed line.

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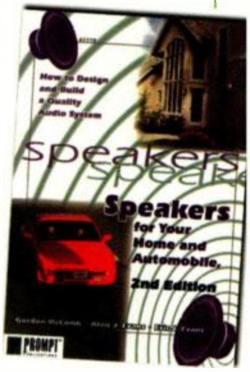
SPEAKERS FOR YOUR HOME AND AUTOMOBILE

Reviewed by Mark Florian



Speakers for Your Home and Automobile: How to Design and Build a Quality Audio System, Third Edition, Gordon McComb, Alvis J. & Eric J. Evans; Prompt Publications; 1998; 171 pages. Available through Radio Shack stores as "Building Speaker Systems," #621093. Also available from Old Colony Sound Lab, PO Box 876, Peterborough, NH 03458, (603) 924-6371, FAX (603) 924-9467, E-mail custserv@audioXpress.com. Part #BKS60, $24.95, shipping wt. 1 lb.

Over the course of eleven chapters, this book covers basic sound and speaker operation, including systems for the automobile and home-theater applications. Three appendices at the end are reserved for design equations, enclosure dimension tables, and metric conversions. I'll describe each chapter in detail and then finish up by providing an overall impression of the book.

BEGIN WITH BASICS

Chapter 1 starts off with an introduction to sound itself—how it travels through the air in waves, how distance affects the volume of the sound, and the various frequencies of musical instruments. This lays the foundation for the question of why speakers need more than one driver to reproduce the entire range of human hearing. The instruments are displayed in a chart, showing their frequency ranges—divided into low (woofers), middle (midrange), and high (tweeters)—along with a piano keyboard at the bottom. The chapter ends with a simple description of a driver and an explanation of how it works.

Chapter 2 goes into more detail, with a look at frequency response, sensitivity, damping, and different types of distortion. The three main driver categories—woofers, midranges, and tweeters—and how they differ regarding the above parameters are discussed next. Coaxial and triaxial drivers—widely used in autos—are also included. This chapter examines many of the factors affecting performance: power rating, voice coil and magnet size, cone material, suspension, impedance, and cone resonance. Finally, the chapter explains terms associated with a few of the Thiele/Small parameters.

Chapter 3 examines the speaker enclosure and discusses the differences between sealed and vented boxes. It offers a chart to help you select an appropriate box size for a sealed system, and includes several charts and tables for designing vented box systems.

Chapter 4 is devoted to construction techniques for the cabinet: plywood versus particleboard, layout and cutting of the various pieces, different types of corner joints to use, assembling the cabinet, and installing the drivers.

Chapter 5 briefly discusses different ways to finish a cabinet and to attach grille cloth to frame and fit it to the finished speaker.

Chapter 6 deals with properly wiring the speaker using the pre-assembled crossover boards available from Radio Shack. It also covers L-pads and their use in the tweeter network, and recommends dynamic overload protectors to protect the tweeter and fuses for protecting the whole loudspeaker.

Chapter 7 shows you how to connect your new loudspeakers to your amplifier, and includes a basic troubleshooting guide, polarity test, L-pad test, and sound-level test using the popular Radio Shack sound-level meter. Speaker placement is also covered.

Chapter 8 contains four construction projects: a single-driver compact bookshelf unit, a small two-way system, a large three-way floor-standing system (these three require a sealed box), and another three-way floor-standing system using a vented box. Each of these projects includes a full parts list, which is available from Radio Shack, a cutting guide, diagrams and measurements of each piece, and cabinet assembly and component wiring instructions.

Chapter 9 is an introduction to car audio systems, with suggestions for improvements, such as using box-mounted speakers, an equalizer and power amplifier, and a fader. Active crossovers, as well as woofers, mid-ranges, and tweeters, are also discussed.

Chapter 10 covers specific automotive installations in coupes and sedans, hatchbacks, pickup trucks, and large vans/sport utility vehicles. This chapter includes a wiring diagram for hooking up an equalizer to separate amplifiers for the front, rear, and subs. It also shows how to add a portable CD player and different head unit. Each design includes box enclosure dimensions for adding subwoofers, where applicable.

