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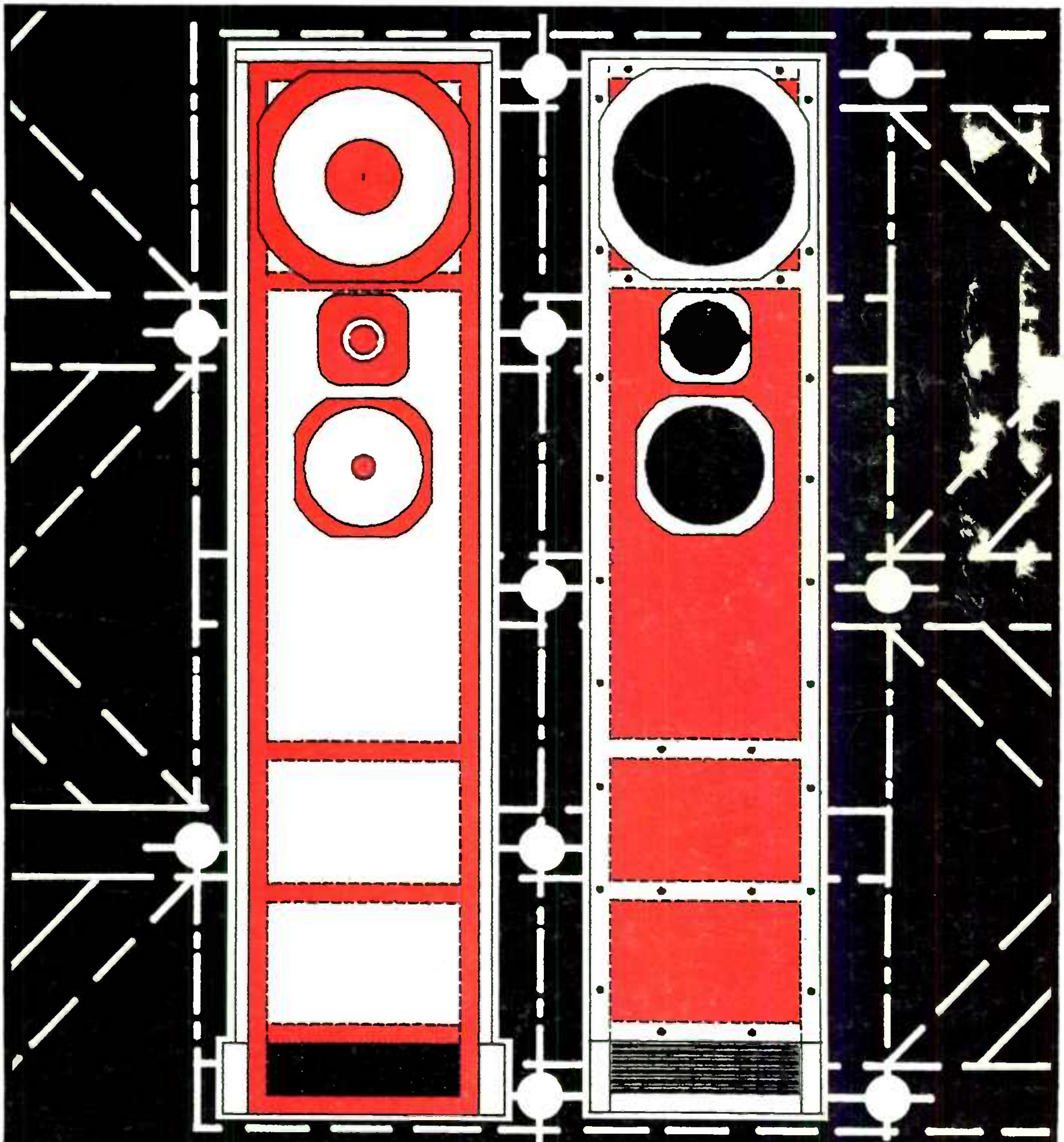
Speaker Builder

THE LOUDSPEAKER JOURNAL



INSIDE THE BROTHER JON

World Radio History

What do ...WILSON AUDIO, VTL, AUDIO RESEARCH, HALES, SONIC FRONTIERS, NHT, CARY, ARTEMIS, NESTOROVIC, PARADOX, MAS, WHATMOUGH, JACKSON BROWNE STUDIOS, ATHENA PRODUCTIONS, WATER LILY ACOUSTICS... **have in common?**

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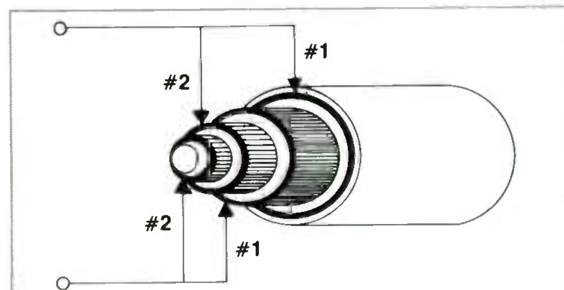

This cross-sectional drawing shows the coaxial construction of a MultiCap. For simplicity's sake, only two of the ten sections are included.

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Oakville, ONT Canada L6L 6M5
(416) 847-3277 FAX (416) 847-5471

Fast Reply #JG703

World Radio History

Good News

A new upgrade to Speaker Designer, the loudspeaker design and modeling program for MS-DOS systems, lets you save your designs to disk and manage your design files via a new management feature. **STUART E. BONNEY** has added extended input error trapping and correction functions, new sample input files, and dual driver designs to version 2.0.

The program, which retails for $27.50 (part #SOF-SPD1B5, add $2 for shipping and handling), is available from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458 (603) 924-6371, FAX (603) 924-9467.

The long dormant **BOZAK AUDIO LABORATORIES** re-entered the audio market with five speaker systems. Featuring full-cut veneers and hand-rubbed finishes, the Bozak Acoustic Isolation Enclosure consists of one large bookshelf and four standing systems. Prices range from $1,350 to $4,500 per pair. According to the manufacturer, the design reduces distortion (caused by driver-induced cabinet vibrations) by isolating the air the drive units use from the cabinet's exterior with a viscous foam-filled cavity.

Contact Bozak Audio Laboratories, 539 Norwich Ave., Taftville, CT 06380, (203) 886-1510, FAX (203) 886-1413 for details.

Fast Reply #JG1457

AUDIOSOURCE's VS Two, a shielded video loudspeaker, features a built-in amplifier and selectable line or speaker level input. The VS Two is designed to work with complex audio/video setups and surround systems including Dolby Pro Logic.

Sold individually, you can use the VS Two as a center-channel speaker to provide movie dialogue tracks. Purchased in pairs, it operates either as a rear-, side-, or front-channel surround speaker or as a simple extension for a stand-alone audio-for-video system. As it is fully shielded, you can place the VS Two near televisions and monitors without electromagnetic interference.

The VS Two features dual 4" woofers matched to a 1" ferrofluid-cooled dome tweeter. Frequency response is 70Hz–20kHz with an 8Ω input impedance level for the speaker input and a 47kΩ impedance for line level input. The 30W amplifiers include signal sensing circuits which automatically turn the system on or off.

For details, contact AudioSource, 1327 N. Carolan Ave., Burlingame, CA 94010, (415) 348-8114, FAX (415) 348-8083.

Fast Reply #JG99

Car stereo retailers can create on-the-spot custom subwoofer designs for customers with **BLAUPUNKT**'s CAD program, BlauBox ($199.95). It also prints out scale plans and dimensions for building subwoofer boxes.

BlauBox predicts the acoustical performance of various woofers and boxes. By entering the dimensions of trunk space allotted for an enclosure, the user can perform a variety of "what if" calculations based on the enclosure shape, volume, and acoustic configuration, woofer selection and crossover parameters. The program also prints frequency plots for each proposed configuration as well as detailed plans and dimensions for cutting the enclosure panels.

BlauBox designs rectangular, wedge-shape, and tubular enclosures and supports ten of the most common acoustic configurations including sealed, vented, bandpass single vent, bandpass double vent, bandpass single vent with inductor, bandpass double vent with inductor, and bandpass series vent. It also supports Isobarik variations of each design allowing a roughly 50% enclosure volume reduction.

The program runs on any IBM compatible computer with DOS 3.1 or later and on any IBM VGA display. It will output to Epson 9/24 pin and HP LaserJet printers or any printer with compatible emulations.

For additional information, contact Blaupunkt, 2800 S. 25th Ave., Broadview, IL 60153, (800) 950-2528.

Fast Reply #JG1477

Continued on page 5

World Radio History

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World Radio History

Continued from page 3

From **TRUE IMAGE AUDIO**, MacSpeakerz is a loudspeaker design CAD program for the Macintosh. Version 2.5 offers two frequency response scale choices: 0dB Mode and dB SPL Mode. The new dB SPL scale shows the predicted sound pressure level of a speaker at any distance and any input power level. Speaker designers can use the SPL scale along with the MacSpeakerz excursion response to see precisely how loud the system can play. Now you can evaluate the speaker's power and excursion limits in terms of SPL.

Other improvements with V.2.5 include additional choices for the dB scale's resolution, an expanded user's guide, greater print capability, and Isobarik enclosure analysis. The list price is $299 and you can order it direct from True Image Audio by calling (800) 621-4411, (619) 480-8961, FAXing (619) 480-8961, or writing 349 W. Felicita Ave., Suite 122, Escondido, CA 92025.

Fast Reply #JG1355

KINERGETICS HOLDINGS LTD., a London-based venture capital group, announced it has acquired KEF and signed an agreement to acquire Celestion International Ltd., pending approval of Celestion's shareholders.

Kenergetics Holdings is a newly-formed investment company with three shareholders: GP Venture Capital Ltd., Kinergetics Research, and a UK-based venture capital company.

Both KEF and Celestion International Ltd., are among the largest UK loudspeaker manufacturers.

Continued on page 8

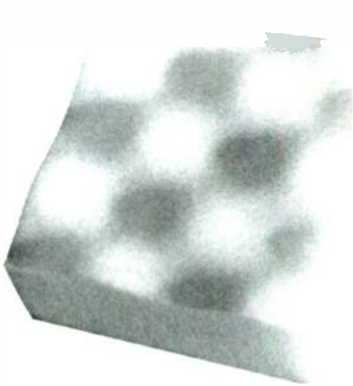
OUTLINE's electronic speaker turntable is designed for audio measurement laboratories making polar plots of loudspeaker systems. The turntable makes it possible to measure speaker directivity performance.

The ST1/ET1 ($975) works in conjunction with the Audio Teknology LMS and DRA MLSSA or other measurement systems driving external equipment with TTL signals. The ST1 turntable is a cylinder measuring 35cm. in diameter and 10cm. high. The unit features motor-driven heavy-duty bearing gear suitable for use with large, heavy loudspeaker systems up to 300kg.

The ST1/ET1's top and bottom plates have five fixing points allowing installation of custom hardware. The ET1 is a standard 19″ EIA rack that controls the functions of the ST1 turntable. This allows automatic or manual operation and the choice of several parameters such as angular step increments.

Further information is available from Outline, Via Leonardo da Vinci, 56 25020 Flero, Italy 011 39 (030) 3581341, FAX (030) 3580431.

Fast Reply #JG274



NETWELL NOISE CONTROL's AZ-FireFlex Acoustical Foam noise control panels are made of a porous melamine foam and meet Class A fire code ratings for flame spread and smoke density. Panel sizes are 24 × 48 × 2″ and come in custom sizes and three neutral colors—white, beige and gray.

Direct your inquiries to NetWell Noise Control, 6125 Blue Circle Dr., Minneapolis, MN 55343, (800) 638-9355.

Fast Reply #JG644

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Our Norsorex gaskets lead the battle to seal and isolate your loudspeaker components from the enclosure, putting vibrations and air leaks to rest for good.

Originally developed as a surround material for our highest quality loudspeakers, Norsorex is a super-damped (or dead) material. By mounting between the loudspeaker frame cabinet, the Norsorex gaskets completely decouple the loudspeaker from all vibrations and resonances of the cabinet, achieving pure sonic quality.

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Gaskets are available for all Polydax standard drive units. And we are now proud to introduce gaskets for various standard American size woofers (6 1/2", 8", 10", & 12").

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Fast Reply #JG1445

← ***Fast Reply #JG29***

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About This Issue

Good sound reproduction is the Holy Grail of every audiophile. **Howard Mureen** ends his search for this elusive prize with an "Acoustic Resistance-Tuned Enclosure." In his article beginning on page 10, he takes you step-by-step through its construction and testing, and answers some classic questions.

Have you ever wished your computer could calculate and plot vented-box responses? On page 16, **Paul Rahnefeld** describes how you can create your own "Non-Optimum Vented-Box Spreadsheet Documentation." He defines the components and parameters of his spreadsheet, and explains how to calculate and plot responses.

On page 22, **Robert Spear** and **Alex Thornhill** continue the saga of their prize-winning speaker system, "The Brother Jon." Part 2 of a three-part series takes you behind the scenes of its construction.

Beginning on page 34, **Marc Bacon** solves a problem, sees the light, and learns some lessons as his two-part series on "The Danielle" concludes.

In "Electronic Sound Absorption" **Peter Muxlow** describes how to improve the quality of the sounds you're hearing through active-noise control and loudspeaker location. Find out how on page 48.

Our intrepid Contributing Editor, **David Moran**, critiques the ever-popular Bowers & Wilkins loudspeakers in this issue's "Moran in the Market." For an intriguing solution to a baffling problem, see his review on page 74.

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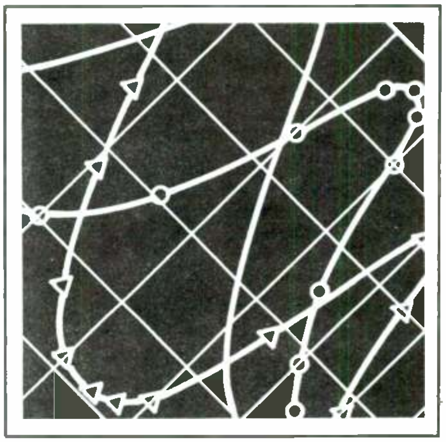
Speaker Builder
THE LOUDSPEAKER JOURNAL

VOLUME 13 NUMBER 5 SEPTEMBER 1992



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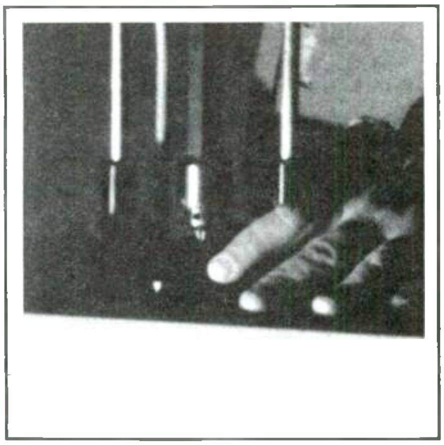

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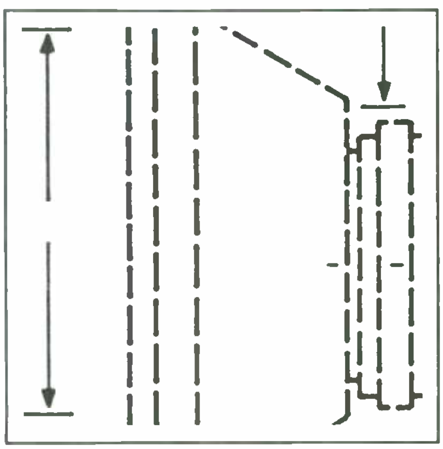

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FEATURES

DEPARTMENTS

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Continued from page 5

QUART's QM 214 Universal is the latest addition to the company's Sound Set Series, a line of speakers designed to drop directly into your vehicle's existing factory speaker cut-outs. With Sound Sets, you can upgrade speaker performance and keep your investment out of sight.

Designed for 4" openings, the QM 214 Universal features a 4" woofer and a ¾" surface- or flush-mount titanium dome tweeter. Quart provides outboard crossovers with variable tweeter settings. Rated power is 40W with a frequency response measuring 62Hz–32kHz. Mounting depth is 2" or 50.5mm.

The QM 214 Universal retails for $259 per pair. Quart also offers a QM 215 Universal designed for 5¼" factory cut-outs and a QM 218 Universal for 6½" openings.

For additional details, get in touch with MB Quart Electronics USA, Inc., 25 Walpole Park South, Walpole, MA 02081, (508) 668-8973, FAX (508) 668-8979.

Fast Reply #JG356

HOW DO YOU LIKE YOUR EGGS?

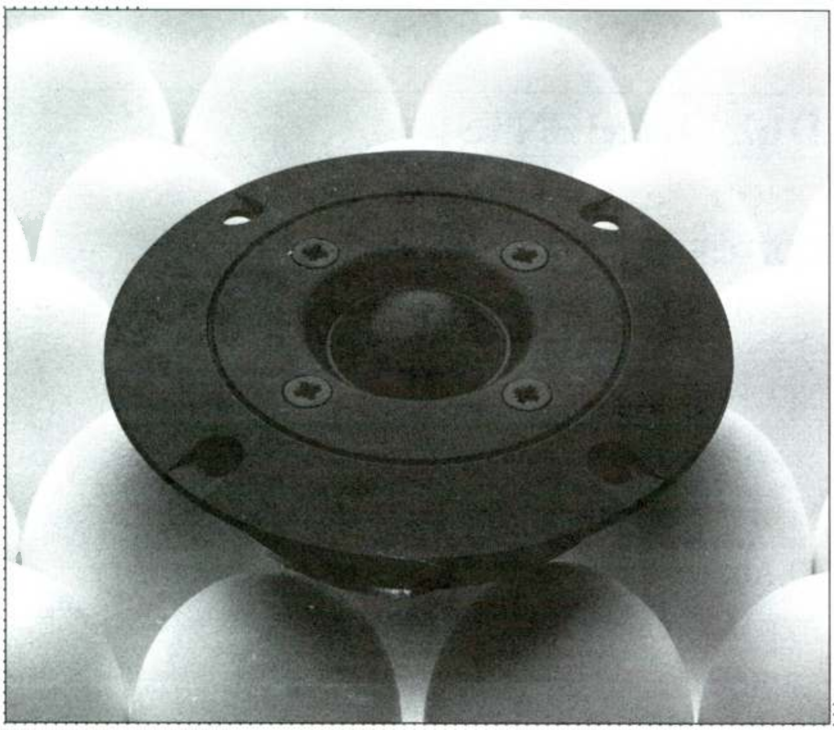
Mother Nature made sure her eggs wouldn't scramble when she created the egg shell.

TWO25M

She made the tip of an egg the strongest point. This shape was applied to the dome profile of our new **TW025M** tweeter. By optimizing the stiffness of the diaphragm, our engineers ensured that the dome would act like a perfect piston at all frequencies, with no out-of-phase breakup at the tip.

Our unique faceplate design allows for smoother sonic characteristics by minimizing edge diffraction without adversely affecting the dispersion pattern of the tweeter.

If you're tired of scrambled high frequencies, order up a pair of our new **TW025M** tweeters. ***Your ears will love the taste.***



polydax SPEAKER CORPORATION ***Unsurpassed Performance Characteristics...***

Fast Reply #JG1112

AUDIENCE announced it is now exclusively manufacturing and distributing the SiderealKap, a metallized polypropylene capacitor with low DA, DF, and ESR designed by Sidereal Akustic. It features a self-healing design with multi-gauge stranded oxygen-free copper leads, and low-leakage, high-insulation resistance.

Their DC operation can include power factoring, line filtering, and high-level audio. You can use them with RF circuits, in computers and high-sensitivity instrumentation, and in blocking, coupling, or bypassing in AC.

For prices and additional information, get in touch with Audience, 1848 W. 1st St., San Pedro, CA 90732, (310) 521-0033, FAX (310) 521-0485.

Fast Reply #JG1463

POLYDAX SPEAKER CORPORATION, a subsidiary of Audax Industries, introduced a new line of Norsorex gaskets. Originally developed as a surround material for the company's best loudspeakers, Norsorex is a super-damped material. Mounted between loudspeaker frames and cabinets, Norsorex gaskets decouple vibrations and resonances.

Gaskets are available for Polydax drive units and four sizes to fit standard American woofers (6½", 10", and 12").

To find the nearest Polydax distributor, contact Polydax Speaker Corp., 10 Upton Dr., Wilmington, MA 01887 (508) 658-0700, FAX (508) 658-0703.

If you use an Amiga computer, **dissidents'** SpeakerSim ($112) can help with your loudspeaker designs. It is intended for audio/sound engineers, musicians, and hi-fi enthusiasts interested in designing or customizing their loudspeaker set-ups. The package features a variety of graphing modes, supports the IFF ILBM standard, and will copy its display to any Workbench-supported printer, or the Epson HI-80 plotter. It runs on any Amiga with at least 512K of RAM and one disk drive. SpeakerSim multi-tasks and uses a standard Intuition interface.

For further information, contact dissidents, 730 Dawes Ave., Utica, NY 13502, (315) 797-0343.

Fast Reply #JG1476

World Radio History

Editorial

MUSIC SAMARITANS

Almost all our friends are casual listeners to their music—whatever preferences they may have in terms of the type of music usually entering their space from a speaker or two. This is true even though we are living in a century during which the presence of music has increased almost exponentially every decade or so.

We might reflect on the fact that no group of humans in the world's history has had a greater quantity and variety of music available to them, from more ages and in more types. And yet we might well ask whether the quantity of music has not eroded, in some sense, the power of music to move, soothe, inspire and motivate the average listener.

One of the benefits of attending a concert is the kind of attention we usually feel obliged to give to musical performances for which we have paid money. This doesn't include those few who find it irresistible to do a running verbal commentary during a performance.

But in our living rooms, music all too often becomes mere accompaniment to other activities. The evening meal on TV trays, background to card games, sonic wallpaper to a project. One of the newest efforts to make music ubiquitous (along with the commercials) is the spread of daytime formula radio to the workplace. As Lucille Ball says to her boss (in one of the early episodes of "I Love Lucy"), "I got so used to having music on while I studied in high school that now I can't get used to all this silence."

But in one sense if music is "everywhere" it is actually nowhere. We no longer hear it. If most of your friends are like mine, that is where they live. Thus music on the stereo is just an inaudible part of the environment.

Part of the reason for this is that we can buy very ordinary sound for very little money. Ordinary sound is seldom compelling or enticing. I was struck recently by the array of FM clock radios at my local discount store. A Chinese FM clock radio with a digital clock readout and a telephone was priced at $40. Its tiny string wire for an "antenna" captures my good music station 80 miles away. The capability we can buy for pennies is a hazard.

Most of our friends and neighbors know high quality audio is possible and probably better but they almost invariably say, when an audiophile mentions it, that such stuff is beyond their ear's capability, or some such thing. Or they regard it as overkill, which it sometimes is.

I find it always a pleasure to invite friends in for a listen. I try to do it with some restraint, avoiding a maxed out performance of the 1812 Overture as a first sample. The main, and most difficult, trick is to persuade people to merely listen with their full attention. Just listen. Sometimes it grabs them, sometimes not.

I've never believed it made any sense to hit the missionary trail merely for the cause of good sound. I do believe it is a beneficent act to assist any human to discover the satisfactions of one of his or her primary and deeply rewarding appetites. I suppose we might regard such activity as a subtle form of teaching. And surely not everyone, or even a majority of those with whom we share, will discover this precious, innate capacity.

But few satisfactions are more rewarding than introducing a fellow human to the charm, delight and satisfaction of concentrated listening. The act has rewards similar to those of teaching, seeing the surprise in the eyes of your friend at doing something heretofore thought to be ordinary or uninteresting, or beyond the pale. To discover so powerful an appetite without ever having been aware of its existence is a revelation, an undiscovered part of yourself.

In these days of shortages and boredom with the ordinary, the gift of discovering music's real power and dimensions is something every audiophile might well consider sharing with as many as possible. After all, this avocation isn't really about hardware and software, performances, distortion or bargain prices. It is about the music and its power to add a unique dimension to a human life.—E.T.D.

World Radio History

ACOUSTIC RESISTANCE-TUNED ENCLOSURE

BY HOWARD F. MUREEN

For more years than I would like to remember, I have been chasing the elusive ghost of good sound reproduction. Although I have built many enclosures, I achieved second harmonic only in the lower octaves until I discovered the R-J enclosure.

More than thirty years ago, my brother Robert designed a 2.87 ft.^{3} acoustic-resistance enclosure. It had a 12″ speaker mounted on the front with full cone radiation and a 64 in.^{2} slot located in the back panel (*Fig. 1*).

The slot's width, the distance between the port panel and the tuning panel, determines acoustic resistance. Robert tuned the box by increasing or decreasing the space with the panel. Reducing the space by one-half increased the acoustic resistance eight times.[1] He selected a University 6201 coaxial 12″ driver for this design. It worked so well, we built a pair for each of our stereo systems (*Photo 1*). The original boxes are part of my living room ensemble today, residing on either side of the sofa.

PHOTO 1: Original enclosure.

PORT SIDE. About three years ago, I changed the drivers and updated my enclosures by converting them to a three-way system. The improvement was considerable. I installed a pair of Swan 305 woofers (Madisound) and changed the 64 in.^{2} slot to a 48 in.^{2} port (6″ × 8″ hole) in the center of the back panel. The tuning arrangement remained the same. I tune the system by spacing the inside panel in relationship to the ported back panel.

After my success with the acoustic resistance enclosure, I thought others might be interested in building a similar system.

Several questions remained:

1. Does the size (area) of the port tune the box?
2. Does a critical port size exist?
3. Must the impedance peaks be equal?
4. Must the frequency peaks be equally spaced from the trough?
5. Would a smaller enclosure work as well?

To find the answers to these questions, I set up testing procedures.

TEST BOX CONSTRUCTION. I decided to construct a test box and run curves with three different port sizes. I selected 2.55 ft.^{3} to use as the box volume for all the tests because the size is convenient and many modern drivers operate well within this volume (*Photos 2, 3, and 4*). The port in the back panel was arranged for expansion from 36 in.^{2} to 64 in.^{2} and the duct path (space between the two panels) would never be less than 4″. Four inches appeared to be a logical

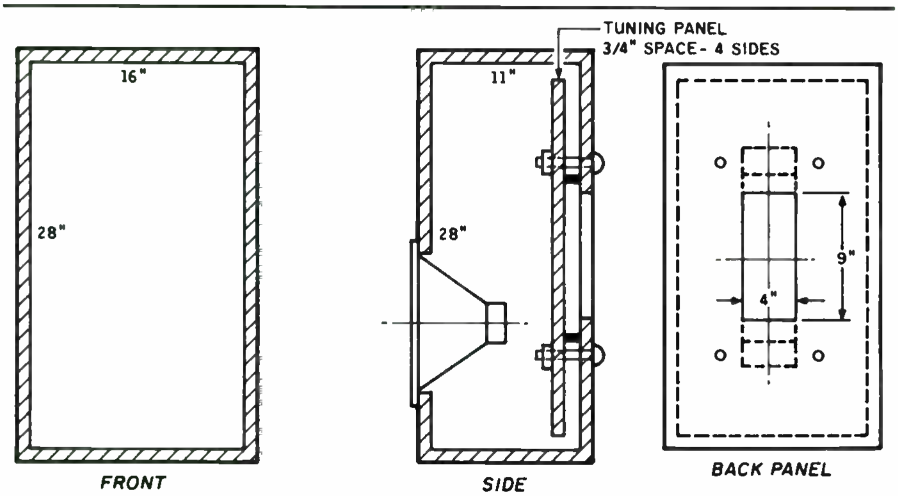


FIGURE 1: Test box drawing inside dimensions 16″ × 28″ × 11″, 36 in.^{2} port.