Finally, Chapter 11 provides a brief overview of each element in a home-theater system, and offers guidelines for seating and speaker placement considerations and for wiring up the system. A section is devoted to using a sound-level meter to match levels between the various loudspeakers, which I highly recommend.

Appendix A presents simplified design equations for sealed and vented enclosures. Up to this point, the book is relatively devoid of equations, instead relying on tables and charts to simplify the procedure. A preface here states that the equations were chosen to give the best system performance in the home, not in a large environment or outdoors and that "they work best...when speakers are used that have Q_{TS} between 0.3 to 0.5 and V_{AS} from 6 to 12." Evidently, this section is for the hobbyist who prefers to delve a little deeper into the theory and explore further.

Appendix B contains several enclosure dimension tables, broken down depending upon the size of the woofer and whether you choose to build a one-, two-, or three-way loudspeaker. By looking up the desired volume, you will find the inside dimensions for height, width, and depth based on the golden ratio (1.6:1.0:0.6 HWD).

Appendix C contains conversion factors for English and metric units, a prefix table and corresponding multiplication factors, and a table of fractional dimensions with their corresponding decimal and metric equivalents.

The extensive glossary contains six pages of terms and their definitions and is followed by a complete index.

OVERALL IMPRESSION

This book is clearly aimed at someone with a budding interest in loudspeakers who doesn't want any equations to get in the way. As such, it covers many concepts and terms, but not beyond a simple, basic level. It's appropriate for junior- or senior-high school students who are interested in audio and wish to assemble their first loudspeakers without a lot of shopping around to decide what to buy.

But beyond that, this book is unsuitable for those desiring more in-depth coverage or who are handy with a hand calculator. For those, I highly recommend Ray Alden's excellent book, "Advanced Speaker Systems," also available from Radio Shack.

SB Mailbox
from page 55

sion that what is being experienced in filled transmission lines—where there are two distinct transmission paths—is a combination of the complex addition of velocities in the primary medium (air) and the secondary medium (filler), the attenuation properties of the secondary medium, the resonant phase combinations of the system, and the resonant mode and damping characteristic of the driver. For me, the proof that a two-phase heterogeneous medium, such as air and a material whose density is several orders of magnitude greater, will have the same thermodynamic properties as a homogeneous compressible fluid, i.e., Bradbury's theory, remains to be delivered. (There is a second-order effect which also needs to be mentioned: the potential for the filler to cause reversion to isothermal compression rather than adiabatic. This reduction is small, for air 0.85, and is minor when compared to the effect of Bradbury's density function, which at low frequencies may reduce the velocity to one-fourth that of free air.)

The next series of tests will be with Acousta-Stuf, which may be a better material than wool, since its properties are easier to control.

I have written a TL simulation program to design a transmission-line bass speaker for my stereo system. This program requires two key quantities: the attenuation and velocity of sound in the transmission line.

I used a 3″ × 6″ duct 14′ long to measure attenuation. The 3″ inside walls were covered with 2″-thick Radio Shack fiberglass. This arrangement duplicated the mean conditions in the speaker's transmission line. I could move an electret microphone at the end of a 3′ rod along the center of the line.

I located a 4″ speaker on the outside of the wide wall close to the start of the line and used a 45° end piece to "bend the sound" to the direction of the line. Losses in the remaining 11′ part of the line beyond the microphone minimized standing waves caused by reflections at the line's end.

I have recently used this arrangement to measure velocity in the line. I used two methods—a resonance measurement similar to that used by Don Jenkins (*SB* 7/98) and a second absolute method based on phase shift.

For the resonance method, I uncoupled an initial 4′ section of line and located the microphone at the start of the line close to the speaker. I found the quarter-, half-, and three-quarter-wave resonances with a variable frequency generator and amplifier as a signal source. The microphone output was minimum at the quarter- and three-quarter-wave resonances and maximum at the half-wave point.

Note that a microphone placed at the open end of the line would have inverted the results. I did this with and without the fiberglass and from the frequency data determined the propagation factor relative to the bare line. I also measured with a single 1″ thickness of fiberglass. The results were in substantial agreement with Jenkins' findings.

For the phase-shift method I reconnected the 11′ section of line and fed a sine wave to the speaker as before. This time I synchronized the scope to the square-wave output from the sine-wave generator. I then measured the distance I needed to move the mike to cause a given phase shift (90°, 180°, and so on). *Figure 6* shows the calculated velocity for the 2″-thick fiberglass. I found the results for the 1″-thick fiberglass too scattered for a curve.

The phase-shift results appear to approach Bradbury's theoretical predictions for the 2″ case. I suggest that the velocity of propagation in the bare line is already less than that in open air, so that the actual velocity in the presence of stuffing will necessarily be less than that obtained by the resonance method.

I would like to offer two observations based on other tests. I have noticed that the absorption in the fiberglass was dependent on orientation; that is, the absorption is greatest across the grain and least along the grain. Also, the absorption depends on how well the fiberglass is anchored to the inside wall of the transmission line. The fiberglass in my speakers is glued to the narrow inside surfaces of the line.

Jenkins' article was very helpful in pointing out the inaccuracy of the assumed velocities that I was using in my TL design calculations.

John Mattern
Baltimore, MD

Don Jenkins responds:

Mr. Mattern has provided some interesting data on the apparent velocity reduction in transmission-line devices with various types of loading. His results provide another look at how the measurement technique produces different conclusions about the effect of loading in the line.

In my response to a previous letter on this subject (*SB* 2/99), I reported some additional tests using a direct "time of response" technique to measure the sonic velocity in a wool-stuffed line. I concluded that there is no reduction of the sonic velocity due to the wool stuffing.

My conclusion is that the apparent reduction in velocity being calculated is influenced by the technique used for the measurement and type of analysis made from the data. I believe that what is being measured is the complex addition of the fundamental velocity through the air, some attenuated velocity through the filler medium, resonance phase combinations, and the damping and resonance characteristics of the driver.

Thanks to Mr. Mattern for sharing his data with *SB* readers.

HELP WANTED

I'm trying to find a voice coil for a ribbon tweeter in a pair of custom speakers that I own. "Manufactured Under License From the Rank Corporation, London" is the only identification on the back of the tweeter. The ribbon tweeter opening is $\frac{3}{4}'' \times 2''$. The faceplate is designed for a wide dispersion measuring $4\frac{3}{8}'' \times 4\frac{3}{8}''$. The frame for the voice coil is $3\frac{5}{16}'' \times 3\frac{11}{16}''$ and has a radius on the top and bottom.

Paul Blaubach
paul@officerelief.com

Where can I find the old loudspeakers that contained different colored lights, which were "sound activated": bass—blue, lead guitar—red, drums—green, and so on. These were popular back in the '70s. I am remodeling my den into a "pad" complete with bean bags, beads, lava lamp, black light, strobe, and other '70s paraphernalia.

Neal Lykins
n.lykins@worldnet.att.net

I understand that ESS Inc. is out of business. Does anyone have any plans of the crossover circuits and modifications for the ESS-AMT 1a bookshelf speakers?

Peter Hoenen
Peter_Hoenen@t-online.de

I'm a new subscriber living in Colombia, South America. I'm also the happy, proud owner of a second-hand pair of old JBL Hartsfield, horn-loaded corner speakers, which I bought ten years ago and have managed to restore its woodwork and finish. I also have added a pair of JBL 2405H horn tweeters to the original set, which is actually driven with three amplifiers and an electronic three-way crossover, achieving excellent performance.

I would like to know whether there are some further improvements I can make to these speakers, perhaps replacing the old 375 midrange driver with a recent model with titanium diaphragm, like the 2246H. Also, are there any literature, test reports, plans or specifications that I could obtain for this model?