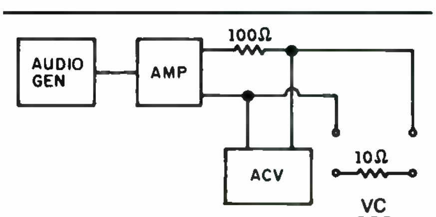


FIGURE 2: Circuit for tests conducted.

World Radio History

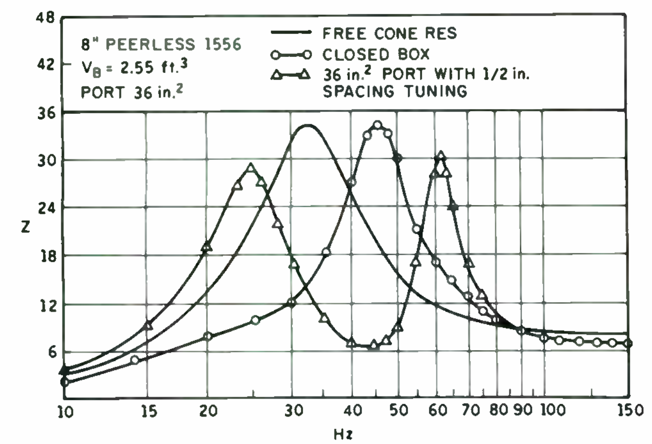


FIGURE 3: 8″ speaker, free cone closed box and tuned box with 36 in.² port, ½″ panel spacing.

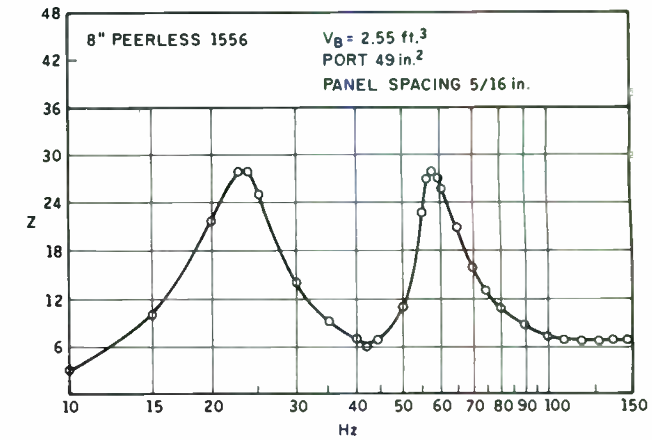


FIGURE 4: 8″ speaker, 49 in.² port, 5⁄16″ panel spacing.

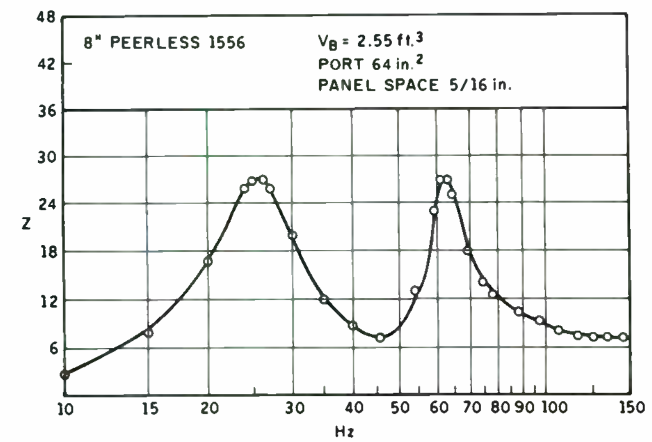


FIGURE 5: 8″ speaker, 64 in.² port, 5⁄16″ panel spacing.

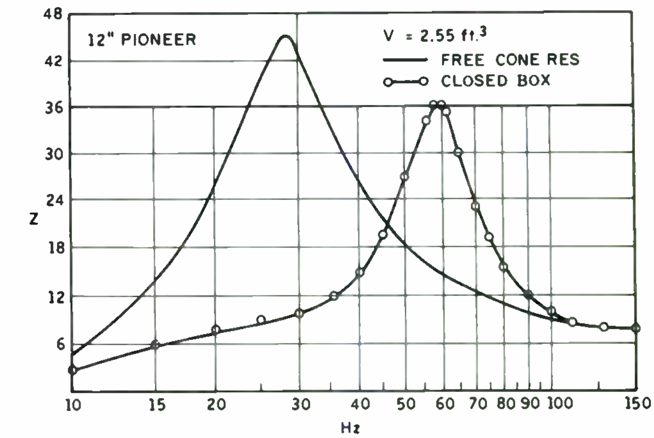


FIGURE 6: 12″ speaker, free cone and closed box.

length to use in order to keep the duct space from becoming either too deep or too narrow.

The acoustic resistance is a function of the duct passage length and the width as expressed by the following equation,

$$R_A = \frac{kl}{t^3 w}$$

where k is a constant, l is the duct passage length, w is its width, and t is its thickness. (Space between port panel and tuning panel.)

With the 36 in.² port, the upper and lower passages would exceed 4″, but all four passages would be about the same and not less than 4″ in length with the 64 in.² port.

I constructed the inside panel to provide ¾″ clearance from the screw strips that fasten the back panel to the enclosure walls. I chose this measurement because I did not expect to exceed this spacing between the port back panel and the tuning panel.

I mounted the front speaker panel in the same manner as the ported rear panel, on screw strips. I cut the speaker panel to provide for a 12″ driver. Later, when I used an 8″ driver, I mounted an adapter panel inside.

I constructed the enclosure of ¾″ particleboard and the tuning panel of ¾″ plywood. By caulking all its leaks, I sealed the box. I mounted the tuning panel to the port panel by four ¼″ × 2½″ round head bolts with a ¼″ T-nut in the tuning panel. The holes through both panels are 5⁄16″ in diameter. I used a flat washer under the heads of the four bolts. By placing small pieces of wood near the bolts, I was able to create a space between the two panels. Tightening the bolts drew the panel against these spacers (*Fig. 1*).

This arrangement proved convenient when conducting tests. I could set the enclosure face down on the workbench, loosen bolts separating the panels, insert different sized spacers, tighten the bolts again, set the box upright, and resume testing.

Once I tested all the drivers with the 36 in.² port, I removed and disassembled the back panel. With the use of a saber saw, I enlarged the port to 49 in.² I plotted the curves for all the drivers, and continued testing up to a 64 in.² port. (I did not use damping in the test enclosure.)

TESTING. I will cover only the tests concerning the 8″ Peerless #1556 driver (Madisound) and the 12″ Pioneer #A30FU20-52F (Parts Express). I used a Hewlett-Packard 200CD audio frequency generator, a Radio Shack Micronta LCD digital multimeter, and a Fisher 601 receiver with 100W amplifier in this project. The test hookup is shown in *Fig. 2*. I adjusted the output from the audio generator and the amplifier to 10mV across a 10Ω resistor for all the conducted curves, and read the plotted points across the speaker's voice coil. With each speaker, I plotted a free cone resonance curve and a closed box curve. By removing the spacers and pulling the tuning panel up against the port panel, I closed the box.

I used a 36 in.², 49 in.², and a 64 in.² port with the tuning space between the port panel and the tuning panel from 3⁄16″ to 1 3⁄16″ and plotted curves for each condition. We will discuss only the best combinations.

Figure 3 shows the free cone resonance and the closed box and the 36 in.² port with ½″ panel spacing for the 8″ speaker. *Figure 4* shows the same speaker with a

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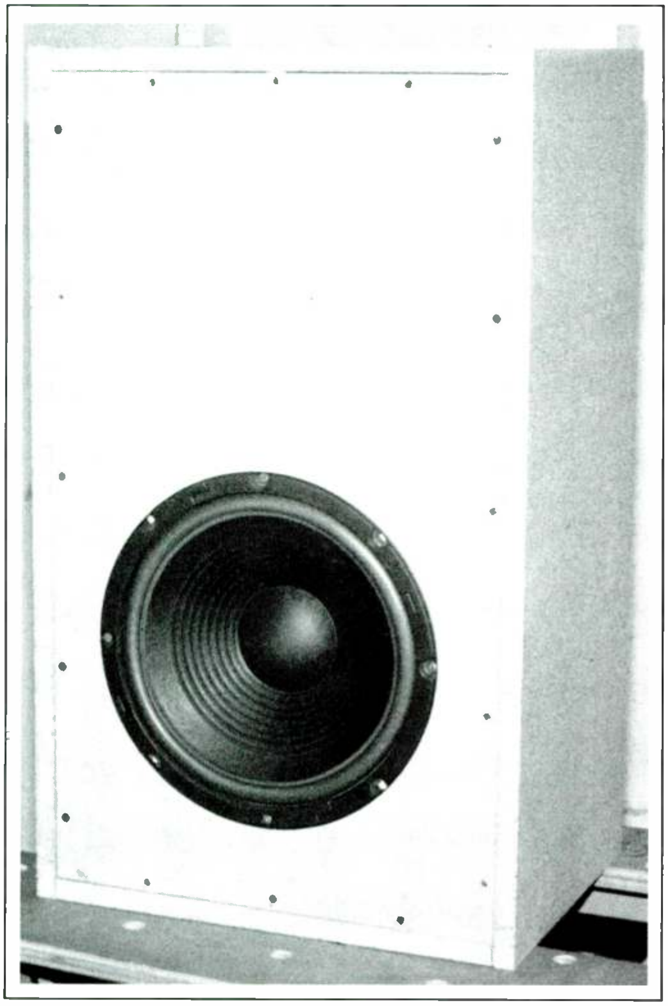

PHOTO 2: Test box front view with 12" speaker.

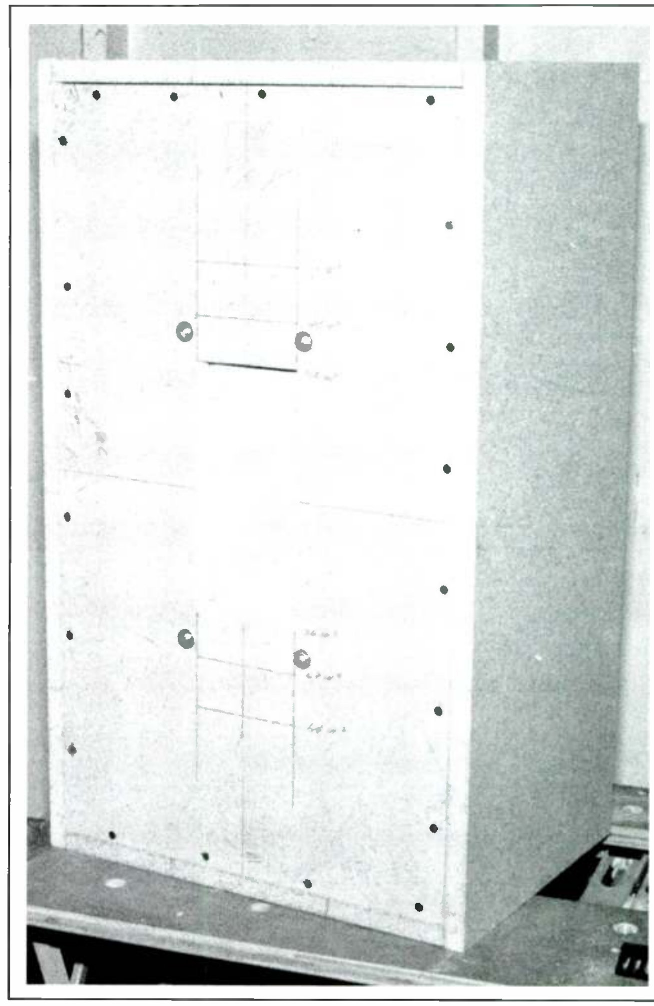

PHOTO 3: Test box rear view with 36 in.^{2} port. Lines show cut-out expansion for 49 in.^{2} and 64 in^2 ports.

49 in.^{2} port with 5⁄16" panel spacing. *Figure 5* has a 64 in.^{2} port and a 5⁄16" panel spacing.

I adjusted the panels so that the impedance peak amplitudes were as nearly equal as possible and the frequencies from the trough to the lower and higher peaks were equally spaced. Slight variations of 1Ω–5Ω impedance and/or a frequency variation of up to 5Hz indicated no degradation in sound reproduction.

PANELING. Bringing the panels closer together increases the acoustic resistance. This tends to lower the Q of the enclosure. Also, as the panels get closer, the system approaches a closed box condition.

For a closed box for any given enclosure, this sets the lowest frequency at which the higher peak (f_H) can occur. As the space between the panels increases, the acoustic resistance effects load less, while increasing the amplitude of f_l (lower frequency) and reduces the amplitude of f_H (higher frequency). This effectively tunes the enclosure upon attaining the correct spacing and provides proper loading for the system.

The acoustic resistance-tuned enclosure appears to be optimum as is borne out by listening tests. The peaks will be equally spaced in frequency from the

Continued on page 14

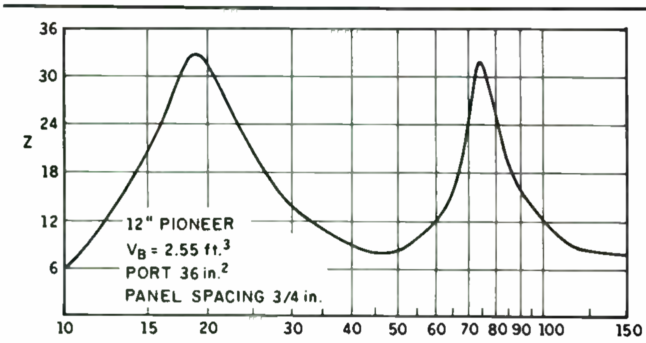

FIGURE 7: 12" speaker, 36 in.^{2} port, 3⁄4" panel spacing.

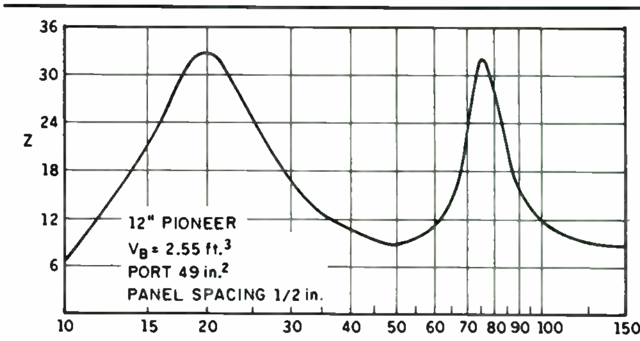

FIGURE 8: 12" speaker, 49 in.^{2} port, 1⁄2" panel spacing.

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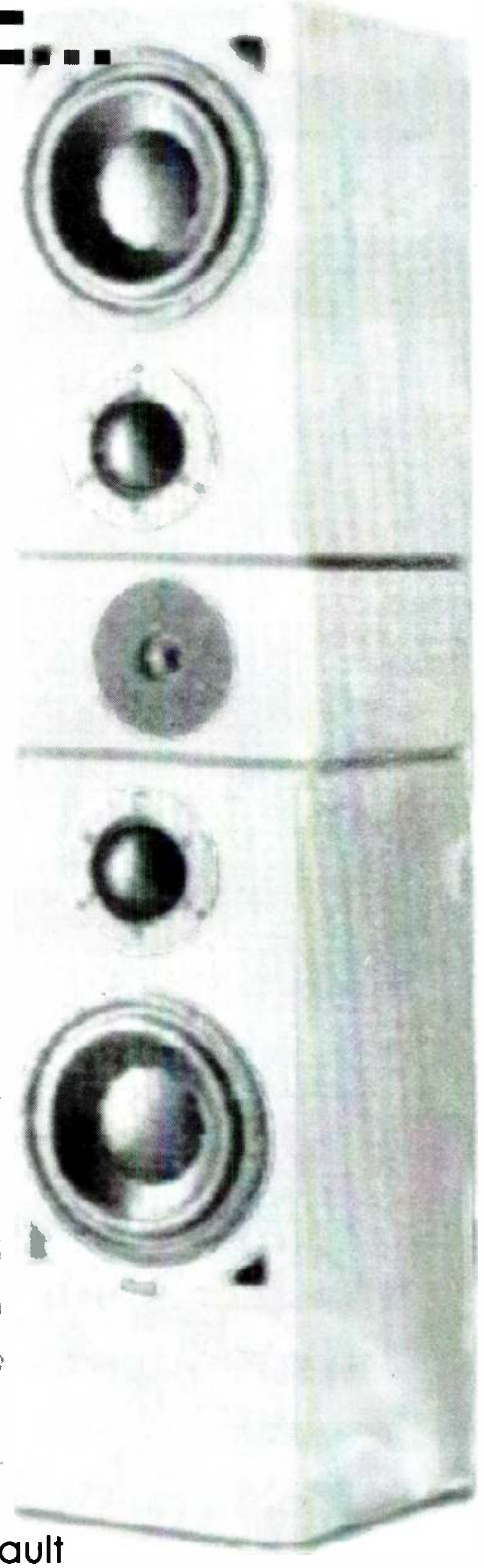

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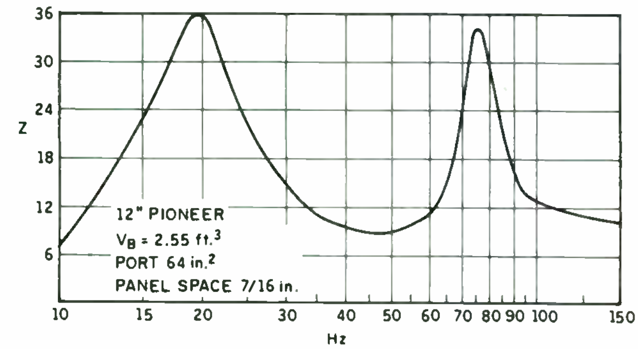

FIGURE 9: 12" speaker, 64 in.^{2} port, 7/16" panel spacing.

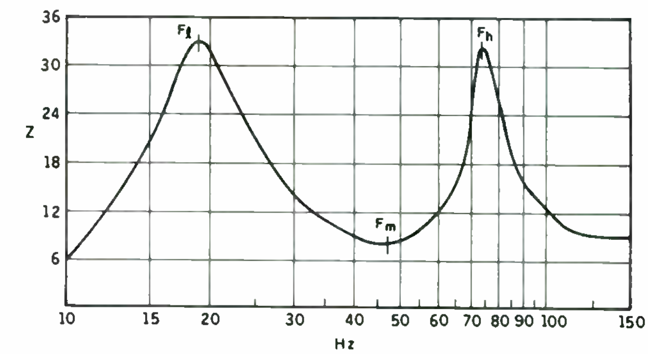

FIGURE 10: Typical impedance response showing f_l, f_M, and f_H.

Continued from page 12
trough (f_M) to each peak upon reaching the equal impedance condition, *Fig. 10*.

Tuning the enclosure will also shift the F_l, F_M, and F_H to slightly different frequencies. The greatest change seems to occur in the F_H impedance peaks.

When I decided to build the 2.55 ft.^{3} box for these tests, I knew beforehand both speakers would perform in that volume. The pertinent manufacturing specifications for the 8" Peerless and 12" Pioneer speakers are:

8" Peerless #1556 TX205F/8:

f_S	= 29Hz	*(32Hz)
Q_{TS}	= 0.32	*(0.489)
V_{AS}	= 3.71 ft.^{3}	*(3.59 ft.^{3})

12" Pioneer #A30FU20-52F:

f_S	= ______	*(28Hz)
Q_{TS}	= 0.357	*(0.347)
V_{AS}	= 11.8 ft.^{3}	*(11.8 ft.^{3})

* (My test values, *Equation 3*)

I recommend anyone wishing to build a box calculate the V_B by using the accepted equations as a starting point.

I designed the original enclosure for 80–85Hz—any good speaker will perform as long as its free cone resonance is less than 70–75Hz. In fact, many of today's speakers have an f_S of less than 60Hz. Consult (sidebar): Additional Data for equations to calculate V_B, F_B, as well as D. B. Keele's equation for V_B using speaker Q_{TS} and V_{AS}.[2]

Curves in *Figs. 6–9* concern the 12" Pioneer speaker and show the free cone response, the closed box, and the optimum adjustment for 36 in.^{2} to 64 in.^{2} port openings.

THE ANSWERS. My test results revealed the answers to many of my questions:

1. Does the size (area) of the port tune the box? Yes. Without the panel, the port would tune the box to F_B (*Equation 2*, Additional Data). The port area of the three sizes used made little difference in system tuning while the panel spacing made a great difference. The size of the port appeared to have little effect on system tuning even when the port area was larger than the area of the speaker cone, such as with the 8" speaker with a 64 in.^{2} port. The right panel spacing could tune each area. The port area determines the box frequency and the panels tune the system (speaker in the box).

2. Is there a critical port size? There appeared not to be in the tests I conducted. Again, panel spacing was a critical adjustment regardless of the port area. The port sets the f_B—about 80Hz-92Hz for my tests. When the box is tuned, the F_H shifts slightly to a lower value.

3. Must the impedance peaks be equal? Music reproduction was good when the impedance peaks f_L and f_H were equal in amplitude. By ear, I could not detect much difference within a 5Ω variation, but I found equal impedance peaks to be optimum.

4. Must the frequency peaks be equally spaced from the trough (f_M)? This appears to happen naturally when f_l and f_H impedances are equal. Again, 5Hz made little noticeable difference, in sound reproduction.

5. Will a smaller enclosure work as well? The answer is yes. I placed the 8" speaker in a 1 ft.^{3} box with a 2 in.^{2} port and a panel spaced at ¾". The sound was good and improved when I added damping.

CONCLUSION. Constructing an acoustic resistance-tuned enclosure is relatively simple; you can finish it any way you like. There are no critical factors to consider when building the enclosure. You can tune it reasonably well with a good ear, although I recommend using equipment as psycho-acoustics can fool

Additional Data

Air resonance of a Helmholtz resonator can be approximately determined:

$$f_B = \frac{C(A)^{1/4}}{2\pi(V)^{1/2}} \quad (1)$$

where f_B = box frequency in hertz, A = area of port (in.^{2}), V = enclosure volume (in.^{3}), and C = speed of sound in air (in./sec.).[1]

You can rearrange the above equation for calculating V_B by:

$$V_B = \tfrac{1}{2}\sqrt{2070\ [(A)^{1/4}/f]} \quad (2)$$

where V_S = enclosure volume (in.^{3}), A = area of port (in.^{2}), and f = Hz.[1]

$$V_B = 15Q_{TS}^{2.87}\ V_{AS} \text{ (Keele, D. B.)} \quad (3)$$

Where V_B = enclosure volume (ft.^{3}), Q_{TS} = total driver Q, and V_{AS} = compliance equivalent volume of the driver (ft.^{3}).[2]

About the Author

Howard F. Mureen's interest in radio and audio began at the age of 12. He attended ground and aircraft radio school in Fort Monmouth, NJ during WWII, after which he began a more serious study of speaker enclosures. He attained a degree in electrical engineering and was employed in that field until his retirement in 1990. He currently resides in North Texas with his wife.

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you. A slight variation in V_B can cause changes requiring careful re-tuning.

The 8″ Peerless driver fits better inside the box than the 12″ Pioneer driver. Many speaker builders consider Keele's equation, $V_B = 15\ Q_{TS}\ V_{AS}$, to be optimum (more nearly flat response for an enclosure) for calculating box volume. The 8″ Peerless has a V_B equal to 2.12 $ft.^3$ (using manufacturer's specifications) and the 12″ Pioneer's V_B is 9.21 $ft.^3$ Both drivers, however, perform well in my test box. Therefore, using a speaker with a free cone resonance lower than the box resonance works well for this type of enclosure. Neglecting other parameters, however, may prevent optimum performance.

port. I fine tuned the system by spacing the two panels and correcting until the f_L and the f_H were equal in impedance amplitudes.

A CLASSIC CHOICE. My original speaker enclosures (*Photo 1*), are constructed of ¾″ plywood with a ⅛″ birch veneer finish. Outside dimensions are 20¼″ × 20¼″ × 14″, and the inside volume is 2.87 $ft.^3$ The actual volume is somewhat less because of the speaker, tuning panel, and crossover mounted inside the enclosure.

I replaced the 6″ legs with 13″ legs and placed the midrange and the tweeter at or near ear level (when seated). The two enclosures are located at each end of our sofa and hold lamps, flowers, and pictures in a medium-sized living room.

The Swan 305 woofer speakers I now use in the enclosures seem to be made for them. Except for the speaker panel, I lined every surface inside the enclosure with 1″ fiberglass damping.

My taste in music is mainly classical. At low volume, the enclosure reproduces the lower octaves effortlessly, although this system performs equally well at any volume. The outstanding feature of this system is the ease of tuning for optimum good sound reproduction.

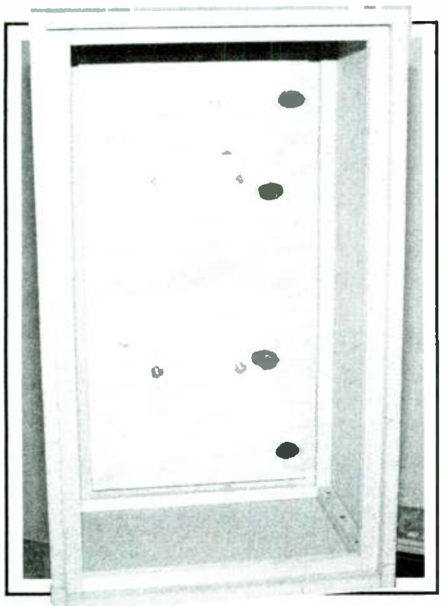

PHOTO 4: Test box inside view with front panel removed. Tuning panel in view on port panel.

Assume the upper peak (f_H) represents the box resonance and the lower peak (f_L) the driver resonance, when the driver is mounted in the box (*Fig. 10*). The trough (F_M) impedance of the curve represents the system frequency with the driver and enclosure working together.

By using *Equation 2* in the sidebar, I tuned the 2.55 $ft.^3$ box to about 80Hz using the 36 $in.^2$ port, 86Hz with the 49 $in.^2$ port, and 92Hz with the 64 $in.^2$

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1. Joseph, William and Frank Robbins, "Practical Aspects of the R-J Speaker Enclosure," *Journal* Audio Engineering Society, January, 1953.
2. Weems, David W. "Designing, Building & Testing Your Own Speaker System," 3rd Edition. Available from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458-0243, (603) 924-6371, (603) 924-6526.