Jorge Padilla Mejia
Cr. 4 #52A-65 apt. 801
Bogota, Colombia
South America
Jpadilla@andinet.lat.net

I build my own speaker boxes and frequently insert and remove drivers. My problem is that the neoprene gasket tape I use adheres to the baffle as well as to the speaker, making driver removal difficult, often taking some of the baffle with it. Is there a gasket material that doesn't become an adhesive after it is compressed? Is cork gasket tape available?

Scott Elder
793 E. Virginia
Stayton, OR 97383

Readers with information on these topics are encouraged to respond directly to the letter writers at the addresses provided.—Eds.

From time to time, *Speaker Builder* publishes the website addresses of speaker-related companies. If you would like your firm's wesite address to appear within a future issue, submit the information to:

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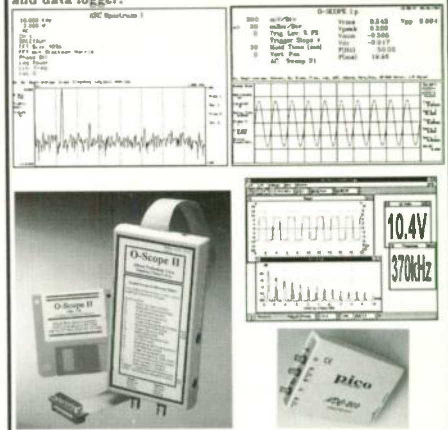

Tools, Tips, & Techniques

THICK DRIVER-HOLE DIFFRACTION

By Alan Ersen

No serious speaker builder would mount a midbass driver behind a thick baffle *(Fig. 1)*, since the undesirable effects of diffraction and early reflections or cavity resonances would degrade the sound. Front-mounted or flush-mounted is usually considered the way to properly install a driver *(Fig. 2)*. Since there is an ever-growing trend to make front baffles thicker, it's almost as though drivers are being mounted into a tunnel!

Are cones of open-back drivers acoustically opaque? Almost always some sort of foam or stuffing material is used to prevent any of the interior sound from bouncing back out through the cone. But what about the sound that is reflected within this very short tunnel just behind the cone? Is this a problem? Is it audible? Yes, it is!

The need is greater than most builders realize to treat surfaces in proximity to the back side of the cone. One solution would be to reshape the baffle hole inside the enclosure. This would be similar to what is done on the outside of an enclosure to minimize diffraction and early reflections. Shape this short tunnel so that sound is reflected away from the back side of the cone *(Figs. 3* and *4)*. Or apply some sound-absorbing material, such as felt or open-cell foam *(Fig. 5)*. Self-adhesive weather strip would be easy to use, and the difference will be well worth it.

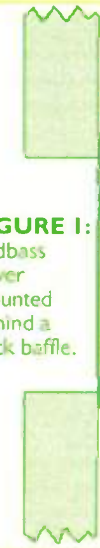

FIGURE 1: Midbass driver mounted behind a thick baffle.

FIGURE 2: Driver flush-mounted.

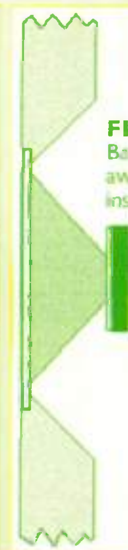

FIGURE 4: Baffle angled away on inside.

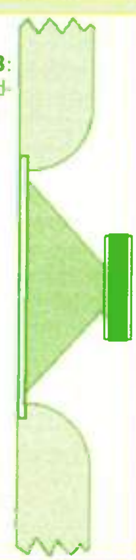

FIGURE 3: Baffle rounded over on inside.

FIGURE 5: Sound-absorbing material helps reduce reflected sound.

TITANIC 1200

Dayton Loudspeaker Co.®

The Dayton Loudspeaker Company is proud to introduce the **Titanic 1200 Subwoofer**. We feel Webster's definition of Titanic as "of great size, strength, or power"; "of or like the Titans", perfectly describes this driver! With specifications like 16Hz Fs, 14mm Xmax (linear), 90dB SPL (2.83V) and 350W power handling, we're sure you will agree that this subwoofer is truly **Titanic!**

We assembled a team of the best speaker designers in the industry with one thought in mind ... to build the finest home theater subwoofer on the market! These engineers were chosen because of their expertise and pioneering designs of long excursion, high output subwoofers. A dozen prototypes were built and rigorously tested before we were satisfied with the final design parameters.

The latest state-of-the-art manufacturing equipment and the finest materials available are used to ensure that each driver is built to the highest standards of quality. CAD design and CNC machining allow for precision fit and close tolerance alignment to increase flux density and enhance heat transfer. Only the finest components are utilized: a heavy cast aluminum basket to control unwanted resonance, a talc-filled polypropylene cone to ensure stable, non resonant operation, Santoprene® rubber surround for extended life and long excursion, an ultra high power voice coil assembly with a high temperature resistant Apical® former (which is far superior to standard Kapton®), and quality, high tech adhesives to hold it all together. Steel parts are coated with a black high emissivity coating (originally developed for NASA) which improves heat dissipation and lowers distortion. All of these components cost more, but are worth it!

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Although the 12" Titanic was designed primarily as a sealed box woofer, we found it is also well suited for 4th order bandpass enclosures. One possible design is a 4.5 cubic foot bandpass that yields a frequency bandwidth of 17.5Hz - 70Hz (-3dB). This design produces an output of 112dB and remains linear down to 28Hz at full power!

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Try it for 30 days ... If you don't feel this is the best home theater subwoofer you've ever heard, we'll refund your money! The Titanic 1200 is covered by our unconditional 5 year replacement warranty.

Thiel-Small Parameters

◆Power handling: 350 watts RMS/ 450 watts max. ◆Voice coil diameter: 2" ◆Voice coil inductance: 1.96 mH ◆Nominal impedance: 4 ohms ◆DC resistance: 3.66 ohms ◆Frequency response: 16-400 Hz ◆Magnet weight: 84 oz. ◆Fs: 16 Hz ◆SPL 90dB 2.83V/1m ◆VAS: 9.894 cubic ft. ◆QMS: 8.22 ◆QES: .42 ◆QTS: .407 ◆XMAX: 14.2 mm ◆Net weight: 14.6 lbs. ◆Dimensions: A: 12-1/8", B: 11-1/8", C: 6-9/16", D: 6", E: 2-3/4"

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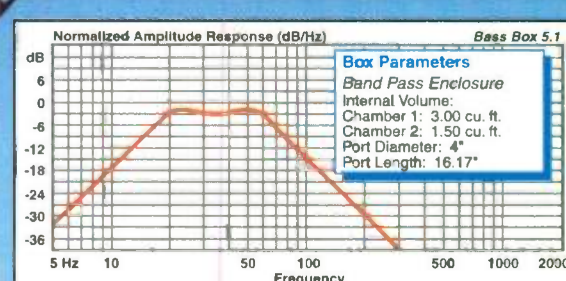

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The 1978 C.E.S. in Chicago was the very first time that Morel Acoustics USA, Inc. presented their product to the public. It became clear, early on, that the loudspeaker industry was in need of high quality speaker drivers. Shortly thereafter we introduced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

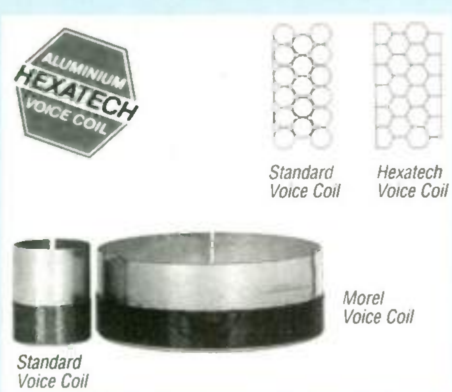
Through the course of the years Morel brought many unique and innovative products to the speaker industry. The introduction of the 3″ voice coil in a 5″ basket, using hexagonal shaped aluminum wire, utilizing a double magnet system and ducted design woofers and mid-basses are a few examples of the company's 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:

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