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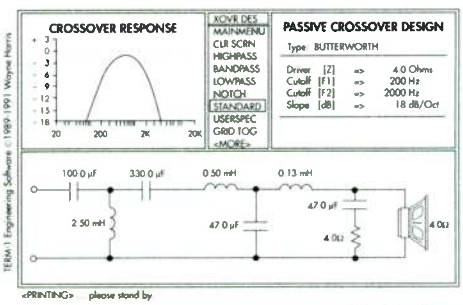

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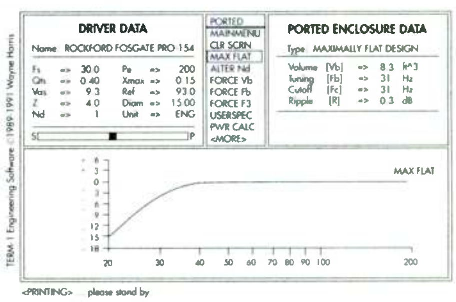

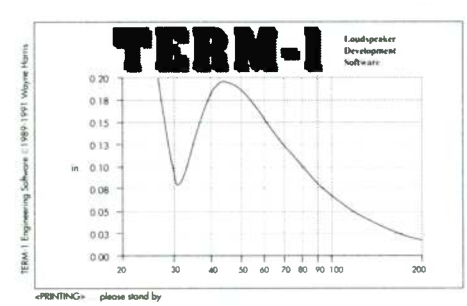

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NON-OPTIMUM VENTED-BOX SPREADSHEET DOCUMENTATION

BY PAUL E. RAHNEFELD

The Non-Optimum Spreadsheet is my response to the lack of computer programs that can easily calculate and plot vented-box responses based on enclosure volume. This spreadsheet calculates an optimum alignment based on Q_{TS}, V_{AS}, and f_S and a non-optimum alignment based on f_S, V_{AS}, and $V_{B\alpha}$. The results of these calculations are quite accurate, even though they are only approximations. The least accurate calculation, as compared to BOXRESPONSE, is V_B(opt), which is still 95% accurate.[1] Both alignments appear on the computer screen at the same time to allow for comparison.

I designed the Non-Optimum Spreadsheet using the Quattro spreadsheet program. The disk available from Old Colony Sound Lab includes the translation for LOTUS 1-2-3.

Program	File Name
Lotus 1-2-3 Ver. 2.0	VENTED.WK1
Lotus 1-2-3 Ver. 1A	VENTED.WKS

Lotus 1-2-3 operates much in the same way as Quattro.

The Non-Optimum Spreadsheet runs in the protected mode, which means you can enter data only into certain cells. This safeguard protects the spreadsheet formulas. Also, if the spreadsheet does not allow you to enter data into a cell, data is not needed for that cell. The unprotected cells which will accept data are highlighted.

ABOUT THE AUTHOR

Paul Rahnefeld works in quality assurance for an aerospace contractor at Cape Canaveral, Florida, currently with propulsion systems for expendable launch vehicles. His interest in loudspeakers has led him back to school where he is currently working toward a degree in Electrical Engineering.

Now let's take a look at each area of the Non-Optimum Spreadsheet.

SPREADSHEET COMPONENTS. User Input can be broken down into three groups:

1. T/S parameters. These parameters are on the first line of the user inputs and include f_S, Q_{ES}, Q_{TS}, Known Q_{TS}, R_E, V_{AS}, V_B (which is included here as a matter of convenience), and V_D. All of them except for V_B, are used to describe a given driver.
2. Electrically adjusted Q_{TS}. These parameters appear on the second line of the user inputs and include R_X, Q_{ES}', and Q_{TS}'. These allow you to electrically adjust the Q_{TS} of a driver by adding a series resistance to that driver.
3. Known driver/enclosure combination. These parameters also appear on the second line of the user inputs and include f_L, f_C, f_H, f_B, f_{SB}, V_{AS}/V_B, and V_{AS}. They allow you to describe a known driver-enclosure combination by inputting f_L, f_C, and f_H. The spreadsheet will then automatically calculate f_B, f_{SB}, V_{AS}/V_B, and V_{AS} for this combination.

The optimum enclosure line describes the output parameters for an optimum enclosure, based on the T/S parameters, including the optimum enclosure volume for the given driver.

The non-optimum enclosure line describes the output parameters for a non-optimum enclosure, based on the T/S parameters, and box volume. It includes the response anomaly (ripple) for the non-optimum enclosure.

The ducted port calculations allow you to calculate the duct length(s) for single or dual ports, and for optimum or non-optimum enclosures. You also may calculate the duct length for a known driver-enclosure combination.

The vented response sensitivity table allows you to calculate the response of an optimum or non-optimum enclosure based on user input. You also can calculate the response of a known driver-enclosure combination. I've included a line that tells you which response will be calculated. Once the spreadsheet has calculated a response, you can plot it using the graphing capabilities of your spreadsheet program.

DEFINITIONS AND USES. In this section, I explain each parameter's use, in the order in which it appears.

Driver Name: Enter the driver and/or system name to the right of the arrow. This is not required, but if you print the spreadsheet out, the name will identify it.

f_S(Hz): Driver free-air resonance. This is a required input.

Q_{ES}: Driver Q at f_S resulting from electrical resistance. This input is not required if Q_{TS} is already known, but the spreadsheet will automatically calculate Q_{TS}, if you input Q_{ES} and Q_{MS}. Q_{ES} is also used to calculate no% and Q_{TS}'.

Q_{MS}: Driver Q at f_S resulting from mechanical resistance. As with Q_{ES}, this input is not required if Q_{TS} is already known. The spreadsheet will automatically calculate Q_{TS} if you input Q_{ES} and Q_{MS}.

Q_{TS} and "Known Q_{TS}": Total driver Q at f_S. Q_{TS} and "Known Q_{TS}" are basically the same, but you input them differently. If Q_{TS} is not known, the spreadsheet will calculate it automatically from Q_{ES} and Q_{MS}. If you already know Q_{TS}, you can input it directly into the spread-

Continued on page 18

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BLACK HOLE

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If you've been building speakers for some time, you know how much guesswork goes with speaker damping and stuffing. The choices seem endless: fiberglass, wool, Dacron, flat foam, convoluted foam, felt, tar, plus various "magic" compounds that you're invited to brush or pour into your new cabinets. Everyone has their own recipe, and who knows if it's a recipe for disaster? Or what effects the vapors emitted by these chemicals might have on the glues that bond your woofer surround to its cone and chassis? In this era of costly, space-age drivers and computer-assisted design, we think such risks are totally unacceptable. So we went to work to find the ideal solution.

The problems are fairly well-known: a driver transforms electrical energy into mechanical energy. This mechanical energy is transformed into acoustical energy which is radiated to the outside of the cabinet - the useful front wave - and to the inside - the sometimes-useful back wave. Unfortunately, it is also transmitted though the frame of the driver to the cabinet itself, which acts as a very large "cone" of very small excursion. This means that the spurious resonances and vibrations of the cabinet have to be controlled in a predictable and reproduceable way. That's how we came to BLACK HOLE 5 and the BLACK HOLE PAD.

First, THE PAD. It's a thin (1/16 inch) black flexible viscoelastic damping material (filled vinyl copolymer) with maximum performance between 50 and 100 degrees F (we hope that that covers the temperature range of your listening room) and excellent flame resistance - it meets UL94 V-O. Thanks to its outstanding damping characteristics, THE PAD will dramatically reduce the vibration energy stored in the walls to which it is applied.

Easy to cut and apply, THE PAD has a pressure-sensitive adhesive back: simply peel off the release paper and press hard onto a clean surface. You can use THE PAD on just about anything you suspect of vibrating: driver frames, thin panels like car doors, and, of course, the walls of your speaker cabinets. And it can be used to recess a driver without using a router: just laminate enough layers to match the thickness of the driver frame and apply to the front baffle. Finally, it is the ideal material for "constrained layer" wall construction, where two panels are laminated on each side of a damping material for optimum transmission loss. Because THE PAD has a fine grain leather finish, you can wrap an entire cabinet exterior and give it an attractive appearance at the same time!

For applications which require **maximum damping, isolation and absorption,** we've developed BLACK HOLE 5. One and 3/8" thick, BLACK HOLE 5 is a high-loss laminate that provides optimum acoustical damping performance. It consists of five layers:

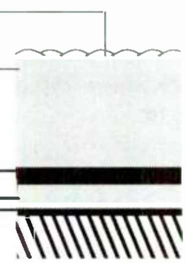
Thin diamond-pattern embossing, densified with a polyurethane film surface. This unique surface layer dramatically improves the performance of the whole acoustical system, especially the lower mid-range and mid-bass frequencies where simple acoustical foam loses its effectiveness.

One-inch deep polyester urethane foam, structurally optimized for acoustical damping. Highly effective at "soaking" maximum sound energy with minimum thickness.

Barrier septum, 1/8 inch thick. Made of limp flexible vinyl copolymer loaded with non-lead inorganic fillers, it is a "dead wall" that isolates the vibrations in the walls of your cabinet from the vibrations created inside the enclosure.

Polyester urethane flexible open-cell foam, 1/4 inch thick. Thanks to special vibration-isolation characteristics, it decouples the vibrating structure (the wall) from the rest of the damping system, thus optimizing performance.

High-loss vibration damping material, same as The Pad. It is strongly bonded to the cabinet wall with pressure sensitive adhesive.



These layers are laminated using an adhesive-free mechanical and thermal process, thus optimizing performance and eliminating the risk of solvent fume damage. BLACK HOLE 5 can be used in any enclosure, as well as for acoustical panels to improve the characteristics of your listening room. *YOU PROVIDE THE MUSIC; BLACK HOLE FIVE WILL TAKE CARE OF THE NOISE!*

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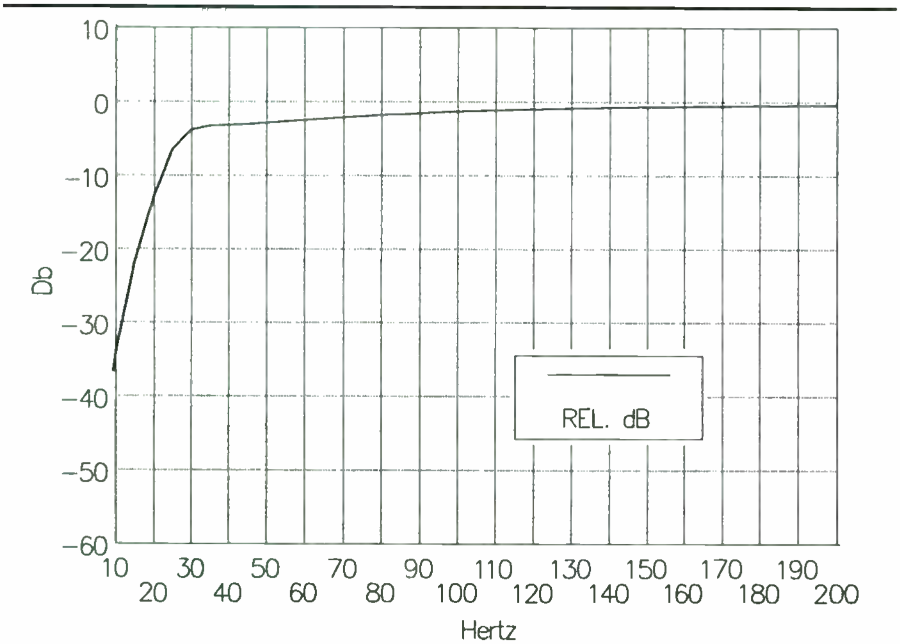

FIGURE 1: Vented-box response for the Audiom 15 VX (V_B1 = 9ft.^{3}).

Continued from page 16
sheet using "Known Q_{TS}". Additionally, if you wish to adjust Q_{TS} temporarily, just input the adjusted Q_{TS} into "Known Q_{TS}", and the spreadsheet will recalculate the other parameters based on this adjustment. Notice that when you input "Known Q_{TS}", Q_{TS} will read zero, even if you have input Q_{ES} and Q_{MS}. When you are finished with the adjusted Q_{TS}, enter zero into "Known Q_{TS}", and the spreadsheet will automatically recalculate for Q_{TS}.

R_E(ohms): Voice coil resistance in ohms. R_E is not a required input, but it is used to calculate Q_{TS}', as explained later.

V_{AS}(ft.^{3}): Acoustic compliance of the driver. V_{AS} is a required input and must be expressed in cubic feet.

V_B(ft.^{3}): Net volume of enclosure. V_B is required to compute the non-optimum alignment. If you do not input V_B, the non-optimum parameters will read zero.

V_D(m^3): Peak displacement volume of driver. V_D is an optional input. It is used to calculate minimum port diameter and Par (P_{AR}).

R_X(ohms): Value of resistor in series with driver to adjust Q_{TS} electrically. R_X is optional. If it is set to zero, Q_{ES}' and Q_{TS}' also will read zero.

Q_{ES}': Adjusted Q_{ES} calculated using R_X(ohms). This is a protected cell and will read zero if R_X(ohms) is set to zero.

Q_{TS}': An electrically adjusted Q_{TS} calculated from R_X (ohms) and Q_{ES}'. This parameter accounts for the electrical adjustment to the driver Q by adding a series resistance to the driver. This is a protected cell. If you wish to use this option, you must input Q_{ES} and R_E. While Q_{TS}' is displayed, Q_{TS} will read zero. Also, if "Known Q_{TS}" is input, Q_{TS}' will read zero.

Note: R_X, Q_{ES}', and Q_{TS}' should normally be set to zero. The order of precedence for Q_{TS} is: "Known Q_{TS}", Q_{TS}', Q_{TS}. This is the order the spreadsheet uses to perform its calculations. Q_{TS}' and "Known Q_{TS}" must be set to zero for normal spreadsheet use—that is, using Q_{TS}.

f_L(Hz): The lower impedance peak of a vented enclosure in hertz. This parameter is measured from a known driver-enclosure combination.

f_C(Hz): The closed-box impedance peak in hertz. This parameter is measured by blocking off the vent of a known enclosure and finding its resonance point.

f_H(Hz): The higher impedance peak of a vented enclosure in hertz. This parameter is measured from a known driver-enclosure combination.

f_B(Hz): The resonant frequency of a vented enclosure in hertz. This parameter is used to plot the response of a known driver-enclosure combination and is calculated from f_L, f_C, and f_H. This is a protected cell. During plotting, f_B(Hz) has precedence over the non-optimum f_B.

f_{SB}(Hz): The resonant frequency of the driver's moving system in a vented enclosure in hertz. This parameter is used in place of f_S to plot the response of a known driver-enclosure combination and is calculated from f_L, f_H, and f_B. This is a protected cell.

V_{AS}/V_B: The ratio of V_{AS} to V_B for a known driver-enclosure combination. V_{AS}/V_B is α for this combination. It is calculated from f_L, f_H, and f_B. This is a protected cell.

V_{AS}': The acoustic compliance of the driver in a known vented driver-enclosure combination. V_{AS}' is calculated from $V_{AS}/V_B \times V_B$(Known). This is a protected cell.

Note: To plot the response of a known driver-enclosure combination, select the non-optimum plotting function. If f_B and f_{SB} have been calculated, they will automatically be selected for use in the plot. If you wish to plot the regular non-optimum alignment, set f_B and f_{SB} to zero, by entering zero into f_L. The parameters f_C and f_H will not affect plotting, but to keep the spreadsheet in order, enter zero into these cells also. Normally, these parameters should be set to zero.

The following definitions apply to both optimum and non-optimum alignments, except as noted. These are all protected cells.

f_3(Hz): The frequency, in hertz, where the output is down 3dB. The value also designates the beginning of the low-end rolloff.

H: The tuning ratio (f_B/f_S).

f_3/f_S: The f_3 ratio.

Alpha: The box volume ratio V_{AS}/V_B.

no%: The free-air reference efficiency.

Par(dB): The displacement-limited acoustic power output in decibels.

V_B(opt) (ft^3): The net volume of an optimum enclosure for a given driver in cubic feet.

R_H(dB):The response anomaly (ripple) of a non-optimum alignment.

Continued on page 20

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Peerless

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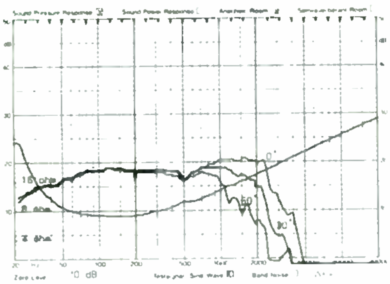
1857



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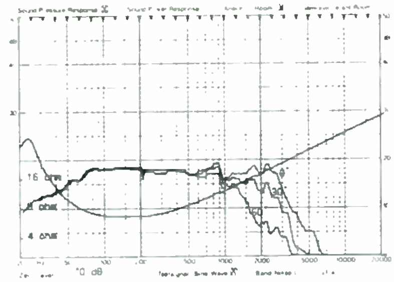

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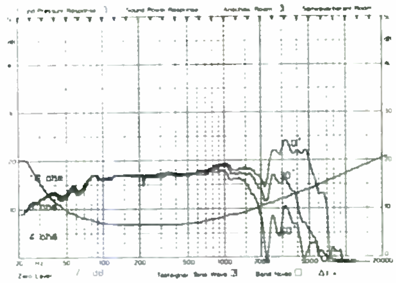

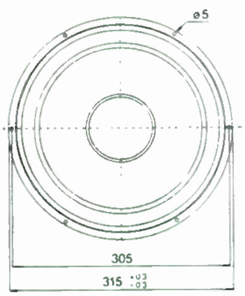

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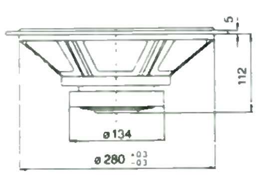

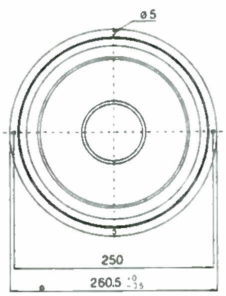

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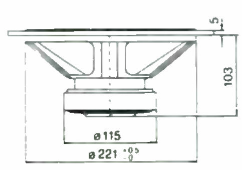

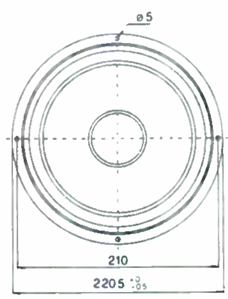

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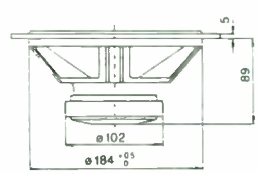

SPECIFICATIONS	1857	1727	1709	PARAMETERS	1857	1727	1709
Rated power handling				Fs (Hz)	24	22.3	25
Longterm Max IEC (W)	220	220	150	Vas (Ltrs)	210	136.2	86.9
Voice Coil				Qts	0.44	0.34	0.45
Diameter / length (mm)	39/26	39/26	33/17	Qes	0.49	0.38	0.54
Nom/min impedance (Ω)	8/6.3	8/6.2	8/5.4	Qms	3.72	2.62	2.65
DC resistance (Ω)	5.5	5.4	5	Zmax (Ω)	46.9	41.9	29.3
Inductance (mH)	2.8	3.3	1.2	Xmax (mm)	9	9	5.5
Former	aluminium	aluminium	aluminium	Sd (cm^2)	520	310	225
Layers	4	4	2	Cms (mm/N)	0.55	1	1.21
Wire	copper	copper	copper	Mms (g)	80.2	50.8	33.4
Cone	polypropylene	polypropylene	polypropylene	Rms (kg/s)	3.25	2.71	1.98
Surrounnd	rubber	rubber	rubber	Bl (N/A)	11.6	10	6.9
Magnet				**Sensitivity**			
Diameter (mm)	134	115	102	dB (2.83V/1m@Hz)	89.3@124	87.8@123	86.9@173
Weight (kg)	1.28	0.87	0.54	Max linear SPL rms (dB/W)	110/170	110/315	107/105

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Continued from page 18

Refer to G.R. Koonce's article "How To Use Non-Optimum Vented Boxes" (*SB*, 3/87, p. 24).

DUCTED PORT CALCULATIONS. Enclosure Options. With this option, you can calculate the duct lengths for both optimum and non-optimum enclosures. Enter your choice (O for optimum, or N for non-optimum) in the cell to the right of the arrow. The spreadsheet will automatically select the parameters needed to calculate the duct length. Note: If f_B(Hz) and f_{SB}(Hz), under user inputs, are not zero, the spreadsheet will calculate the duct length for the known driver-enclosure. This applies only when you select the non-optimum enclosure. Normally, f_B and f_{SB} will be set to zero, and the spreadsheet will calculate the non-optimum enclosure duct length.

Port Diameter. The spreadsheet allows for single or dual port calculations. It assumes that the vent ports are round and are the same diameter, as this is the normal situation. Enter Y for dual ports or N for a single port. Input the port diameter into the cell next to D1. If you have selected dual ports, you will see the cell next to D2 load with the D1 port diameter. Then the Dual Port Eff. Diam., the effective diameter of the combination of the two ports, will load automatically. If you select the single port option, D2 and Dual Port Eff. Diam. will read zero. D2 and Dual Port Eff. Diam. are protected cells.

TABLE 1

USEFUL CONVERSION FACTORS

To convert:		
m^3 to $ft.^3$	multiply by	35.314
liters to $ft.^3$	multiply by	28.317
cm^3 to $ft.^3$	multiply by	3.532E-05
$in.^3$ to $ft.^3$	multiply by	5.787E-04
$ft.^3$ to m^3	multiply by	0.02831
$in.^3$ to m^3	multiply by	0.638E-05

Minimum Req. Port Diam. This suggests a minimum port diameter to use based on an equation by Small.[2] This is only an approximation, but you should try to keep your port diameter above this figure. This is a protected cell.

Duct Length. Duct length is dependent on port diameter, f_B, and V_B. The spreadsheet automatically selects the proper parameters to calculate duct length. This is a protected cell. (Please read the note under Enclosure Options above.)

RESPONSE PLOTTING. Enclosure Options. Select optimum or non-optimum enclosure type by entering O or N in the cell to the right of the arrow. If you select N, and f_B and f_{SB} are not zero, the spreadsheet will calculate the response of the known driver-enclosure combination. I've included a line under the option line to tell you which response will be calculated.

Response Calculating and Plotting. The following example shows you how to calculate and plot a response. The example is for Quattro; you may or may not follow the same procedures with your spreadsheet programs.

1. Select the optimum or non-optimum enclosure option and notice which response will be calculated.

2a. Bring up the spreadsheet's main menu and select the Advanced option.

2b. Select the What-If option.

2c. Select the 1 Variable option. The spreadsheet will ask for a "Block of Cells to Use as Data Table." When you see this, the block C36..D76 should already be loaded. If it's not, load this block of cells as the data table. Press Return. The spreadsheet will ask you to "Input Cell From Column," Cell C36 should already be loaded. If it's not, then load this cell. Press Return. Now you should see the frequency column loaded with numbers. These are the relative response points for each frequency point. You should not have to load any block values at these commands. When I initially ran the spreadsheet, I input values that Quattro saved as default values.

3. Press Esc twice to get back to the main menu. Select the Graph option, then select View to see the driver's response plot. Again, I input the proper graphing parameters, but you may change them to suit your taste. Quattro cannot produce logarithmic graphs, but it does provide a good representation of the driver's response (*Fig. 1*).

FINAL NOTES. When entering data, use the arrow keys instead of Return. These keys enter the data in the selected cell and move the pointer to the next cell. By using them, you avoid the possibility of overwriting data.

When converting data from metric to English units, let the spreadsheet program do the math (in the upper left-hand corner). For example, if converting 70 liters into cubic feet for V_{AS} input you would select the V_{AS} cell, type 70/28.317 (*Table 1*) and press an arrow key. The converted data would then be placed in the V_{AS} cell.

The Non-Optimum Spreadsheet is easy to use and all the columns except J appear on the screen at one time. The J column is used to perform some of the calculations, so don't make any changes to it.

Again, thank you for your interest in the Non-Optimum Spreadsheet. I hope this documentation helps you use the spreadsheet. If you have any comments, gripes, and so on, let me know.

REFERENCES

1. Bullock, R. and R. White, BOXRESPONSE, available from Old Colony Sound Lab.

2. Dickason, Vance, *The Loudspeaker Design Cookbook* 3rd ed., The Marshall Jones Co., 1987.

Non-Optimum Spreadsheet software (IBM only, 1 × 5¼", DS/DD) is available from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458; telephone (603) 924-6371; FAX (603) 924-9467. Order item #SOF-NOS1B5: $25.00 plus $2 shipping in the USA, $4.50 elsewhere. Please remember that spreadsheet software such as Quattro or Lotus 1-2-3 is required and *not supplied.*

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Part II

A PRIZE-WINNING THREE-WAY TL

BY ROBERT J. SPEAR and ALEX THORNHILL

On October 26, 1991, an experimental three-way transmission line (TL) speaker system that Alex Thornhill and I designed won first prize in the 3rd Annual A&S Speakers Sound-Off held in San Francisco.[1] The following is the second part of a series recounting the building of a prize-winning speaker system.

In Part I, we detailed the system's design history.[2] Now, we will address the practical aspects of the enclosure's construction. In the final part, we'll explain how to assemble and install the crossover networks, and ways to finish the enclosures.

Before we begin, heed my warning: This is a project neither for the novice constructor nor the faint of heart. The enclosures will weigh over 80 lbs. when complete, even without sand-damping. The internal design is complex, although no individual step is really difficult. Using high quality parts throughout ensures that your investment—in time and money—will pay off in a speaker system you'll enjoy for years to come.

When writing these instructions for assembling the Brother Jon, we assumed you will obtain the enclosure materials from a local supplier and order the kit of drivers and crossover parts separately. We structured the article to help you get started on the enclosures while waiting for the electrical components to arrive. We also numbered the steps to make it easier for you to navigate within the project. Please let us know if you like this format. (Some of the photographs show earlier versions of the Brother Jon.)

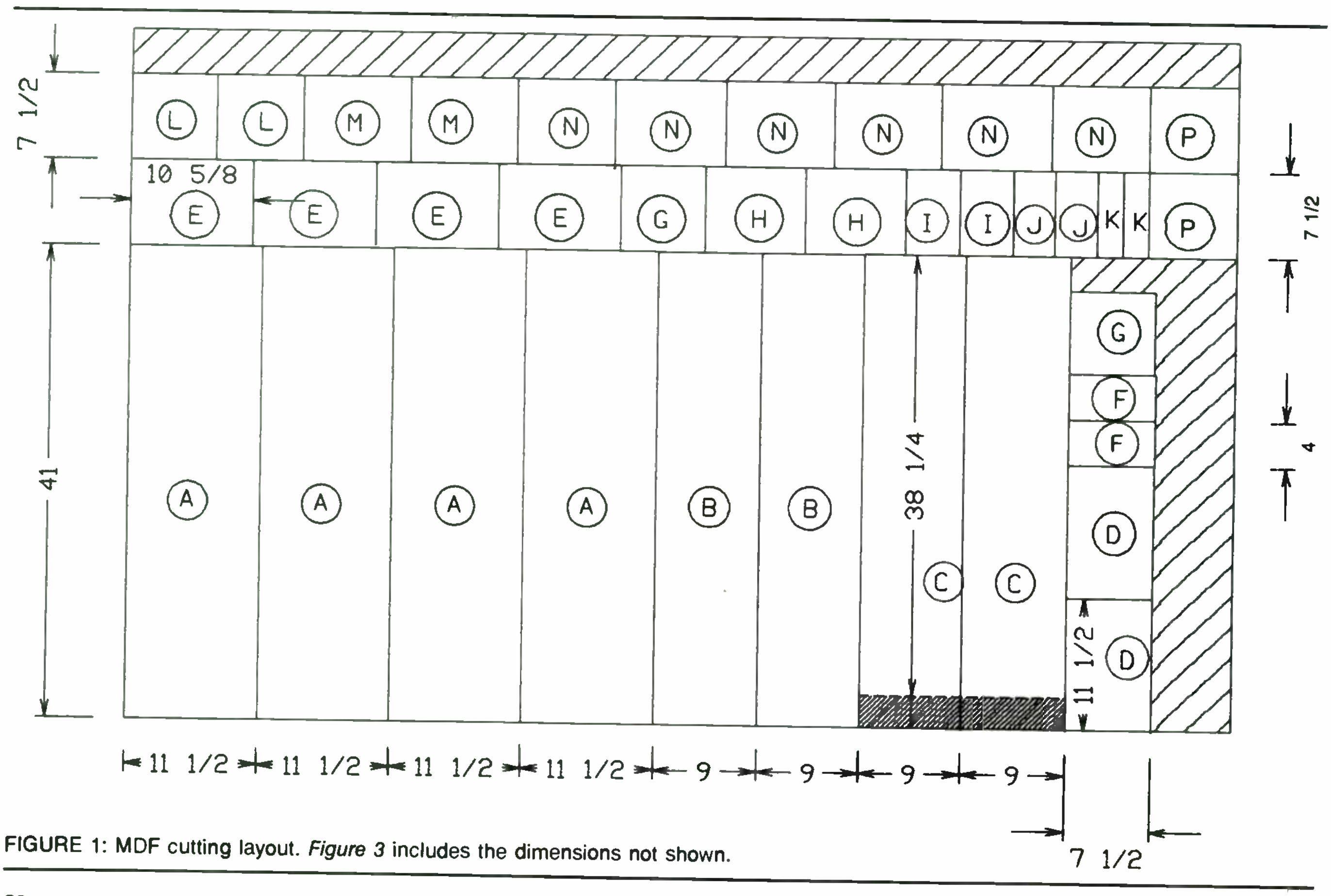

FIGURE 1: MDF cutting layout. *Figure 3* includes the dimensions not shown.

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PHOTO 1: Drilling holes in side panels.

CUTTING PIECES. The cutting diagram (*Fig. 1*) provides the dimensions and layout for the various pieces you'll need to build two Brother Jon enclosures. The material is ¾″ medium-density fiberboard (MDF) normally sold in 5′ × 8′ sheets. Unfortunately, you cannot cut all the pieces for two complete enclosures from a single sheet. You'll need to get three N pieces, two O pieces, and 16 K pieces from other stock.

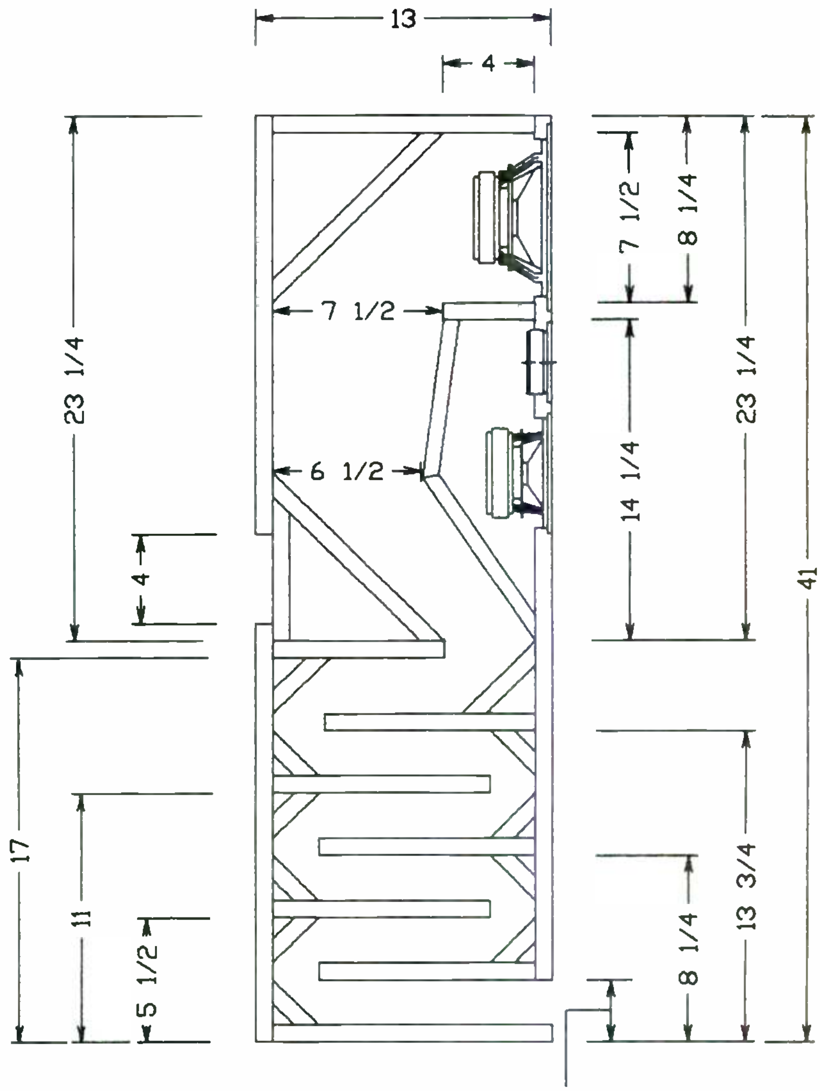

FIGURE 2: Baffle placement dimensions.

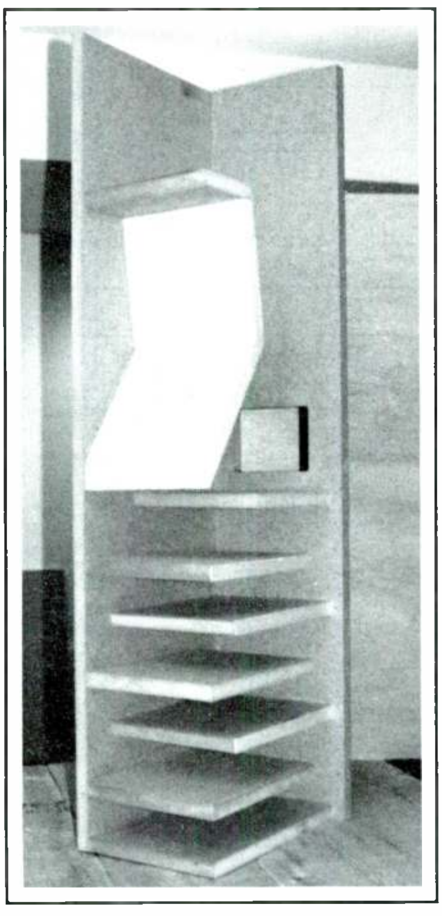

PHOTO 2: Partially completed enclosure showing midrange chamber, horizontal dividers, and opening for speaker leads.

If you don't lose much material in squaring sheets or saw kerfs, you may be able to eke out many of the K pieces. Many shops have enough ¾″ scrap lying around to cut the rest of the pieces. If you must use particleboard for the internal baffles, try to get the smooth-surfaced variety sold in 30″ widths for counter tops; it has a denser core. All pieces forming the outer enclosure (panels A, B, C, D and O) should be MDF. For your convenience, you will find a list of required materials at the end.

WATCH OUT! MDF can be thicker than its stated dimension. If you fail to take this into account when you have the pieces cut, you'll end up with a poorly-fitting enclosure. For example, the width of the Brother Jon's internal baffles is 7½″. The total width of the enclosure is this dimension plus the combined side-wall thicknesses (¾″ × 2 = 1½″) for a total enclosure width of exactly 9″. MDF 1/16″ thicker would increase that to 9⅛″, so front and rear panels cut 9″ wide would be too narrow.

Measure the thickness of the MDF panel and have the B and C panels cut correspondingly wider. The glue in the joints expands the dimensions slightly, so leave a small margin for error. We designed the cutting diagram to minimize these problems. We also devised a layout to accommodate for modest deviations in the widths of the B and C panels without affecting how any of the other pieces are cut. MDF thickness also affects the spaces between horizontal baffles; if this is the case, lay out the enclosure pieces in Step 1 with reference to the baffle centerlines rather than their edges.

Many shops intentionally cut pieces such as B and C wider than necessary to allow room to realign the panels when

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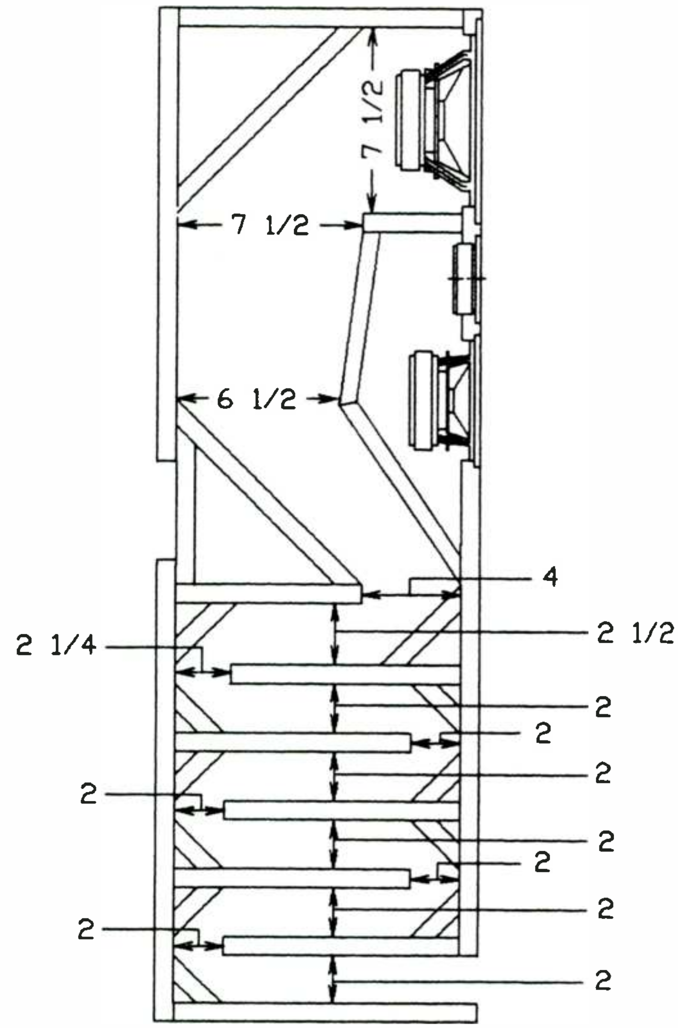

FIGURE 3: Internal duct dimensions.

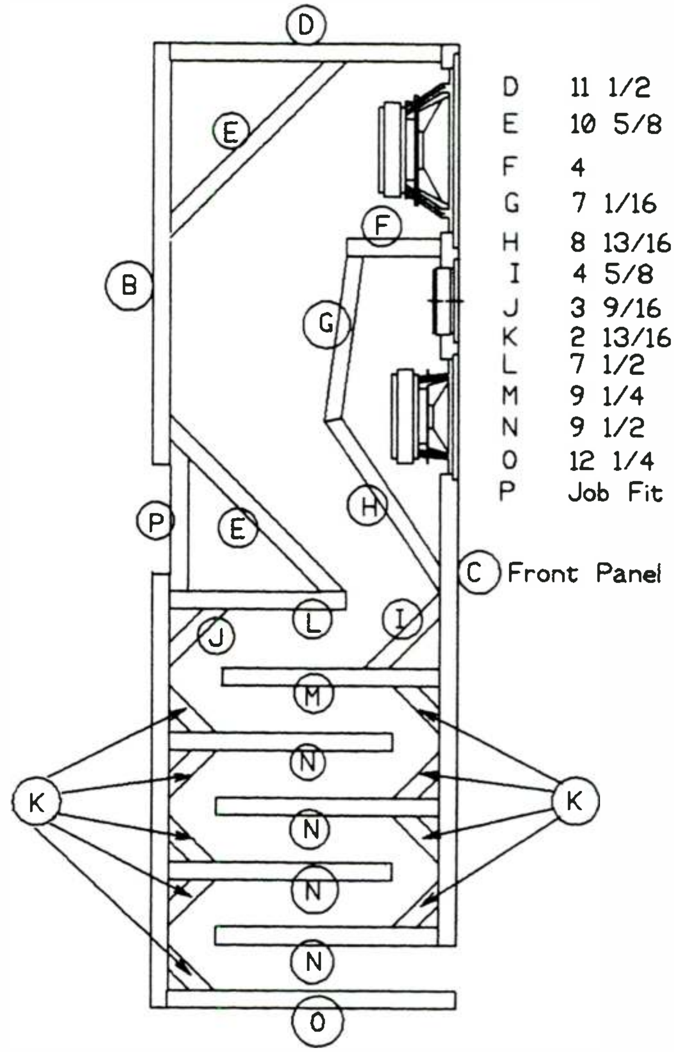

FIGURE 4: Internal baffle layout. Note that all internal baffles are 7½" wide and dimensions for 45° pieces are taken on the longer side.

needed. Then, they sand or plane the overhanging edges flush to the box. A bit later on we'll discuss how to use this technique to your advantage. Do not assume the factory edges of MDF sheets are square or the boards are perfect rectangles—they are probably not. At the yard, specify that you want all cuts made off a trued side and you don't want any pieces left with factory-cut edges.

Ensuring accuracy at the start gives you a much better chance of constructing a good enclosure. If the yard man tells you it does not matter whether or not you cut all your edges, take your business elsewhere. If you decide to cut the pieces yourself, refer to our article on squaring particleboard.[3]

BASIC LAYOUT.

1. Begin with side panel A. Using a soft lead pencil, lay out the speaker enclosure's internal components as shown in *Fig. 2*. Use a piece of MDF scrap on edge to outline the actual baffle thicknesses on the panel. It's not necessary to draw the small reflector baffles (I-K in *Fig. 4*). Mark the centerline of each outline drawn.

2. Repeat this step on a second side panel A. Align the second panel next to the first and using a long ruler or T-square, transfer the layout to speed up things. When the enclosures are assembled, the layout drawing will face the inside. Leave the third and fourth A panels blank.

3. Follow *Fig. 5* to mark screw locations along the baffle centerlines drawn on the first A panel. Use an awl or a nail to punch screw locations into the panel to center the bit. Drill all the holes with a bit sized for #8 screws. If you use a drill alignment jig, it will keep the holes at right angles.

Continued on page 26

TABLE 1

CUTTING LIST BY PIECE

For all pieces with 45° angles, the measurements are made on the longer side. The list below gives quantities for two enclosures.

PIECE	DIMENSION	QTY.	45°	MAT.
A	11½" × 41"	4	no	MDF
B	9" × 41"	2	no	MDF*
C	9" × 38¼"	2	no	MDF*
D	7½" × 11½"	2	no	MDF
E	7½" × 10⅝"	4	yes	MDF
F	7½" × 4"	2	no	MDF
G	7½" × 7¹⁄₁₆"	2	*Fig. 1*	MDF
H	7½" × 8¹³⁄₁₆"	2	*Fig. 1*	MDF
I	7½" × 4⅝"	2	yes	any
J	7½" × 3⁹⁄₁₆"	2	yes	any
K	7½" × 2³⁄₁₆"	18	yes	any
L	7½" × 7½"	2	no	any
M	7½" × 9¼"	2	no	any
N	7½" × 9½"	8	no	any
O	7½" × 12¼"	2	no	MDF
P	7½" × custom fit	2	maybe	MDF

*Adjust to compensate for MDF thickness

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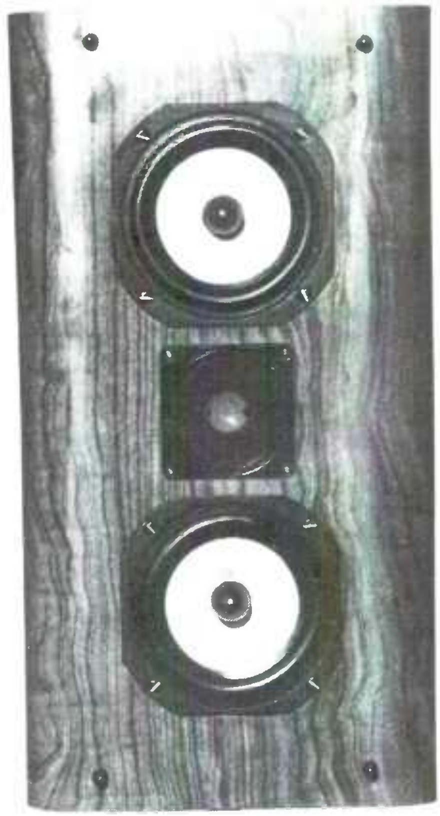

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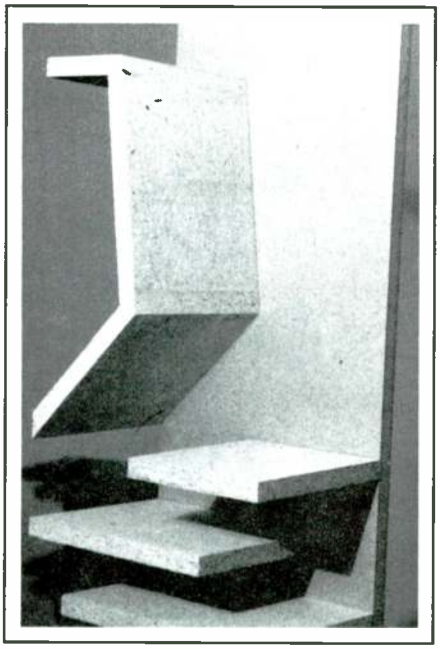

PHOTO 3: Rear view of midrange chamber.

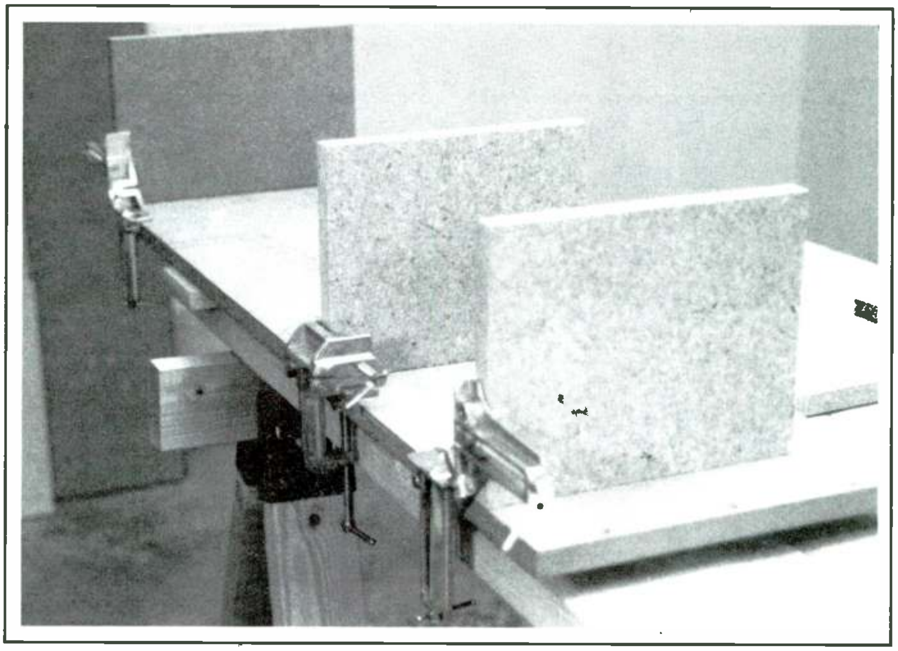

PHOTO 4: Aligning horizontal baffles using 90° angle clamps.

Continued from page 24

4. Clamp an undrilled panel A under the drilled panel A and align all the sides as shown in *Photo 1*. Using the drilled panel as a template, drill holes for the #8 particleboard screws into the lower panel.

5. Repeat the previous step until all A panels are drilled, always using the first panel as your template. This keeps all screw holes aligned and permits panls to be interchanged if they become mixed up along the way. Alternatively, if you have bigger clamps and a longer bit, you could drill all four panels at once. Set aside the two blank A panels for use in Step 29.

CHAMBER ASSEMBLY.

6. Drill two screw holes through piece F and into the edge of piece G as shown in *Fig. 6*. Use adjustable clamps to hold the pieces or secure one piece in a bench vise. Using a drill guide, set the angle by eye. A tight-fitting nail in the first hole will keep the pieces aligned while you drill the second hole. Prepare piece H of the midrange chamber as above.

7. The next step describes the first fastening operation and should be used as a model for all those following. While the adhesive choice is up to you, we recommend a construction-grade latex-based adhesive because its superior gap filling qualities ensure a leak-free cabinet.[4]

8. Countersink the holes in pieces F and H. Apply adhesive to the joints and screw them together. The F or H pieces may slide out of alignment as you tighten the screws. You can prevent slippage by clamping a piece of scrap against the back of panel G to block the sliding panel. Leave the clamp in place until the glue has dried. Repeat this step for the other chamber.

9. The front edge of the midrange chamber assembly aligns with the front edges of the A panels as shown in *Photos 2* and *3*. Drill screw holes into the edges of the midrange assembly using the holes in the side of panel A as a guide (*Photo 5*).

10. You must trim the butt edge of F facing the enclosure so it's in the same plane as G and looks similar to *Photo 3* (See also *Fig. 6*). Take the excess off F with a block plane or a rasp, and clean up with files and sandpaper. Lastly, slightly round the sharp edges facing the enclosure.

11. Fasten the midrange chamber to the side of the A panel. Spread glue on the edges of the assembly and attach it with 1⅝" #8 particleboard screws. Repeat this step with the other side panel.

HORIZONTAL BAFFLES.

12. Attach panels D, L, M, N, and O to panel A in any order. *Photo 4* shows baffles held in place with 90° clamps. Clamp two or three at a time, turn the assembly over, check the baffle positions, and drill the screw holes. Remove the clamps, apply adhesive and screw the baffles in place. Work up panel A sequentially, fastening all baffles flush with one edge, and then repeat for the other edge.

13. Continue this procedure until all the horizontal baffles are in place and then repeat on the second unit. Clean up any

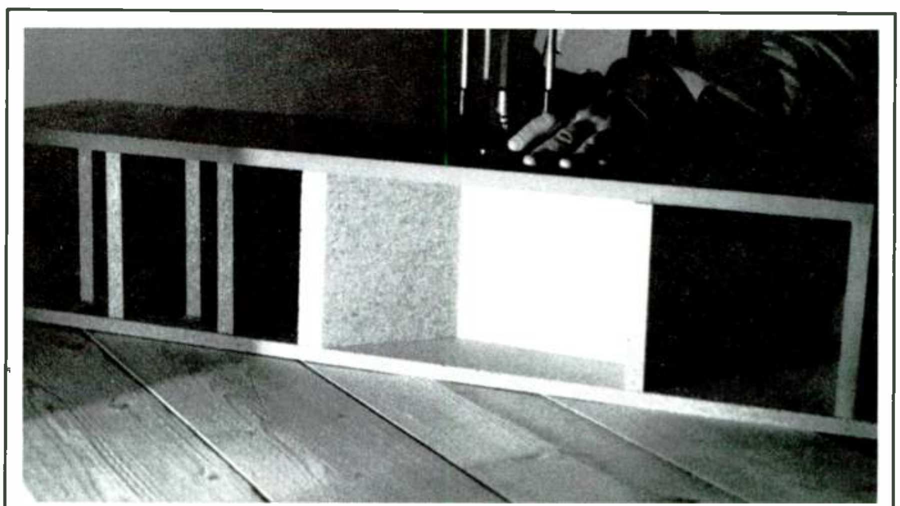

PHOTO 5: Drilling screw holes into internal baffle edges using pre-drilled side panel as a guide.

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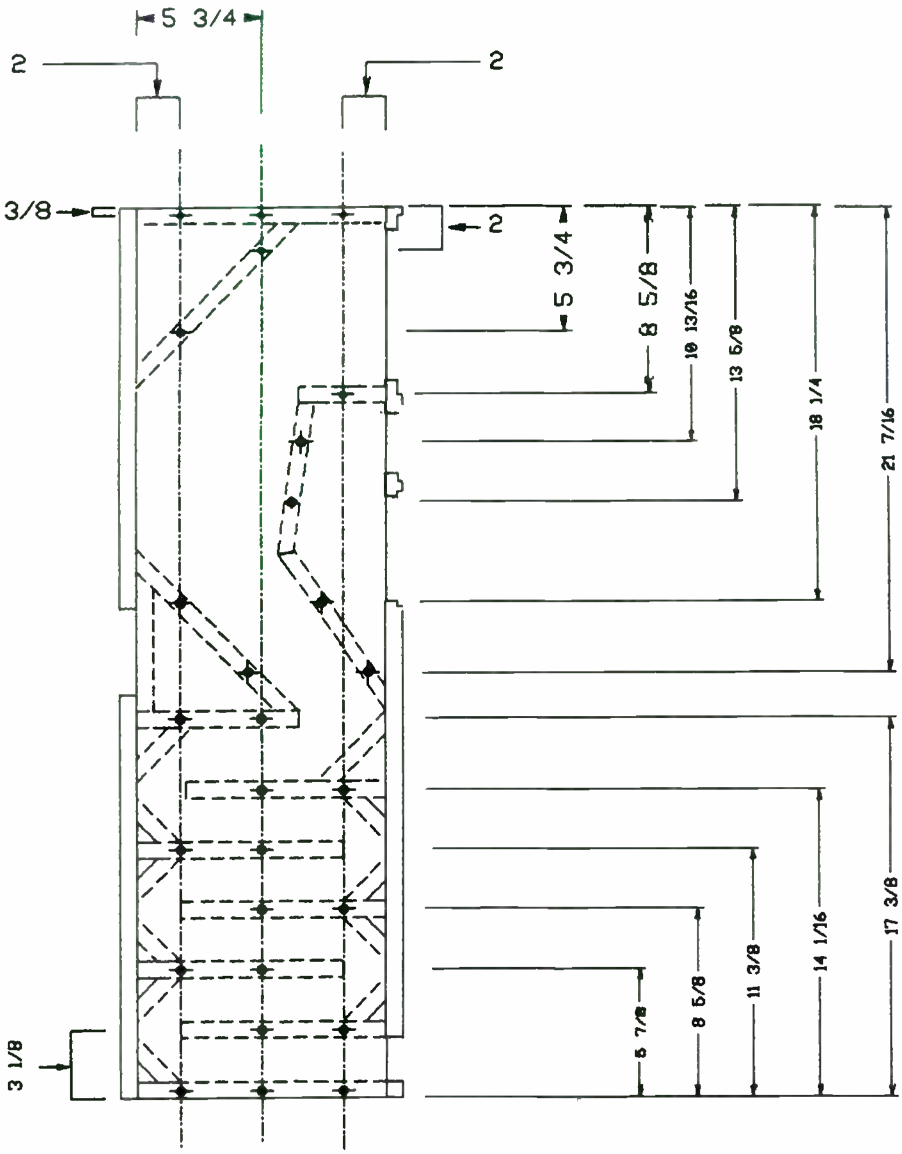

FIGURE 5: Side panel screw layout guide.

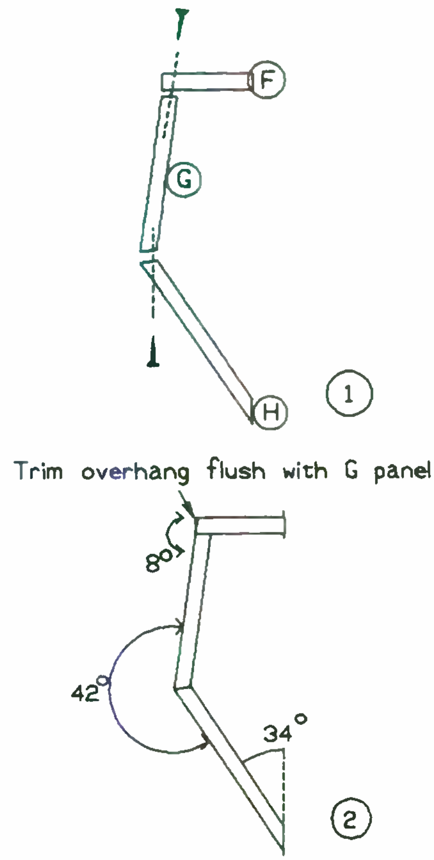

FIGURE 6: Midrange chamber assembly.

glue that squeezed out while it's still wet.

14. Position rear panel B and secure it with clamps. Lay out and drill the screw holes through panel B into the rear edges of panel A. Use *Fig. 7* as a general guide even though it shows the front baffle. *Figure 8* shows how top panel D and bottom panel O fit the assembly. In general, space all screws a minimum of 2″ from baffle edges and about 4″ apart.

15. Mark lines on panel B that correspond to the centerlines of all horizontal baffles the panel touches. Mark screw holes with a pointed tool then drill and countersink them. Glue and screw the back panel down. Repeat Steps 14 and 15 for the other enclosure.

TERMINAL BOARD.

16. To recess the speaker terminals (we used spring clips, but you can substitute other types), mark the place on panel B that lies between lower baffle E and baffle L. Leave at least ¾″ above baffle L and 1″ below E (*Fig. 4*). The recess must accommodate three pairs of clips. Cut out the hole with a saber saw and clean up the edges with a router or files. Cut a suitably sized piece of MDF to make mounting board P. For best protection, choose a type of mounting terminal no taller than the recess is deep (¾″). Note: If you wish to surface-mount the terminal clips, omit this step and follow the layout instructions described in Step 17 on panel B instead of panel P. *Photo 8* shows an alternative method using a "splash guard" to protect the speaker terminals for when you lay the enclosure on its back.

17. Lay out the mounting holes for the spring clips and the speaker wire lugs on board P and drill them. The orientation for the terminals is a centered vertical stack. Drill holes just outside the four corners of the recess in panel B and into the corners of board P as shown in *Photo 9*. Glue P to the inside of B, and drive screws from the outside.

18. Give the recessed board P and the edges of the cutout in panel B several coats of flat black paint.

DIAGONAL REFLECTORS.

19. Install the reflectors E following the usual method of drilling, countersinking,

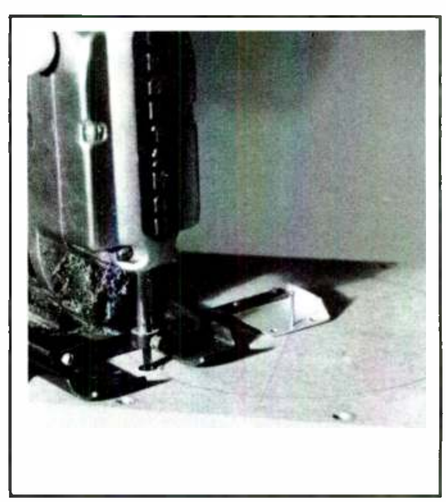

PHOTO 6: Cutting woofer mounting hole with a saber saw and guide assembly.

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and fastening with glue and screws. The angled butt ends depend on adhesives to secure them to the B and C panels, so position E baffles carefully before drilling. Use clamps or wedges to gently draw the pieces together, if necessary.

Remember, the front baffle is cut wider than the cabinet. Align the baffle flush with one side of the enclosure, which will place all the overhang on the other side. When following Step 20, keep in mind that the centerline you draw on the baffle should align with the centerline of the enclosure or your speakers will end up off-center. You may omit the following steps if you have purchased a routed front baffle. If the thickness of the baffle is greater than ¾" (it should not be less!), it should cause no problems other than to increase the enclosure's depth slightly. We'll show you how to deal with that in Part III.

20. Draw a centerline down the long axis of baffle B. Following *Fig. 7*, mark the centers for the drivers. Drill a small hole through the baffle at each driver center. Repeat this step on the other front baffle.

21. Lay out and predrill the holes for fastening baffle C to the front edges of the A panels and to any horizontal baffles panel C touches (including F). Avoid sinking screws under the woofer frame. If you merely wish to surface-mount the drivers, attach baffle C next (*Fig. 7*). However, recessing the drivers is highly recommended (See sources below).

DRIVER HOLES.

22. Recessing the drivers requires skill with a router used with a template. If you surface-mount the drivers, follow the steps for cutting the holes and ignore the instructions for recessing the speaker frames.

23. If you are routing the recesses for the drivers, do this first before cutting the mounting holes. Temporarily secure the front baffle to the box with a few screws to stabilize it while you rout. Remove the baffle, flip it over, and fasten it temporarily again. Cut the mounting holes from the back side of C.

24. *Photo 6* shows a saber saw jig held with a tight nail in the centering hole. You may also use the saw freehand. This technique suffices for the woofer and midrange mounting holes. Next, drill out the "ears" for the tweeter lugs. Cut the tweeter hole with a hole saw in an electric drill, a circle cutter in a drill press, or an adjustable wood bit in a hand brace.

25. Fasten baffle C to the edges of the A, D, and lowest N pieces with glue and screws. Use clamps and a wide piece of scrap in the area of the woofer hole for additional pressure.

SMALL REFLECTORS.

26. Install angled reflectors I, J, and K next. Lay the enclosure assemblies on

Continued on page 30

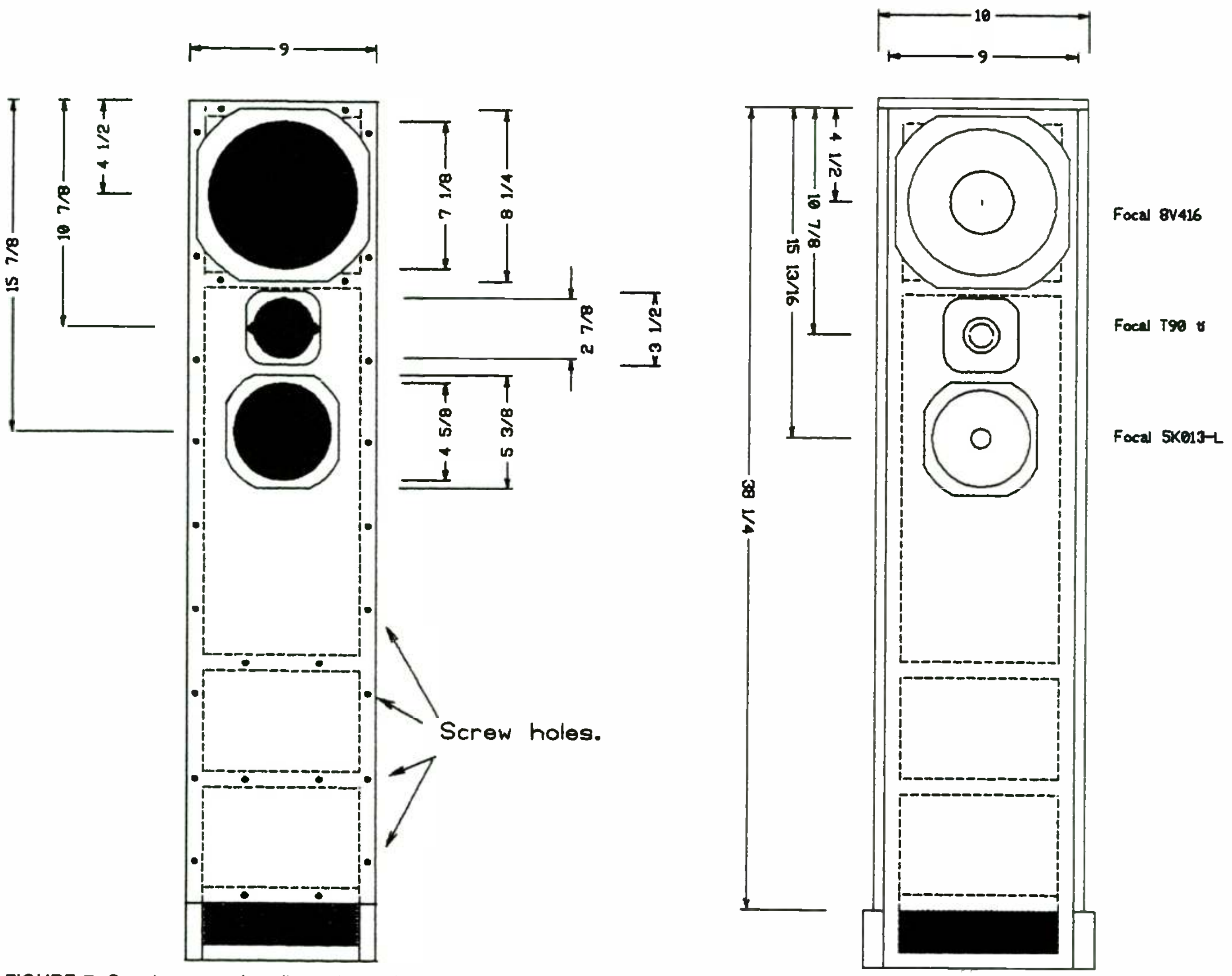

FIGURE 7: Speaker mounting dimensions with front baffle screw layout guide (left), and possible finishing treatment (right).

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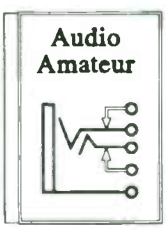

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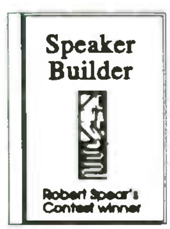

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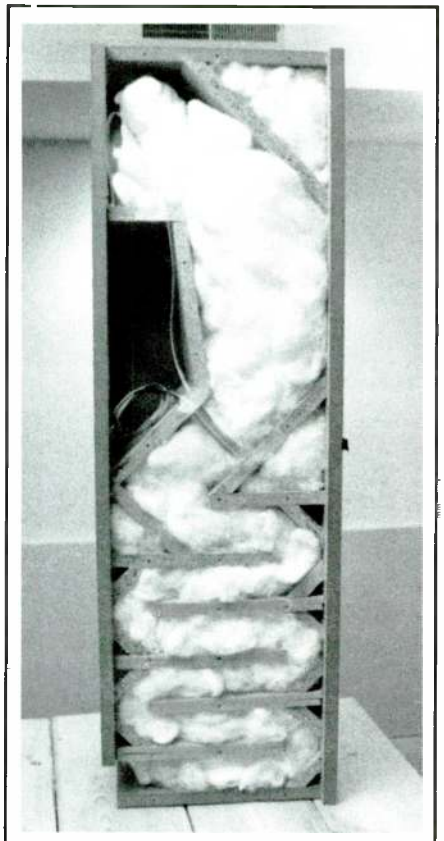

PHOTO 7: Fully stuffed enclosure. Note routing of lead-in wires through midrange chamber.

Acoustics Stuff

We looked for a stuffing ratio that would give us the best transient response, the most nearly flat combined woofer/port output and the least rise in woofer impedance at resonance. To achieve this, we measured the woofer's low-frequency response curve and impedance peak between stuffings. Tuning for best transient response usually causes a gentler woofer roll-off slope in the 80Hz–120Hz region and a slight improvement in the 15-20Hz region. The audible result is some reduction in bass output in the 40-80Hz region—precisely where you need it most—offset by increased clarity and definition in the same range.

The output of the system at 15-20Hz is not significant when using an 8″ driver. We measured it because when response in that range begins to drop in amplitude, the system is over damped. Brother Jon system response (after the woofer has rolled up) is +0.75dB up to the woofer/mid crossover point. Woofer impedance may be hard to find (a TL is a non-resonant system, after all), and resemble a very slight and broad hump instead of a peak.

Where a typical vented box produces two impedance peaks and a sealed box produces one, our finely damped TL produces almost no impedance peak measured at the woofer terminals. This means the woofer presents a constant load to the driving amplifier. Unfortunately, all bets are off when measurements are made through either the F433 or F444 crossover.

If you are using wool or Dacron, the packing ratios should be less than for Acousta-Stuf, typically about ¾lbs./ft.³ instead of the heavier rates we used. If a little ripple in system output is acceptable, stuffing ratios can be further decreased. This may slightly lower f_3 while transient response may be degraded a bit.

You may be interested to know how the Focal woofer we chose might perform in other types of enclosures. Because we didn't build other boxes, we must depend upon Focal's data sheets and offer generalized observations based on Focal's alignment examples for the 8V416.

In a sealed box sized for best transient response (with no or low DCR factored in), f_3 will occur between 55Hz and 60Hz. For the same woofer in a vented box, f_3 occurs between 35Hz and 40Hz, assuming the same type of response curve. The Brother Jon system response falls somewhere in between, with f_3 around 45-50Hz. This does not necessarily contradict the legendary status of TLs as superior low-frequency reproducers. It was simply a tradeoff we made for a compact line. The Brother Jon's mid-bass to mid-range performance is outstanding. Attributing the system's strength to this area, the A&S Sound-Off judges and *Stereophile* concur.

Continued from page 28

their backs, and glue in all the reflectors that touch the back side. Use latex construction adhesive and simply press the pieces firmly in place by hand. Sliding the pieces up and down an inch or so along their long axis while applying firm hand pressure will also help squeeze the glue out evenly. Clean up immediately with a damp cloth on a stick, using excess glue to fill any small gaps.

27. After the glue dries, flip the enclosures on their faces and glue the remaining reflectors touching the front baffle. If you wish, you may place the enclosures on their sides and glue all the reflectors at once. Don't disturb the enclosures for about half an hour after gluing the last piece.

INTERNAL WIRING.

28. Cut three lengths of #16 wire pairs to connect the speaker terminals to the drivers. All wires go through the midrange chamber. The woofer wire goes out the chamber top (*Photo 7*). Divide the paired ends and pass them through the previously drilled holes in board P from

Continued on page 32

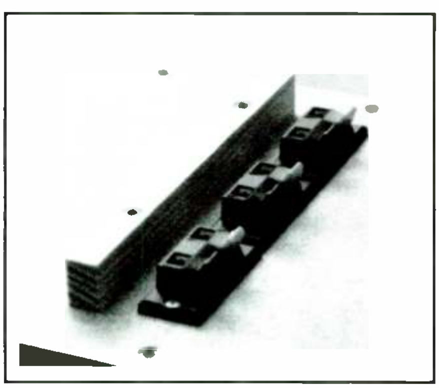

PHOTO 8: Alternative speaker clip mounting.

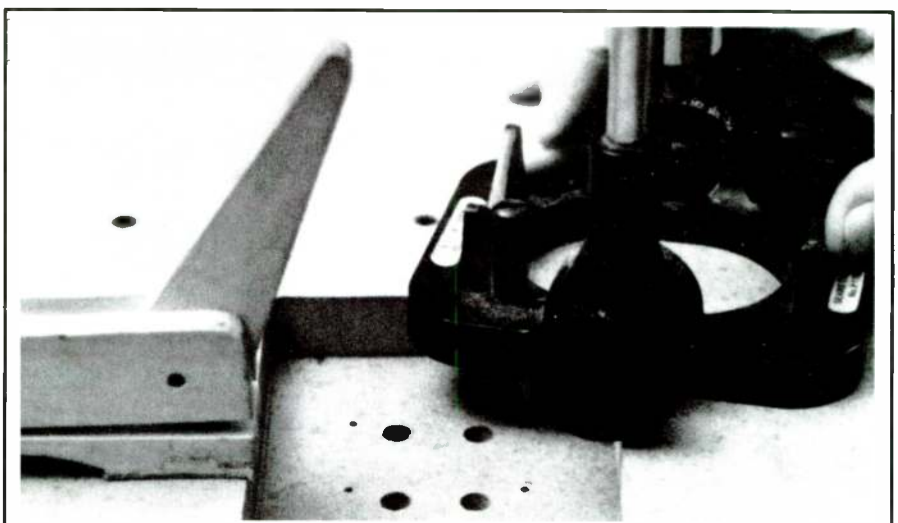

PHOTO 9: Drilling holes to mount panel **P**. Note use of cam clamp to hold panel **P**.

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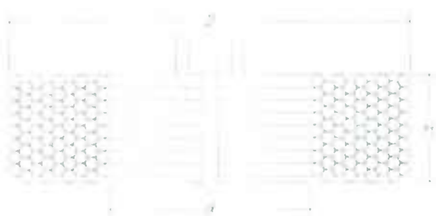

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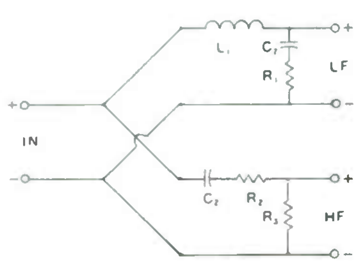

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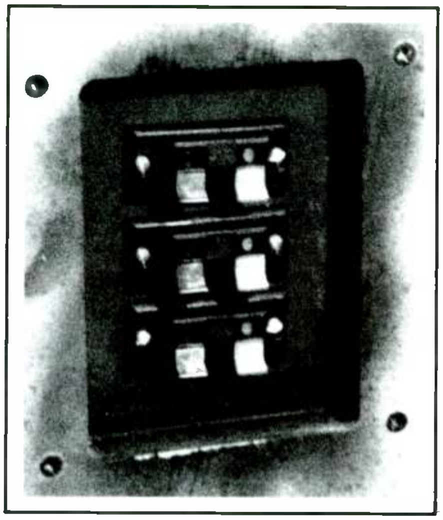

PHOTO 10: Completed speaker clip assembly.

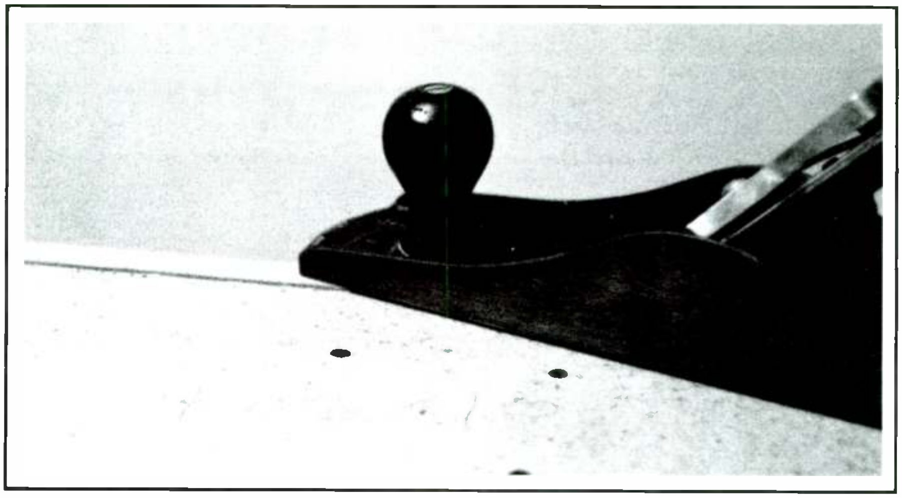

PHOTO 11: View across side of cabinet showing extra width of front panel about to be planed flush.

Continued from page 30

the inside. Solder the wires to the spring clip lugs, then attach the clips to P with small pan-head screws. Note: Tweeter terminals are on top, the woofer pair is on the bottom, and mid-range is in the middle even though this does not match the physical driver arrangement. The terminal assembly should now look similar to *Photo 10*.

29. Place the final side panel A on the enclosure and with an awl or a nail, mark the locations of the screw holes on the edges of E, F, and H. Remove final panel A and set it aside.

30. Bring the wires over the edges of lower reflector E and piece H, avoiding screw hole locations. With a ¼″ round file make three shallow grooves in the edges of E and H to recess the wires. File a single groove in piece F for the woofer lead. Secure the wires with strong tape or hot glue.

31. With colored electrical tape, code the leads in the mid-chamber; if you don't, later it will be hard to tell where to put them. Mark or tape the common side of each pair to observe polarity.

STUFFING.

32. Pack the line with Acousta-Stuf® at a ratio of 1.1:1.2 lbs./ft.[3] Three pounds fills both enclosures since each requires a bit less than 1.5 lbs. Pack the material evenly throughout the line, and bring the fiber up to the rear of the woofer magnet. Note: If you prefer to use wool, stuff at a rate of 0.75 lbs./ft.[3], and pack progressively heavier toward the line terminus. Keep the wool well back from the woofer cone, and use as little as possible in the first foot of the line. See also the sidebar "System Notes." One 12 oz. bag of high-loft Dacron fiber suffices for both midrange chambers. You'll need a second bag of Dacron for miscellaneous purposes.

33. Tease out the fiber tangle until it is uniformly loose and free of snarls. Pack it evenly throughout the line. Use a small stick to push the fibers down between the horizontal baffles. Reserve a few handfuls of fiber for later. Acousta-Stuf is self-supporting and needs no bracing. The baffle layout provides good support for wool except in the area behind the midrange chamber and the woofer, where additional support is required.

34. Some bare wood will be left inside the enclosure around the woofer. Using spray adhesive or some white glue, affix a thin bat of fiber to these areas. Cover the chamber's side and the top but not the reflector baffles. It is not necessary to fasten any fiber on the back side of the woofer mounting hole.

REFERENCES

1. Edgar, Bruce, "Special Report: The 1991 A&S Audiophile Sound-Off," *SB* 2/92, p. 39.
2. Spear, R. J., and A. F. Thornhill, "Design History of the Brother Jon: A Prize Winning Three-Way TL," *SB* 4/92, p. 10.
3. Spear, R. J., and A. F. Thornhill, "Squaring Particle Board," *SB* 1/92, p. 58.
4. Spear, R. J., and A. F. Thornhill, "Quick Latex Adhesives," *SB* 6/91, p. 60.

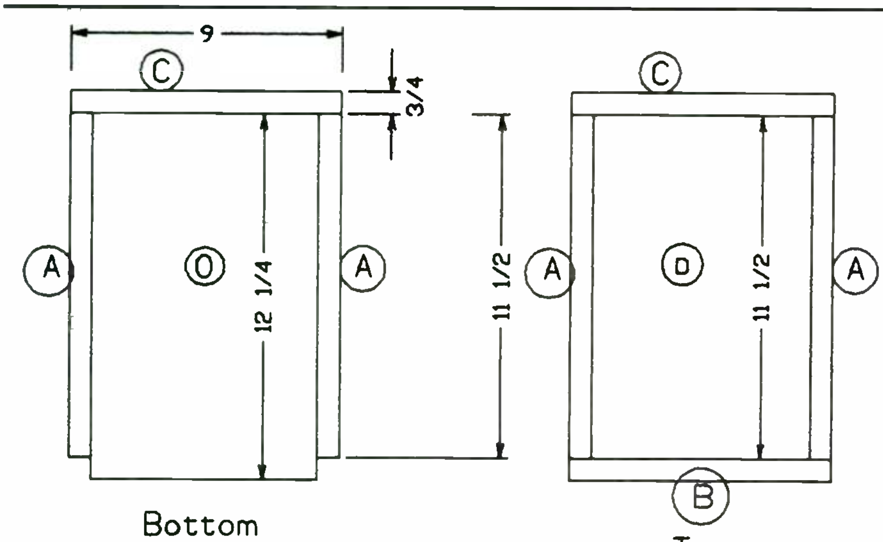

FIGURE 8: Top and bottom view of enclosure panels.

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35. Stuff the spaces behind the E baffles firmly with Dacron fiber. Starting with the largest, use the remaining fiber to stuff behind all other diagonal reflectors. You may opt to fill the voids behind the diagonal reflectors with fine, dry, white sand. Bear in mind this will substantially increase the weight of the enclosures and make them somewhat top-heavy. However, sand-filled voids will damp cabinet wall resonances about 9dB better than fiber-stuffed voids.

CLOSING THE BOX.

36. Set the last panel A in place on the main enclosure assembly. Using the holes in the panel as a guide, drill the last screw holes. Take care that no fiber overlaps any of the edges. If the fibers wrap around the drill bit they can split the baffles or prevent you from withdrawing the bit!

37. Apply a bead of glue to all the edge surfaces and screw the last A panel in place. Repeat on the other unit. If you plan to make adjustments to the stuffing, don't glue the final panel on until you are satisfied with the sound. Remember to glue before applying finishing materials so the enclosure will not leak air. This completes the basic enclosure assembly.

38. Glue fiber to the inside of the newly attached wall at the woofer location, and stuff the mid-chamber. Bring the leads out of the mid-chamber through the driver holes and poke the fibers into the corners of the chamber. Pack the mid-chamber fibers more heavily than those in the line.

39. Check the edges of the front and rear baffles to see if they overhang. If they do, use a long plane to bring their edges flush with the enclosure sidewalls as shown in *Photo 11*. Be sure all screw heads are counter sunk below the plane blade! If you use a power sander, please work in a well ventilated area since MDF dust is nasty stuff. If the panels are a little too narrow, don't despair. Our first ones were, too, and in the next installment we'll show you how to correct this.

The steps above should keep you busy for a while. In the final installment we will discuss speaker mounting, crossovers and their enclosures, cabinet finishing, grilles, and charts showing system performance.

SOURCES

A&S Speakers
3170 23rd St.
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(415) 641-4573
Kit consisting of drivers, crossover components, printed circuit board for crossovers, construction instructions with diagrams and photos. Component kit; same as in #1, above, plus completed, stuffed, and unfinished enclosures. Long fiber wool for stuffing.

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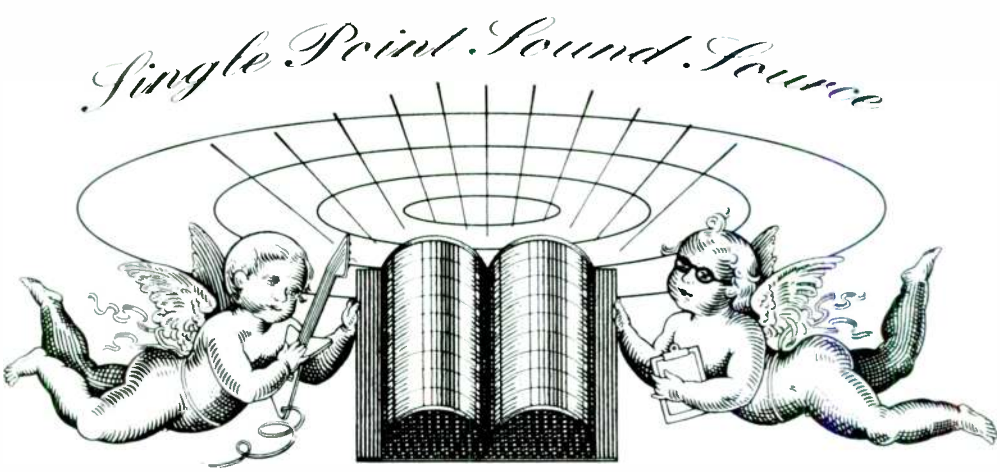

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Part II

THE DANIELLE

BY MARC BACON

In Part I of this article, I described the design process involved in modeling the Danielle, a 75-liter tower speaker using an MTM (midrange-tweeter-midrange) D'Appolito array and a TA-305F clone subwoofer with a series-resonant filter. This time, we will look at speaker construction and listener criticism.

CONSTRUCTION. The original enclosure layout is shown in *Fig. 23* (bear in mind that the system is built in mirror-imaged pairs). Some details of the MTM arrangement are worth noting. The woofer-midrange enclosures are simply proper lengths of 4″-diameter ABS tubing. (*Figure 24* details the volume calculation developed by the Loudspeaker Design Powersheet (LDP).) The drivers are glued to the front of the ABS tubing with a thin bead of silicone, and the tubes in turn are pushed through holes in the front baffle and held in place with silicone much as a duct would be. This mounting technique has the advantage of providing a round shape to minimize internal resonances and provide greater circumferential stiffness than flat panels. The silicone rubber isolates the drivers from the ABS tubes and the tubing from the front panels.

Working with ABS tubing is much simpler than making up individual cabinets for midrange enclosures. The slanted front required for proper alignment of the zero-delay plane was achieved by allowing the bottom tube to protrude 13⁄16″ from the front panel. For a D'Appolito array with a tilted listening axis, this is one alternative to a stepped front panel. As *Fig. 25* shows, obtaining a flat ZDP for cone midranges and a dome tweeter with a D'Appolito array cannot be done through a simple slanted baffle. The preferred methods are a step or ABS projection or a sloped base. The ABS tube has the advantage of presenting a rounded surface to tweeter reflections.

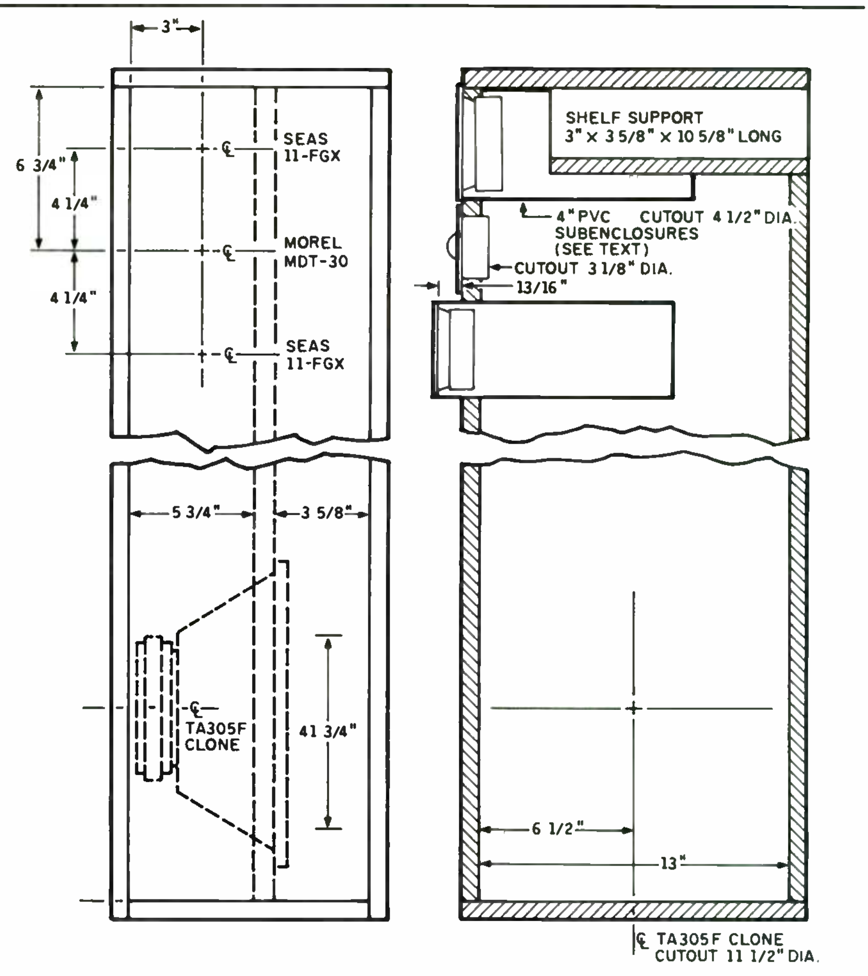

FIGURE 23: Original layout. For clarity, cleats and bracing not shown. See text for details.

The disadvantage of using the ABS projection is the aesthetic constraint to make perfect cutouts, as well as the requirement of mounting the grille frame on posts away from the front baffle (*á la* Infinity). Furthermore, for aesthetic purposes the driver diameter must be very close to the tube's outside diameter, and in order to reduce diffraction effects, the protrusion should only be as long as required for alignment.

Mount the midranges 4.25″ from the tweeter, or about one wavelength at the crossover frequency. They are off-center on the baffle in order to reduce the se-

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2.3 Truncated Cylinder - input values marked *
Press Alt-Z for HELP
Press Alt-M to return to previous menu

Divide net Vb x 1.2 if box is stuffed at 0.5 lbs./ft^3

          Net Vb (l):          2 *
    Driver volume (l):       0.25 *
      Port volume (l):          0 *
    Cleats, etc. (l):          0 *
        Total Vb (l):        2.25

    Box diameter (in.):        4 *
Front Panel Width (in.):        0 *


     Box Height (in.):      10.93
      Box Height (cm):      27.75
```

FIGURE 24: LDP cylindrical enclosure volume calculation.

verity of the response step. Stuffing consists of a 9″-square pad of 1″ Radio Shack fiberglass rolled up like a jelly roll and slid into the ABS tube. The rear wall is simply an ABS pipe cap.

The subwoofer cabinet dimensions were developed as follows (as you will see, my logic was flawed). I reasoned the tweeter should be approximately 37″ off the ground (see Part I for the geometrical considerations involved in crossover modeling). The 12″ woofer forced a 13″ minimum inside dimension as well. I settled for the arrangement shown in *Fig. 1*, which left some overvolume for cleats and braces.

In keeping with Vance Dickason's recommendations (*The Loudspeaker Design Cookbook*, fourth edition) for using a large port area to reduce nonlinearity, I chose to use a shelf port. I put it on the back for cosmetic reasons. For better imaging, I located it at the top of the speaker, reasoning that what little output was present in the low midrange would seem to come from the same area as the MTM array. I have found that speakers with a long dimension in the vertical plane don't image well, unless all frequencies are produced along that plane (as in Carver ribbon speakers, Martin-Logan electrostatics, and Infinity reference speakers). Unfortunately, this subject is not well covered in the literature.

I chose to locate the woofer near the bottom of the enclosure for ease of construction, while placing the crossover on a small board hot-glued to a side panel near the middle of the enclosure. Keep inductors as far apart as possible and orient their axes in mutually orthogonal directions to minimize mutual inductance.

I cross-braced the cabinet extensively as follows:

1. The construction material is 11/16″ exotic plywood (veneer-faced particleboard) with ¾″-square cleats in all corners.
2. The woofer mounting panel serves to reinforce the already narrow front panel.
3. I took care of the overvolume by tightly wedging randomly oriented rectangular blocks of exotic plywood between the woofer panel and each side, being sure to keep them away from the woofer and the port. I used two of them to support the inside ends of the midrange ABS tubes and stiffen the pipe caps.
4. I suppressed woofer frame resonances by wedging wooden shims between the magnet and the side wall, using hot glue to hold them in place.

BASS WOES. The LDP has several programs which model panel resonances and box standing waves. For brevity's sake they are not reproduced here, but they can be used for avoiding box dimensions which excite panel resonances. The Danielle has a very "dead" enclosure. I built one, and then did an A-B comparison with my Intégrités. It was immediately apparent that something was wrong with the bass—and especially the midbass, where most bass information originates. Although the midrange and treble were very much better, the lack of deep bass didn't make sense. Either I had wired the driver out of phase, the woofer was hopelessly out of spec, or I had not done a good job of modeling.

A quick run through the LDP with woofer F_S, Q_{TS}, and V_{AS} modified by 10% each way showed that this type of bass loading is very tolerant of woofer variations. The driver was therefore not the probable cause. A check of wiring polarity showed no problems either.

I then proceeded to disconnect the satellite section (the speaker is bi-wired), set the Sheffield Drum Record CD (see sidebar) at a moderately high level with full bass boost on the amplifier, and leave the house for a day to visit the in-laws, hoping to break in the woofer suspension before having to cut open the box. When we returned, unfortunately the bass was no better.

I wasn't happy, to say the least. Mathematical modeling had always worked before, with only minor tweaking required. I had trusted my model enough to cut the wood for both speakers, and the basement was a mess. Meanwhile, I had already told my father-in-law that he was to inherit the Intégrités for Christmas, which was only a week away. As always, we learn from our mistakes, as Bruce Edgar showed great courage in admitting ("The Klipschorn Throat Revisited," *SB* 6/91). I suspect most speaker designers have gone through a similar learning experience.

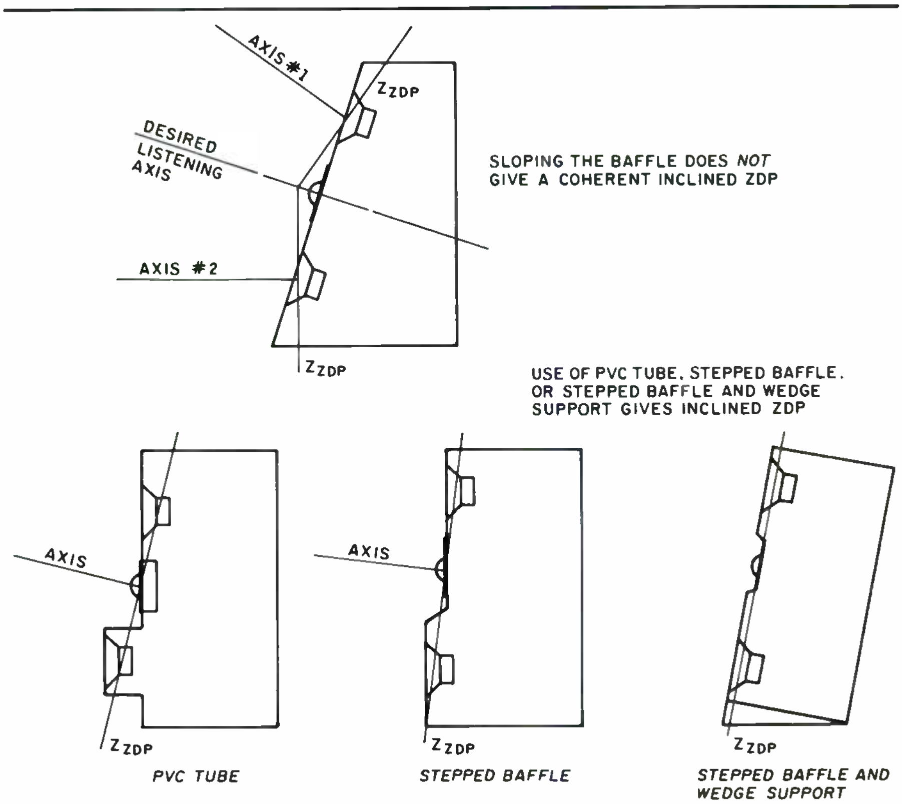

FIGURE 25: ZDP alignment of a D'Appolito MTM with inclined listening axis.

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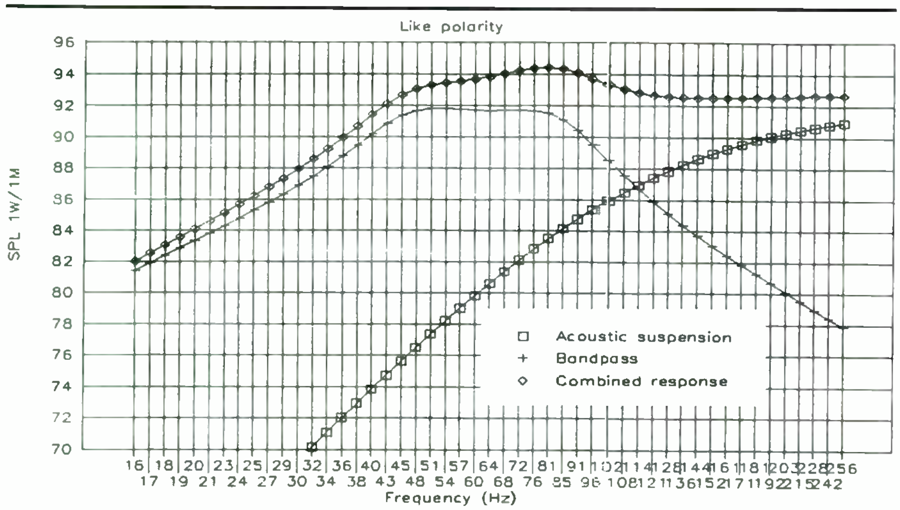

FIGURE 26: LDP revised subwoofer tuning.

```
LOUDSPEAKER DESIGN POWERSHEET
==========================
1.10 BANDPASS SUBWOOFER
 + Series-resonant circuit & adjustable tuning

input values marked *
Press Alt-Z for HELP
Press Alt-M to return to previous menu
Press Alt-V to save values for combination B.P. and A.S.

Graphs available
IMPEDANCE Line      BANDPASS ASW + RLC
RESPONSE  Line      BANDPASS ASW + RLC

                    DRIVER PARAMETERS                         ENCLOSURE PARAMETERS
                    =================                         ===================
               Qms:    2.64 *                           S:      0.61 *
               Qes:    0.38 *                 Desired SPL:      91.8 *
               Qts:    0.332

         Rg, ohms:     0.62 *            SPL difference: 3.726530
         Re, ohms:     5.34 *                        B:   0.8069
              Qes':    0.424
              Qts':    0.365
                                                   Q'T    1.0158
                                                Fs/Qts:   60.21
                                                Fo (Hz):  61.16
           Fs (Hz):      22 *                Vfront (l):  35.77
            Vas(l):     180 *                 Vrear (l):  26.76
                                             Vtotal (l):  62.53
          Xmax(mm):     6.1 *
Max. excursion (mm):     20 *        Approx. Bandwidth:      56.54
        Sd (cm^2):      539 *                      Fl:  See graph
Vd(m^3), calculated: 3.29E-04                       Fh:  See graph
      n0, calculated: 0.0050
iven sensitivity 1W 1m:  90.0 *                      F1:    41.27
alc. sensitivity 1W 1m:  89.0                        F2:    90.62
  Sensitivity with Rg:   88.1                   (F2-F1):    49.35
    Chosen Ref. SPL:     88.1 *

Chosen center (Hz):     50.33 *(Normally choose vent tuning frequency)

                                       Vent tuning (Hz):     63.0 *(Normally choose Fo)
  Chosen Filter Q:      0.531 *         Vent dia. (in.):        3 *
 Filter capacitor: 9.992E-04  Farads   Number of vents:        1 *
 Filter inductor:  1.001E-02  Henries  Vent area (in^2):    7.069

                                     Equivalent dia. (in.):   3.00
                                      Required length (in):   1.60
```

FIGURE 27: Revised predicted box response. Bump at 85Hz was intended to counteract labyrinth effect. See text.

THE LIGHT COMES ON. The answer came two days later, though it is probably self-evident to most *SB* readers. A perfect Helmholtz resonator is based on a tubular port, a spherical chamber, no nonlinearity in the port, and no effects due to turbulence or restrictions at either end. In my attempts to compensate for the 13″ woofer dimension, shelf port, and midrange height, I had totally violated the principle behind the mathematical model. The resulting "monster" was not a bandpass enclosure, but rather a labyrinth with one end closed and the other open, with the exciter (woofer) at the midpoint. The labyrinth strongly damped the 80–100Hz region where the midwoofers were rolling off, and the stagger-tuned bandpass enclosure cut off all but the lowest octave of bass. I have yet to hear such effective muffling of a 12″ woofer!

My Favorite CDs

The following CDs, used to evaluate the Danielle, are among my favorites for speaker testing:

The Sheffield Drum Record, Sheffield Labs, CD 14/20, tracks 5 and 6. This is the best recording of drums (notoriously hard to microphone) that I've ever heard. Individual instruments, cymbals, and snares, as well as rim shots, are incredibly lifelike. This is not a CD with which to relax by the fireside, but it's the best subjective test I know for testing crossover coherence and transient response—even better than a good jazz piano. Don't play this at higher volume levels than you would hear in real life—the dynamic transients are powerful enough in the midrange to cause hearing loss!

Hollywood's Greatest Hits, Telarc CD 14/20, especially tracks 1 and 7. Erich Kunzel, the Cincinnati Pops, and Telarc provide great dynamics, lots of bass energy, and massed instruments.

Transitions, EMI CDP 746461-2, by Frank Mills. Although this is not my taste in music, Mills generates very complex synthesizer notes. Any speaker will sound fine with this CD, but only good ones will sound superb. The synthesizer-based percussion will highlight IM distortion.

A Little Christmas Music, EMI CDKINGS 7 49909 2, by the King's Singers. An excellent recording by the world-renowned male ensemble. The delicate timbres are well reproduced, although without a true soundstage. This CD will highlight box colorations present in the midrange.

THE SOLUTION. I considered alternatives to the problem which would avoid wasting the wood. One was to forget the bandpass principle, mount the woofers on the side (to take advantage of the 13″ dimension), and use a ported enclosure. A quick box sizing using LDP and crossover modeling with CALSOD showed that the TA-305F clone wasn't efficient enough in the low bass to match the 92dB midrange section when rolled off with the 10mH coil. Unfortunately, I didn't have the time to rework the crossover to roll it off higher. Mounting the woofer near the floor to get some added room gain would have helped, but at the same time hurt the imaging.

Returning to the bandpass principle, I

Continued on page 38

World Radio History

LPG

one of the biggest manufacturers of high quality hi-fi loudspeakers in Germany, is now represented in the North American market.

LPG, whose know-how is based on a 65-year experience in designing and manufacturing loudspeakers, offers a totally new loudspeaker design range:

- ✦ woofer with polypropylene and coated paper cones (sizes 5″, 6½″, 8″ and 12″) in steel and diecast baskets for hi-fi and car audio applications
- ✦ midrange units (sizes 4″ and 5″)
- ✦ high quality coaxial-systems (with neodymium dome tweeters) for car audio applications with metal grilles and mounting rings
- ✦ 1″ and ¾″ neodymium dome tweeters with enclosures for flush, surface and angle mounting
- ✦ Titanium and textile dome tweeter and midrange domes

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Norscan Trading Group
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FAX 310-556-0860

Fast Reply #JG1473

World Radio History

Continued from page 36
chose to remove the back and modify the back chamber by moving the partition laterally inside the enclosure to reduce the volume and gain some efficiency. I then added a partition immediately under the lower midrange enclosure. This again added efficiency by reducing the volume and further served to shorten the length of the rear chamber to change its quarter-wave resonance to approximately 170Hz. I moved the port near the center of the front chamber, again to lower the acoustic labyrinth effect, and traded the shelf port for a 3″ ABS tube to get the tube somewhat away from the sides. The results were much improved.

The spreadsheet and predicted bass response of the speaker with new tuning are shown in *Figs. 26* and *27*, respectively, with the final box configuration shown in *Fig. 28*. Bass is present in generous amounts when required, but the overall impression of the speaker is one of very tight transients. It would appear that the 0.5 Q_{TC} of the woofer/midranges and the relatively low crossover to the subwoofer section set the tonal quality for the entire system, even though the system bass response is emphasized by 1dB below the crossover. That is, although system frequency response somewhat resembles a Chebychev vented box alignment with some ripple, the subjective result is much more that of the woofer/midranges and well-damped bandpass speaker.

Related Products

The following products mentioned in this article are available from Old Colony Sound Lab, PO Box 243, Peterborough NH 03458-0243; (603) 924-6371; FAX (603) 924-9467. USA surface shipping cost is $3 per item; others, please inquire. PLEASE NOTE THAT A SPREADSHEET PROGRAM IS NOT INCLUDED WITH THE LDP. Users should purchase Lotus 1-2-3, Quattro Pro, or Excel, any one of which can work in 1-2-3-style.

CALSOD

SOF-CAL2B4G CALSOD w/ graphics IBM 3½″ 67.50

SOF-CAL2B6G CALSOD w/graphics IBM 5¼″ 65.00

Loudspeaker Design Powersheet (LDP)

SOF-PSH1B3 LDP Basic version IBM 3½″ 49.95

SOF-PSH1B5 LDP Basic version IBM 5¼″ 49.95

SOF-PSH2B3 LDP Professional version IBM 3½″ 69.95

SOF-PSH2B5 LDP Professional version IBM 5¼″ 69.95

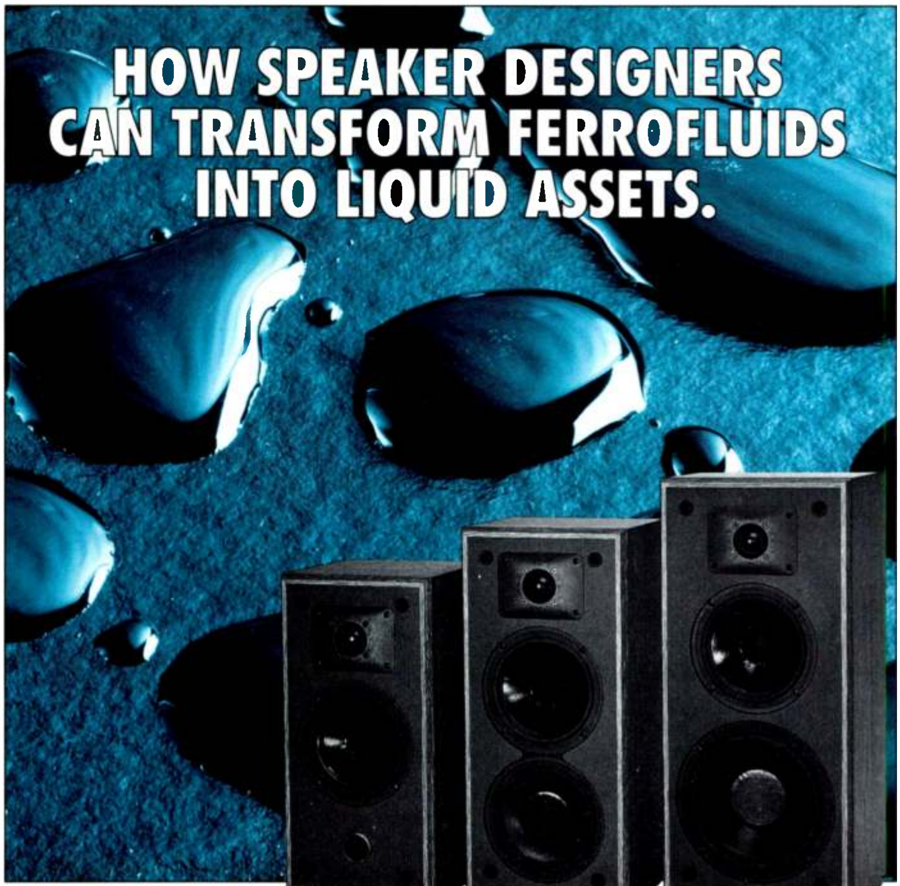
Loudspeaker Design Cookbook

BKAA2 Fourth edition, 1991, 154 pp. 29.95

LESSONS. With all of this fiddling required, the Danielle loudspeaker would not appear to be a good example of why modeling programs are worthwhile. A closer look reveals the following lessons, however:

1. Modeling resulted in an extremely good midrange/tweeter section. The

Continued on page 42



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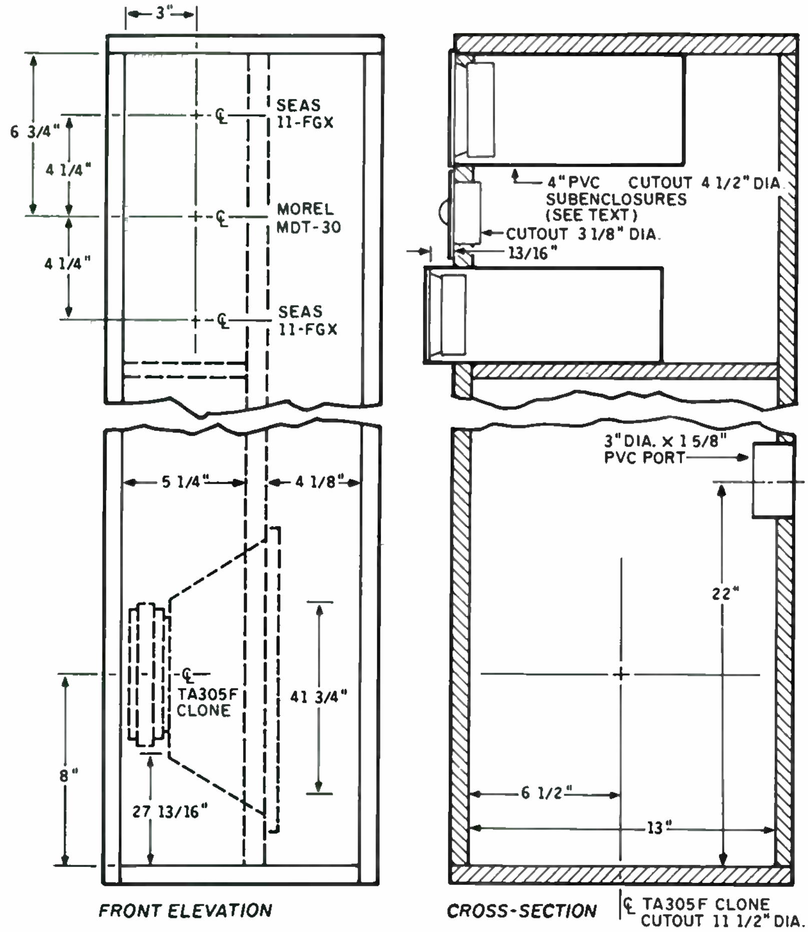


FIGURE 28: Final layout. For clarity, cleats and bracing not shown. See text for details.

Continued from page 38

crossover worked very well as designed, as would have the woofer section had I built the box to match Helmholtz theory. The Intégrités I had made previously were built straight from the LDP with *no* box tuning and worked "as built."

2. Modeling led me out of the mess I got into without building any more prototypes. Without the LDP, I would have probably built and tested for another month instead of simply tweaking the box tuning. The time and money saved was substantial.

3. Accurate modeling depends on knowing the basics of loudspeaker design and not violating the principles which govern the model.

RESULTS. With the boxes now acceptable, I collected subjective results from admittedly biased sources in my immediate family. My wife prefers them to the Intégrités on all counts, especially for the "you are there" illusion. My father, who is a competent cellist and loves music, made unsolicited comments as to the exact placement of each percussion instrument in the Sheffield Drum Record. My father-in-law, who played sax for nearly forty years in different ensembles and can name almost any piece of pre-1960 music he hears, spent hours listening to the speakers and contributed equally positive remarks.

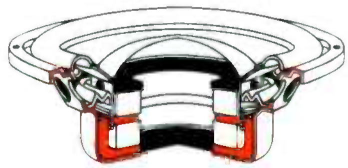
Specifically, the higher 3kHz crossover (versus 2kHz for the Intégrité) and the second-order (versus first-order) slope reduce to inaudibility the treble distortion in the already excellent Morel MDT-30s. The crossover is seamless, and the effect of a conjugate circuit to maintain overall impedance compensation in the midrange provides a very coherent soundstage. True, the 11-FGX drivers have paper cones, but this isn't apparent sonically. The speakers can play very loud indeed, with no hint of compression due to their high efficiency. They are com-

Continued on page 69

Fast Reply #JG45

MW 142

DPC Cone Double Magnet 5″ Woofer



A 5″ unit with a unique design, incorporating an extremely large diameter aluminium voice coil for such a small unit.

Vented double magnet system with steel chassis — damped polymer composite cone — rubber surround — smooth response to upper limit of 5 Khz with excellent on and off axis response and good roll off.

High power handling emanates from this unique design, resulting in a very impressive small bass/mid or mid range unit.

Specification

Overall Dimensions	⌀-142mm(5.5″) x 52mm(2″)
Nominal Power Handling (Din)	150 W
Transient Power — 10ms	1000 W
Voice Coil Diameter	75mm(3″)
Voice Coil Type / Former	Hexatech Aluminium
Frequency Response	48-5000 Hz
FS — Resonant Frequency	52 Hz
Sensitivity 1W/1M	86 dB
Z — Nominal Impedance	8 ohms
RE — DC Resistance	5.2 ohms
LBM — Voice Coil Inductance @ 1 Khz	0.5 mh
Magnetic Gap Width	1.35mm(0.053″)
HE — Magnetic Gap Height	5mm(0.196″)
Voice Coil Height	12mm(0.47″)
X – Max. Linear Excursion	3.5mm(0.137″)
B — Flux Density / BL Product (BXL)	0.6 T / 5.0 NA
Qms — Mechanical Q Factor	2.14
Qes — Electrical Q Factor	0.62
Q/T — Total Q Factor	0.45
Vas — Equivalent Cas Air Load	7 litres (0.25 ft³)
MMS — Moving Mass / Rmec	13gm / 2.06ns/m
SD — Effective Cone/Dome Area	90 cm²
Cone/Dome Material	DPC (Damped Polymer Composite)
Nett Weight	0.97 kg

Specifications given are as after 24 hours of running.

high fidelity range

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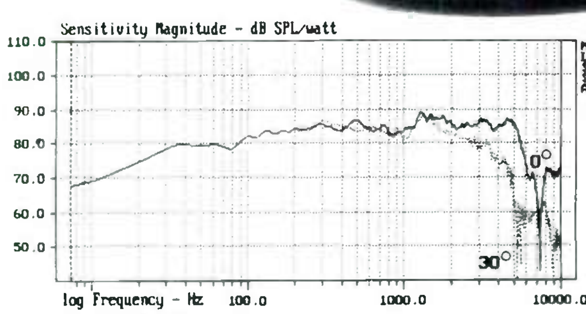

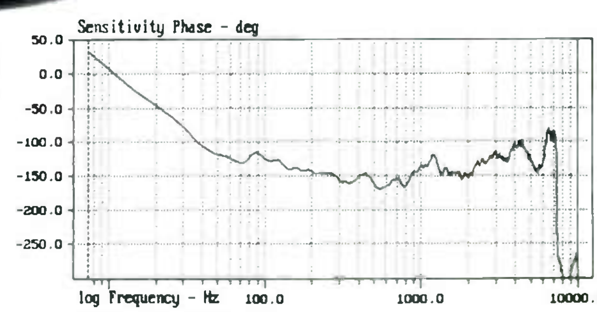

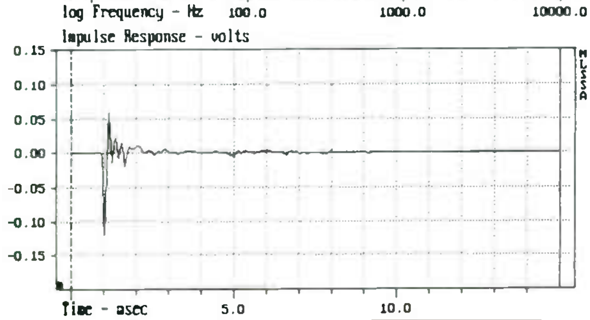

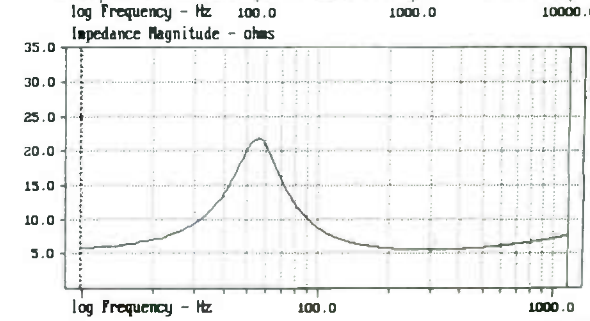

Morel operate a policy of continuous product design improvement, consequently specifications are subject to alteration without prior notice. *Fast Reply #JG1407*

World Radio History

Tools, Tips & Techniques

TAMING ISO-PEAKS & NULLS

Considerable interest has surfaced regarding the Isobarik/compound woofer design. Recently, I tried my first compound woofer system. The "iso-peak/null" referred to in Bill Schwefel's "The Wonder of a Symmetrical Isobarik" (*SB* 5/90, p. 10), is critical to my design.

Design Variables

Unlike Mr. Schwefel's design, I used 8″ P21 series SEAS drivers. The 8″ drivers dictated a larger inter-driver spacing than the 2¾″, which he used with little 4.5″ drivers. My spacing was on the order of 5″, or the minimum distance the rear driver could occupy without hitting the back of the front driver's magnet.

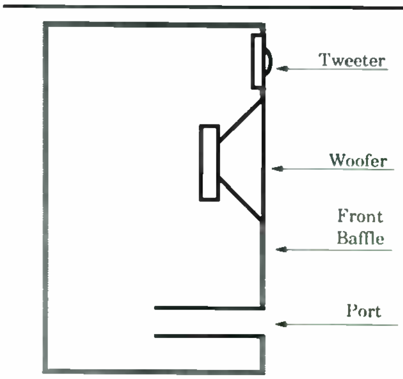

FIGURE 1: Cross-sectional drawing of a typical two-way speaker. This one is ported.

My "Model 990" (built in September 1990), began with a fixed box volume, about 1.25ft^3, for an available set of cabinets. This is the hard way to do a design. It's almost always better to fit the cabinet to the driver rather than vice-versa.

I began by hoping to put two 8″ drivers into a tight mid-tweeter-mid (M-T-M) layout. The tweeter would extend down to 1.25kHz, limiting the extension required of the 8″ drivers. This made selection easier, since I only needed to look at Q_T and V_{AS}, almost any 8″ would have reasonably flat response up to 1kHz.

In testing the driver in the cabinet, it became obvious that two drivers in the cabinet would have limited LF extension, but superb midbass impact. I tested both the sealed and ported versions. I also tried one driver in the same cabinet. This was better, but still lacked the low bass I had hoped for. The cabinet was too small, it simply wouldn't tune below 70Hz.

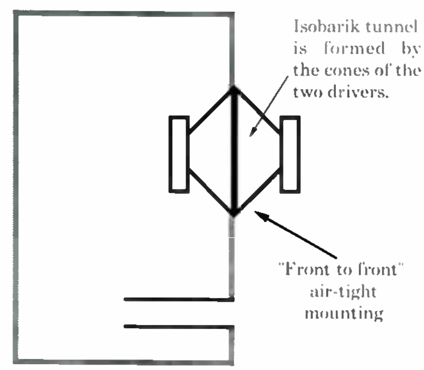

FIGURE 2: Simplified Isobarik driver configuration for bass and subwoofer use only. Drivers are wired electrically out of phase, for mechanical in-phase operation. Mid- and high-frequency radiation is reduced due to the on-axis position of the outer magnet structure, and the lack of a direct path from the center of the driver's cone to the listener.

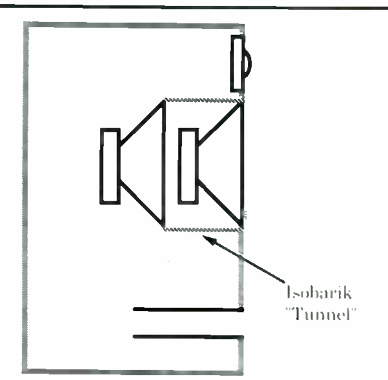

FIGURE 3: Cross-sectional drawing of a typical wide-range Isobarik-speaker system. Two identical drivers have been mounted into a sealed "tunnel."

Isobarik Cavity

What to do? Isobarik to the rescue. Halving the V_{AS}, I figured this should cause the system to tune lower in frequency, given the same volume box. So I tried it, and it worked. But the mids started to sound like ducks, geese, and other honking things!

Since the drivers must operate at midrange frequencies, they both had to face in the same direction. This precluded placing them face-to-face, thus shrinking the volume of the cavity (*Figs. 1–5*).

The cavity resonance, formed by the space between the two drivers of the com-

Continued on page 46

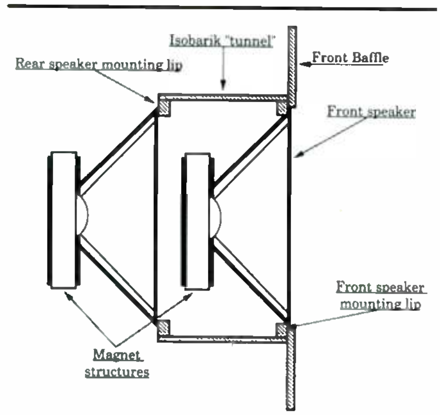

FIGURE 4: Basic Isobarik set-up, before treatment.

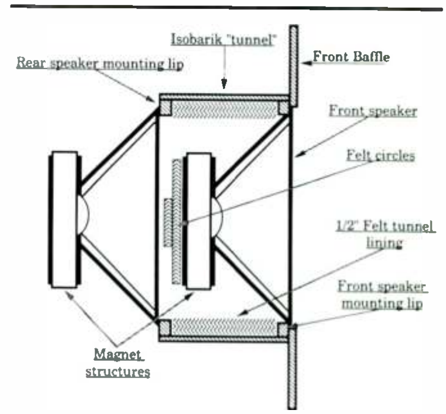

FIGURE 5: Cross-sectional detail of Isobarik tunnel showing placement of sound absorbing felt to minimize Isobarik peaks and nulls.

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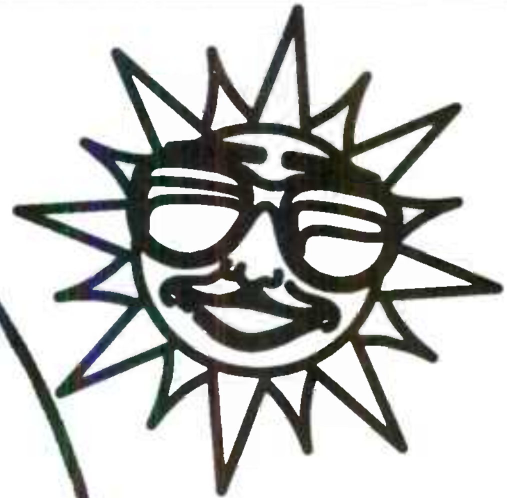
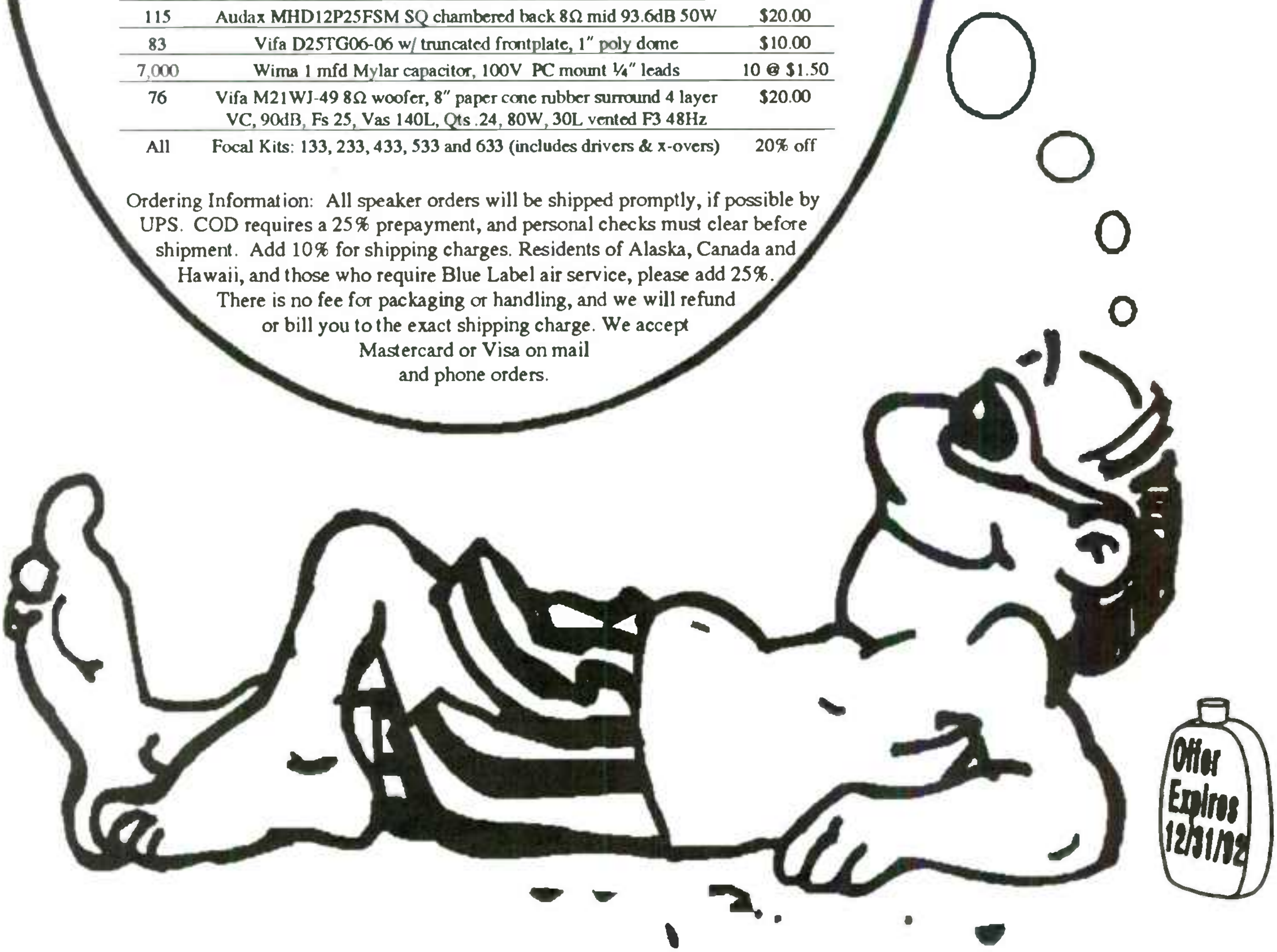


QTY	Item	Price
9	Morel MW220 8Ω woofer, 9" poly, foam surround, for sealed boxes	$53.00
107	Vifa H25TG-31-06 Horn tweeter, 96dB, chambered back	$10.00
16,000	Wesco 1.5 mfd Mylar capacitor, 100V 10%	10 @ $2.00
375	Danmar 12" woofer, paper cone, foam surround 25W	$9.00
99	Peerless 1528 (SKO10) tweeter, 94mm square, 1" dome	$12.00
80	Audax DTW100SP25 4Ω 1" poly dome w/FF Fs 1100, 91dB	$9.00
14	Focal 7N313 Midrange, 94dB, 6" cone, Small sealed box F3 200Hz	$90.00
325	Peerless 2" cone tweeter, 4Ω 89.5dB, Fs 1500Hz, 60W	$5.00
291	Eminence 10" woofer, 100W 8Ω Fs 24, Vas 269L, Qts .33	$25.00
117	Peerless 1646 Horn midrange, 2" dome, 93dB, Fs 470, 120W	$25.00
18,000	10 mfd Mylar capacitor, 100V 10%	$1.20
4	Focal 10N515 10" woofer, 92dB, Fs 26.5, Vas 145L, Qts .33	$70.00
75	Peerless 1581 4Ω tweeter, 3" flange, 1" dome, Fs 1080, 100W 89dB	$9.00
90	Audax Hif87Bism 4Ω, 4" paper cone rubber surround, full range	$10.00
22,000	4.7 mfd Mylar capacitor 63V, 10% ½" leads	10 @ $4.00
6	Morel MW160 6.5" woofer, 8Ω Fs55 Vas 11L Qts .95 120W	$36.00
125	Peerless 1745 5¼" woofer, poly cone foam surround (TO125F)	$23.00
98	Philips AD11400 8Ω, 3¼" Square, 1" fabric dome, Fs 1500	$7.00
1000	Audax DW6x11M 8Ω, 6cm x 11cm 19mm dome, 96.5dB	$6.00
66	Peerless 1531 10" woofer, poly cone foam surround 92dB sealed box	$26.00
115	Audax MHD12P25FSM SQ chambered back 8Ω mid 93.6dB 50W	$20.00
83	Vifa D25TG06-06 w/ truncated frontplate, 1" poly dome	$10.00
7,000	Wima 1 mfd Mylar capacitor, 100V PC mount ¼" leads	10 @ $1.50
76	Vifa M21WJ-49 8Ω woofer, 8" paper cone rubber surround 4 layer VC, 90dB, Fs 25, Vas 140L, Qts .24, 80W, 30L vented F3 48Hz	$20.00
All	Focal Kits: 133, 233, 433, 533 and 633 (includes drivers & x-overs)	20% off

Ordering Information: All speaker orders will be shipped promptly, if possible by UPS. COD requires a 25% prepayment, and personal checks must clear before shipment. Add 10% for shipping charges. Residents of Alaska, Canada and Hawaii, and those who require Blue Label air service, please add 25%. There is no fee for packaging or handling, and we will refund or bill you to the exact shipping charge. We accept Mastercard or Visa on mail and phone orders.



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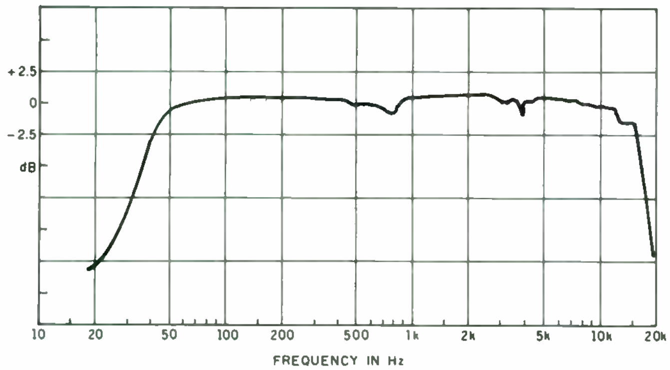

FIGURE 6: The Model 990's frequency response curve. Taken at 1', hanging 6' in the air, microphone on the woofer axis, the response measures within ± 2dB from 50Hz up to 16kHz. Note that the anomaly at 800Hz may not be an "Iso-null." Also the tweeter crosses over just below 2kHz, and does drop like a stone above 16kHz.

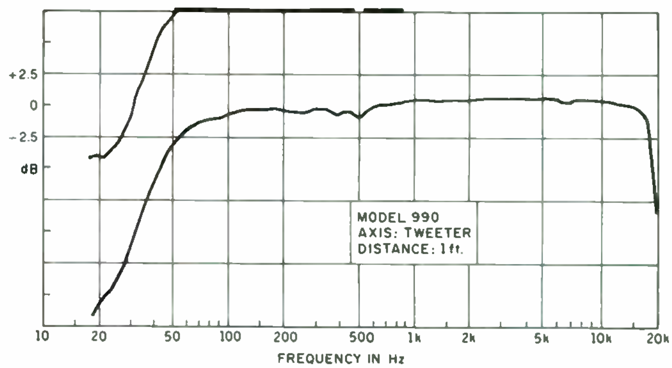

FIGURE 7: This curve was taken as before, but on axis to the tweeter. Note the surprisingly smooth response above 800Hz. Also, the anomaly at 800Hz no longer is present. Both curves show that the treatment appears to have tamed the Iso-null/peaks. Note: Since the speaker did not sound right at first, curves were run after the most obvious problems were fixed, so no curves exist showing the original "honking" condition.

Continued from page 44

pound system, was the problem which needed attention, otherwise the speaker would be worthless, with time and work wasted.

Looking at the cavity, clearly the rear speaker's mid-frequency energy was directed at the front speaker's large magnet structure, a somewhat larger than usual 40-oz. magnet assembly. I experimented with a low-pass filter on the rear driver, but it didn't sound good, and added to the parts count and expense.

Also, I had mounted the drivers with the help of a section of 10" diameter fiber tube. The assembly of the tube and two drivers, along with a flat MDF (medium density fiberboard) front, all mounted into the front of the cabinet. Tubes resonate, as in organ pipes which made me apprehensive.

The solution was adding absorptive material to the cavity and the rear of the magnet structure. I placed ½"-thick felt around the inner wall of the tube and between the two drivers, and then contact cemented the rear of a round piece of felt to the front driver's magnet. A smaller, 2" piece was centered on top of the first 5" piece.

The two felt treatments reduced the cavity resonance substantially. The "honkiness" became almost inaudible. The final

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Fast Reply #JG568

World Radio History

curve is shown in *Fig. 6*. Even so, the midrange was not as clean as one driver alone (*Fig. 7*).

Conclusions

The Isobarik system handles power exceptionally well. It sounds best at higher volumes, having impressive impact. It never becomes "loose" on high level, low frequency bass, staying clean and tight. After some months of driver "break-in," it sounds every bit as good at low volumes. (I didn't test this, but I suspect the cabinets are still a bit too small for the compound drivers. Thus, the system is slightly over-damped.)

From this experience with the compound woofer, I recommend that it is best used when the range of the drivers is limited to low bass.

Minimizing the Isobarik's null and peak is a good idea for compound driver systems operating into the midrange. Consideration of this factor, the taming tradeoffs, and the additional work and materials, should be included in your initial system planning.

Randall Bradley
Hannacroix, NY 12087

TUBES AND FREE AIR

For those tough final assemblies, used bicycle tubes can be *recycled* as elastic clamps by wrapping them around the box. Feel free to shorten by tying a knot. The same tubes are also an economical and durable alternative to large diameter shrink-wrap for covering large cables or clamps. I secure them using a liquid polyurethane rubber (*Freesole* or *Aquaseal*) as a glue/insulator.

I made a current shunt for my digital voltmeter (DVM) using about 10″ of 10-gauge copper wire, two large alligator clips, and two leads terminated in a dual banana plug to connect to my DVM. This yields a reading of 1A/mV, handy for figuring out what your alternator is actually producing.

If you are fortunate enough to have a swept-frequency signal generator, you might be able to determine the current frequency setting more accurately than by reading the dial. My B&K model 3020 has a DC 0–1.0V output that corresponds to the frequency. I calibrated the low frequency range by using Lissajous patterns with my oscilloscope: the 60Hz line providing one known frequency. I made up a calibration table derived from combining 60Hz with other selected oscillator outputs, which allows me to read the frequency on my DVM—excellent for finding free-air resonances.

Brian Dettling
Cuyahoga Falls, OH 44323-2596

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Fast Reply #JG494

World Radio History

Technology Watch

ELECTRONIC SOUND ABSORPTION

By Peter Muxlow

The listening room is the final link between the loudspeaker and the listener and, as such, its acoustic characteristics are very important. The walls, floor, and ceiling reflect sound like a mirror reflects light, and the sound-pressure waves bounce off them. A room's size and shape cause sound waves to cancel and reinforce each other, determined by such factors as wavelength, amplitude, direction and phase.

A standing wave exists whenever a constant reinforcement and cancellation of the wave results in a sound-pressure pattern which is stationary. This occurs when a room's dimension equals some multiple of one-half wavelength of the sound wave. Standing waves, or room resonances, (*eigenmodes* or *eigentones*) are most likely to be noticed at the low end of the frequency range, below 200Hz. You can hear them by playing a low-frequency sine wave, or low-frequency steady-state material (like organ music). As you move around the room, you'll notice the areas of sound cancellation and reinforcement through the change-in-sound level.

Listening Spot

The extent to which the room *eigentones* are energized is determined by the loudspeakers' location. With your room, the first and least expensive step is to optimize the loudspeaker-listening position.[1] A software package exists that makes this easy.[2] This positioning is always a compromise, however, and thus unsatisfactory. If we could alter the room's acoustics so the wall absorbed rather than reflected the acoustic wave, the sound would not be bounced back. Hence no standing waves would be created. This is usually done with passive absorbers and Helmholtz Resonators.[3] Nelson Pass has gone further with the PHANTOM: an active low-frequency acoustic-resonance suppressor.[4]

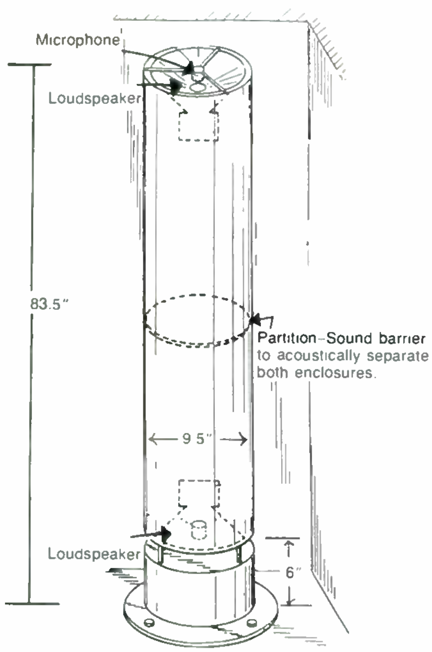

FIGURE 1: A vertical tubular enclosure with loudspeakers at both ends.

Figure 1 depicts a tube with a loudspeaker and microphone at each end. The microphones are located one-inch from the loudspeakers, and feed into inverting-power amplifiers which drive the loudspeakers. The unit is placed near a wall or in a corner, which is the boundary where the sound wave will be reflected and the point of high pressure we wish to absorb. The microphones feed the sound wave to the inverting-power amplifier, and the loudspeakers produce acoustic sound-pressure waves of opposite polarity. This radiates as an interfering wave which cancels out the unwanted signal, creating a spherical zone of reduced sound pressure around each loudspeaker. Curves given in the patent show the working range of the unit: an 8dB sound-pressure reduction of 20–200Hz two feet from the tube. See *Audio* for a review and listening tests.[5]

Active Noise Reduction

Active-noise control is an expanding area. The general principles were patented in Germany by Leug in 1933. In 1958, Olson and May described a general electronic sound absorber, which created a zone of silence in a noisy environment.[6, 7] For conventional closed headphones and hearing protectors, normal sound insulation is passive and rarely exceeds 15dB, from 30–200Hz. With active-noise reduction, an extra 18dB sound insulation is gained. A small electret microphone inside the earcup picks up the unwanted noise before reaching the ear's entrance. The microphone's output is amplified, inverted, and radiated from a transducer, producing an out-of-phase acoustic signal which cancels the noise inside the earcup. Noise cancelling headsets and ear defenders are currently available. For those of you who would like to experiment in this area, a patent exists which is useful.[8] It is particularly relevant in the area of feedback-design stability, one of the biggest problems facing designers.

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3. American Patents 4,319,661, 4,548,292.
4. American Patent 4,899,387.
5. Clegg, Almon H., "Phantom Acoustics Shadow Active L.F. Acoustic Controller," *Audio*, June 1989, pp. 126–132.
6. *Journal* Acoustical Society of America, Vol. 25, Nov. 6, 1953.
7. The Nelson Pass device is specifically designed to reduce room resonances, not to suppress noise.
8. American Patent 4,593,217.

World Radio History

NEW AIRBORNE SPEAKER DRIVER UNITS

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Airborne isn't merely a new car speaker driver unit, it's exclusivity, it's a star borne of many years of evolving design philosophy.

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The high quality features are achieved by using aluminium voice coil former, high temperature voice coil wire, vented magnet system, polypropylene cone, poly dust cap and coated foam surround. The delicate balance of all of those features really lend credence to the term «speaker».

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AIRBORNE Loudspeaker Driver Unit — **PRELIMINARY DATA**

20WP38/4 — **20 cm WOOFER MIDRANGE**

Features

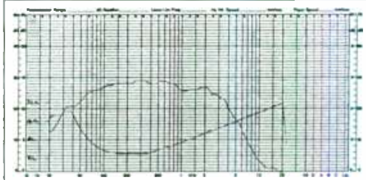
- Aluminium Voice Coil Former
- Vented Magnet System
- Polypropylene Cone
- Poly Dust Cap
- Coated Foam Surround
- Optimized for Vented Box

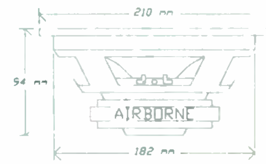
Parameters

Nominal Impedance		4	Ohms
Nominal Power		80	Watt
Music Power		120	Watt
Frequency Range		30-3.0	KHz
Sensitivity	1W/1m	89	dB
Magnet Weight	20 oz	566	g
Moving Mass		25 0	g
Effective Cone Area		212	cm2
Voice Coil Diameter		38	mm
Voice Coil Lenght		16	mm
Air Gap Height		6	mm
Voice Coil Resistance		3.3	Ohms
Voice Coil Inductance		62	mH
Free Air Resonance		30	Hz
Vas		67.8	ltr
Qts		0.32	
Qms		2.95	
Qes		0.36	

Impedance Compensation

Resistor	3 3 Ohms
Capacitor	51 mfd





Recommended Vented Box Size

Type	Box Vol	Fb/Fc	F3	Peak	Vent Dia	Vent Lenght
B4	32 ltr	39 Hz	40 Hz	0 dB	5 0 cm	8 8 cm
SBB4	30 ltr	30 Hz	47 Hz	0 dB	5 0 cm	18 9 cm
SC4	28 ltr	33 Hz	45 Hz	0 dB	5 0 cm	16 1 cm
QB3	28 ltr	37 Hz	43 Hz	0 dB	5.0 cm	12 3 cm

AIRBORNE Loudspeaker Driver Unit — **PRELIMINARY DATA**

25WP38/4 — **25 cm WOOFER**

Features

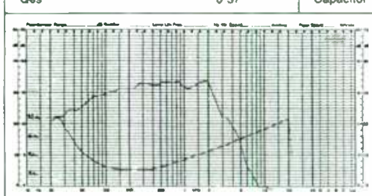
- Aluminium Voice Coil Former
- Vented Magnet System
- Polypropylene Cone
- Poly Dust Cap
- Coated Foam Surround
- Optimized for Vented Box

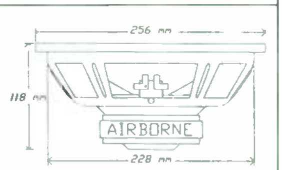
Parameters

Nominal Impedance		4	Ohms
Nominal Power		100	Watt
Music Power		150	Watt
Frequency Range		25-2 5	KHz
Sensitivity	1W/1m	91	dB
Magnet Weight	28 oz	792	g
Moving Mass		34 0	g
Effective Cone Area		344	cm2
Voice Coil Diameter		38	mm
Voice Coil Lenght		16	mm
Air Gap Height		6	mm
Voice Coil Resistance		3 3	Ohms
Voice Coil Inductance		62	mH
Free Air Resonance		26	Hz
Vas		176	ltr
Qts		0 32	
Qms		2 54	
Qes		0 37	

Impedance Compensation

Resistor	3.3 Ohms
Capacitor	51 mfd





Recommended Vented Box Size

Type	Box Vol	Fb/Fc	F3	Peak	Vent Dia	Vent Lenght
B4	85 ltr	33 Hz	35 Hz	0 dB	7 5 cm	9.2 cm
SBB4	80 ltr	27 Hz	41 Hz	0 dB	7.5 cm	18.1 cm
SC4	75 ltr	30 Hz	39 Hz	0 dB	7 5 cm	15.0 cm
QB3	76 ltr	33 Hz	38 Hz	0 dB	7 5 cm	11 4 cm

AIRBORNE Loudspeaker Driver Unit — **PRELIMINARY DATA**

30WP50/4 — **30 cm WOOFER**

Features

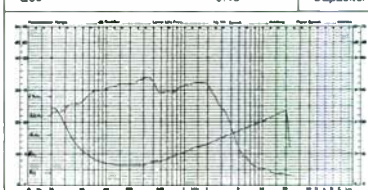
- Aluminium Voice Coil Former
- Vented Magnet System
- Polypropylene Cone
- Poly Dust Cap
- Coated Foam Surround
- Optimized for Vented Box

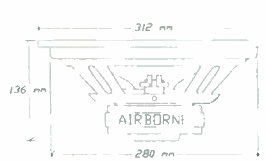
Parameters

Nominal Impedance		4	Ohms
Nominal Power		120	Watt
Music Power		180	Watt
Frequency Range		20-2.0	KHz
Sensitivity	1W/1m	93	dB
Magnet Weight	40 oz	1132	g
Moving Mass		56.0	g
Effective Cone Area		494	cm2
Voice Coil Diameter		50	mm
Voice Coil Lenght		20	mm
Air Gap Height		8	mm
Voice Coil Resistance		3 3	Ohms
Voice Coil Inductance		.62	mH
Free Air Resonance		22	Hz
Vas		232	ltr
Qts		0.33	
Qms		3 46	
Qes		0.46	

Impedance Compensation

Resistor	3 3 Ohms
Capacitor	51 mfd





Recommended Vented Box Size

Type	Box Vol	Fb/Fc	F3	Peak	Vent Dia	Vent Lenght
B4	120 ltr	27 Hz	28 Hz	0 dB	10 cm	20 4 cm
SBB4	111 ltr	22 Hz	33 Hz	0 dB	10 cm	37 8 cm
SC4	105 ltr	24 Hz	32 Hz	0 dB	10 cm	31 5 cm
QB3	107 ltr	27 Hz	30 Hz	0 dB	10 cm	24 9 cm

Fast Reply #JG1469

World Radio History

SB Mailbox

T90K OR SAPPHIRE II?

SB 4/92 provided some mighty meaty reading. David Moran duking it out with John Atkinson, Gary Galo's Aria review and Kimon's reply mixed in with excellent technical articles like Marc Bacon's "The Danielle" made for the most enjoyment I've gotten to date from *Speaker Builder*.

Kimon Bellas of ORCA makes a misleading statement regarding the tweeter used in the Sapphire II (p. 50). Kimon states: "It is important to note the moving assembly and the damping system are exactly identical on both the current T90K and the Focal tweeter used in the Sapphire II." Kimon's statement might lead the reader to believe the tweeters are essentially the same; this is not true, however. The tweeter used in the Sapphire II has a 700g magnet, 500Hz resonance, Q_T of approximately 0.4, and a vented pole piece which we load with damping material and seal to form an aperiodic load. Contrast this with the T90K, which has a 250g magnet, 800Hz resonance, Q_T of approximately 0.8 and a solid pole piece. Even from these basic specifications it is easy to see that the more costly Sapphire II tweeter will not sound like a T90K. Since March 1992 the Sapphire II has been shipped as the Sapphire II*ti*. The *ti* is identical but with the substitution of a titanium inverted dome.

Mike Dzurko, President
Audio Concepts, Inc.
La Crosse, WI 54601

Kimon Bellas, President of ORCA, Design & Manufacturing Corp., replies:

In response to your letter: first, the moving assembly (Kevlar dome, suspension and voice coil) of the T90K is indeed the same as on the T120K or T120KT special unit you are using; second, by damping system I understand you to mean the round pad of thin damping material on top of the pole piece, and the foam donut inside the magnet structure.

You are right to correct me in the sense that the vent in the pole piece, unique to the T120TK, does change the damping characteristics of the tweeter. I certainly had no intention of misleading anyone. I was referring to the actual features: moving assembly and damping material.

I believe anyone active in speaker building knows the substantial difference between the T120 and T90 series of Focal tweeters, as you outlined them. We at Focal feel very strongly about the oversized magnet structure of the T120 series. I am not saying these two tweeters are the same; I am saying they are clearly of the same family.

I hope this clears up any doubts or misinterpretations.

JAMES W. BOCK

James W. Bock, one of the two founders of Swan's Speaker Systems, died in his sleep on the evening of May 7, 1992, after a relatively short bout with lung cancer. Jim Bock was a multitalented man having had careers as a patent lawyer, boatbuilder, restaurateur and woodworker, among others.

Bock entered the speaker field with enormous enthusiasm and extensive experience and capability in woodworking techniques. He was genuinely committed to the highest quality of music reproduction and had a lifelong love of good music, live and reproduced. He continued his commitment to good sound until his death, even visiting the winter CES is Las Vegas in the last months of his life.

With Contributing Editor Joseph D'Appolito he set up the Swan's company on Swan's Island, Maine, to market Joe's widely respected speaker and crossover designs, the most famous of which includes the M-T-M satellite configuration. The design first appeared in *SB* 4/84.

We are indebted to *The Absolute Sound* for information about Jim Bock's passing, where a letter from the present owners of Swan's Speaker Systems appeared in their July/August 1992 issue.—E.T.D.

Glad you asked that! Good Idea!

You really have some great ideas, so why not share them with your fellow readers? We love to receive typed letters (or even better, a word processor file or output) including clearly written comments and questions. Not everyone's penmanship is easily discernible—please don't make us guess.

If you are responding to a previously published letter or article, please identify it by author; it helps us research and get the answers or comments you seek. In addition, please include your full name and address on your letter in case we need to contact you (and your envelope goes south).

Direct your comments, questions, and concerns to *Speaker Builder*, PO Box 494, Peterborough, NH 03458-0494.

One more thing. . . a SASE always puts your letter on the top of the pile.

ANOTHER CONVERT

G.R. Koonce's articles inspired me to attempt an unconventional vented box. Through dumb luck, I happened to have purchased four TA3O5s (without even knowing what I had, before the Swan IV), and decided to try them in a constant pressure system. The attached results in *Table 1* and *Fig. 1* are derived from a spreadsheet which I wrote to design the box. My final box was 6,356 in.^{3} (to compensate for the volume of the Isobarik cylinder), giving me internal dimensions of 16″ × 30″ × 13.24″.

I wanted the response to be ± 1dB below 112Hz. The reason I selected 112Hz is that I built an active crossover (24dB/octave) with the crossover at 112.5Hz. That was an adventure; I have no background in electronics. I do not have the necessary test equipment to accurately determine how close the performance is to the theory, but using *Stereophile*'s second test CD and a Radio Shack sound level meter, I seem to be pretty close.

I tried a construction method I have not seen described in literature: I built a box in a box. The inner one is ¾″ particle-

World Radio History

board and the outer is ¾" oak veneer plywood. I left a ¼" gap between the two which I filled with urethane insulation foam (great stuff). However, when the foam cures, it expands. To avoid a "bowed" outer box I had to clamp it to keep the sides reasonably straight. Secondly, the thickness of the walls increased the height of the box to the point that my satellites (Bill Schwefel's "Korean Wonders," *SB* 5/90) were too high.

The front and rear baffles do not have the foam core, they are simply two pieces screwed and glued. The sides are dead. But, there is some vibration transferred to the cabinet through the front baffle. Next time, I will concentrate on isolating the drivers from the baffle.

Of course, every speaker built is "the best ever heard," but these move the walls and floor of my listening room. The space shuttle launch sequence in Chapter 4 of *The Dream Is Alive* and the first chase sequence in *Terminator 2* are impressive.

Thanks for the inspiration. I had lots of fun, and my friends, family, and guests are always impressed with the performance. This is one hobby which I am going to enjoy for years to come.

Rick Nixon
Atlanta, GA 30324

Contributing Editor G.R. Koonce replies:

I thank Mr. Nixon for his kind words. I'm glad he decided to try something a little different and also that it turned out so well. I think experimenting is one of the fun aspects of home speaker building and I definitely encourage it.

I appreciate Mr. Nixon for his warning on construction using urethane foam and encourage him to do a more complete write-up for *Speaker Builder* on his construction techniques. I believe the TA305 drivers are no longer available, making a complete construction article on his systems unwarranted, but techniques of construction are always of interest.

The compound driver (Isobarik) approach is very simple in concept, but a couple of years ago when I decided to use four inexpensive 16Ω 8" drivers in a closed-box system, practical questions did arise. How close can or must the two drivers be located? What kind of air space do you want between the drivers? How do the two drivers mount: facing each other or facing the same way?

Some of these questions were addressed in *SB* 5/90, p. 11 by Mr. Schwefel and *SB* 4/91, p. 69 by Mr. Cockroft, but it would be helpful to understand in more detail the successful approach used by Mr. Nixon. As he did, it is wise to try to cross over from the compound drivers at a rather low frequency. I mounted my 8" drivers facing the same direction with an absolute minimum spacing between the rear cone and the front driver magnet. This approach allowed me to go to 600Hz on the compound drivers without a problem. For a given closed box Q (Q_{TC} about 0.85) I believe the bass on the compound drivers is tighter and better than other normal closed-box systems I have built with about the same Q.

Again my thanks to Mr. Nixon. I hope he and others will continue experimenting and letting the rest of us know how things work out.

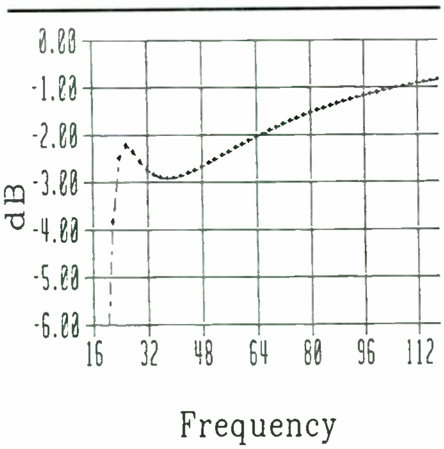


FIGURE 1: The TA305 compound driver response curve.

TABLE 1

TA305 COMPOUND DRIVER

f_S	24.5		
Q_{MS}	5.81		
Q_{ES}	0.323		
Q_{TS}	0.306		
V_{AS}	2.825 ft.²		
Power	100W		
re	5.5Ω		
Diameter	10"		
Piston	78.54 in.²		
EBP	75.85		
Vented Box			
Volume	1.416 ft.²		
Width	13.849"		
Height	22.436"		
Depth	8.587"		
f_B	30.559Hz		
f_3	34.605Hz		
H	0.113dB		
New f_3	22.000Hz		
New Volume	3.504 ft.²		6356.09 in.²
New Width	18.732"		16.00"
New Height	30.345"		30.00"
New Depth	11.614"		13.24"
New f_B	22.869Hz		
New H	-2.641dB		
Alpha	0.806	fl	13.909Hz
Tune H	0.933	fh	37.600Hz
K	0.021	2.45	
Tube Diameter	3.000"		
Tube Length	8.237"		

WHICH IS IT?

I've been reading the articles in *Speaker Builder* regarding vented boxes with great interest and I have a question.

In Robert Bullock's article "Thiele/Small Calculator Programs" (*SB* 1/83, p. 17), the author provides a formula for calculating cone displacement:

$$d = [(\omega^2/h - 1)^2 + (\omega/hQ_L)]^2]/\omega^8$$

The Bullock and White program "BOX-RESPONSE" (*SB* 1/84, p. 13) includes a formula for cone displacement to voltage ratio on page 15, line 420:

Y1 = Y × SQR [(X²/H − 1)² + (X/Q7)²/H]/X⁴

ω and x should be the same, namely $f/f_s/h^{1/2}$, am I right?

Now looking at the expressions $(\omega/hQ_L)^2$ in the first formula and $(X/Q7)^2/H$ in the second, it seems to me there is an error. Rewriting the first one with ω = X, h = H, and Q_L = Q7 gives the expression $(X/Q7/H)^2$ and that is certainly not the same.

So my question is: What is the correct expression?

Per Chr. Hansen
Stockholm, Sweden

Contributing Editor Robert Bullock replies:

I am embarassed to have to report to you that both versions of the formula are incorrect. The correct version is:

$$d = [(\omega^2/h - 1)^2 + (\omega/(hQ_L))]^2/h/w^8$$

As long as h is close to 1, this error would not affect the value of d much.

ARIA 5 REVISITED

I commend Gary Galo for his typically thorough review, (*SB* 4/92, p. 40). Unfortunately, as he indicated, the version of the ARIA 5 reviewed is now obsolete, having undergone a complete redesign. It is currently available in two versions with different tweeters: the ARIA 5TI with Focal's new titanium dome tweeter, and the ARIA 5/Accuton with the Accuton C2-11 ceramic dome tweeter.

The changes to the original design may be summarized as follows:

1. The tweeter changes mentioned above.
2. A complete redesign of the crossover for better driver integration.
3. Physical separation of tweeter and mid/bass driver crossover networks with bi-wire option.
4. An optional high-frequency roll-off network.

The ARIA 5 crossover has been greatly redesigned through careful testing and listening. The crossover frequency has been moved up from 2.5 to 3kHz. The low-pass network has also been simplified to reduce mid/bass driver phase shift, thereby improving driver integration. In my letter to Mr. Eckle (*SB* 4/92, p. 68), *Fig. 1* clearly shows the smoothness of the transition between drivers through the crossover region.

The original Focal crossover network in the units reviewed by Mr. Galo combined

Continued on page 55

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AUDIO ANTHOLOGY: WHEN AUDIO WAS YOUNG VOLUME FIVE — **BKAA3/5** **$16.95**

C.G. McProud, editor

The major theme of this collection of forty-eight articles from *Audio* magazine, published in 1958-59, is the shift from monophonic to stereo reproduction. Twenty-eight years after Blumlein patented the basic stereo idea, its practical implementation finally took place.

Chapters include: The Stereo-Plus System; Compatible Stereo Multiplex Adaptor; A Panphonic Stereo Control Amplifier; A Stereophonic Tape Recorder Control; A Compact Two-Channel Amplifier for Stereo Systems; Multichannel Audio Mixer-Preamplifier; Stereo Without Bankruptcy; For Stereo, the Bi-Ortho Circuit; Stereo Recording Techniques; The Stereo Phasing Problem; The FM Multiplex Converter; A Stereo Compatibility Translator; A Variable Stereo Suppression Control; Stereophonic Recording and Playback Amplifier; Simple Single-Cabinet Corner Stereo Speaker; FM Commercial Eliminator for Fringe Areas; Variable Electronic Crossover and Biamplifier; FM Band Reception in Fringe Areas; Integrated Audio Monitor for Home and Studio Use; Hi-Fi for Lo-Do; Realistic Audio Engineering Philosophy; Sound Reproducing Systems: Monaural, Binaural, Monophonic, Stereophonic; A Heterodyne FM Multiplex Adaptor; A Transistorized Remote-Broadcast Amplifier; Transistor Music System Using Direct Coupling; Universal Stereo Control Center; A Continuously Variable Stereo-Dimension Control; Simple Electronic Switch for Magnetic Sound System; Three-Channel Remote Amplifier; A Transistorized Hi-Fi Preamp; The New "Isodyne" Phase Splitter; Understanding dB, dBm, and VU; Simple Transistor Tester; 60-Watt Amplifier with a Silicon Rectifier Power Supply; A Complete Tone Compensator; An Improved Loudness Control; Spiral Steel Shielding for Audio Circuits; Damping Factor Chart; Puzzled About Amplifiers?; Realistic Bass Without Boom; Output Power Measurements; RC Filter Design for High-Impedance Crossover Networks; Loading the Piezoelectric Cartridge; High-Power Audio Amplifiers; A Paging Preamplifier; Radio Interference in Audio Equipment; The Decibel–Fact or Fable?; and New High Fidelity Loudspeaker Enclosure. 1992, $8\frac{1}{2} \times 11$, softbound. IN PRODUCTION; PLEASE CHECK AVAILABILITY.

AUDIO ANTHOLOGY SPECIALS!: Also available in sets BKAA3/X3, BKAA3/X4, and BKAA3/X5.

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THE TUBE AMP BOOK, VOLUME THREE — **BKGT1** **$27.95**

Aspen Pittman

This long-awaited third edition of the Groove Tubes classic contains hundreds of pages of amp diagrams from more than two dozen manufacturers. In addition to the use of color photos, coverage of mods, maintenance, and history also add interesting and valuable dimensions to the book. If you love tube guitar amps, this book is for you. 1991, 700+pp., softbound.

RÖRFÖRSTÄRKARE — **BKEF1** **$39.95**

Jean Hiraga

This hard-to-find book, edited by the renowned audiophile, is a true treasure trove of tube amplifier information. It is written completely in Danish, but fortunately (for English-language readers) the text occupies only about 20% of the book. The remainder contains literally scores of photos, schematics, drawings, spec sheets, and charts, all thoroughly delightful to peruse. Dynaco, Marantz, and MacIntosh are but a few of the familiar faces to be found in this volume. France, 1986, 150pp., $8\frac{1}{4} \times 10\frac{5}{8}$, softbound.

ELECTRONIC PROJECTS FOR MUSICIANS — **BKAM1** **$24.95**

Craig Anderton

This comprehensive guide, now revised and expanded, shows you how to build your own preamp, compressor/limiter, ring modulator, phase shifter, and talk box, as well as twenty-two other inexpensive electronic accessories. Written in clear language, with simple step-by-step directions and hundreds of helpful diagrams and illustrations. Also includes a $33\frac{1}{3}$-rpm soundsheet for demonstrating electronic effects, as well as a glossary. 1975, 1980, 220pp., $9 \times 11\frac{7}{8}$, softbound.

ELECTRONIC TECHNIQUES: SHOP PRACTICES AND CONSTRUCTION — **BKPH3** **$54.95**

Robert S. Villanucci, et al.

Joined by fellow Wentworth Institute of Technology compatriots Alexander W. Avtgis and William F. Megow, Villanucci has written an excellent hands-on approach to training technicians in all aspects of electronic design and fabrication techniques, demonstrating current solid state devices and using a stereo amplifier system as a motivating example throughout. New chapters in this fourth edition cover surface mount technology and computer-aided design (CAD) of printed circuit boards. An extremely thorough presentation, covering all possible aspects of electronics construction and assembly, presented in textbook style. Appendices, Bibliography, Index. 1991, 591pp., $8\frac{1}{2} \times 11\frac{1}{4}$, hardbound.

INTRODUCTORY OPERATIONAL AMPLIFIERS AND LINEAR ICs: THEORY AND EXPERIMENTATION — **BKPH4** **$49.95**

Robert F. Coughlin, Robert S. Villanucci

This practical text/workbook presents state-of-the-art op amp and more complex linear integrated circuit techniques, complete with illustrative examples. Also included throughout are labs and manufacturers' data sheets. Certainly one of the best teaching tools available for this subject matter. 1990, 460pp., $8\frac{1}{4} \times 11$, softbound.

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UNDERSTANDING & INSTALLING HOME SYSTEMS: HOW TO AUTOMATE YOUR HOME — **BKDG1** — **$29.95**

David R. Gaddis

Now in a second edition, this handbook is designed to provide information that will help the reader to understand and install various home systems, as well as make his own decisions about home automation. In addition to giving standard how-to advice, the author also includes recommendations on materials and suppliers. Chapters include Basic Information, Installing Electrical Wiring, Home Security Systems, Lighting & Appliance Controls, Audio/Video Systems, Telephone & Communication Systems, Environmental Control Systems, and Automation System Controllers. Bearing in mind that this book emphasizes system theory and design rather than step-by-step construction, it is one of the most complete books of its type available anywhere. 1991, 140pp., 8½ × 11, softbound.

BROADCAST SOUND TECHNOLOGY — **BKB9**

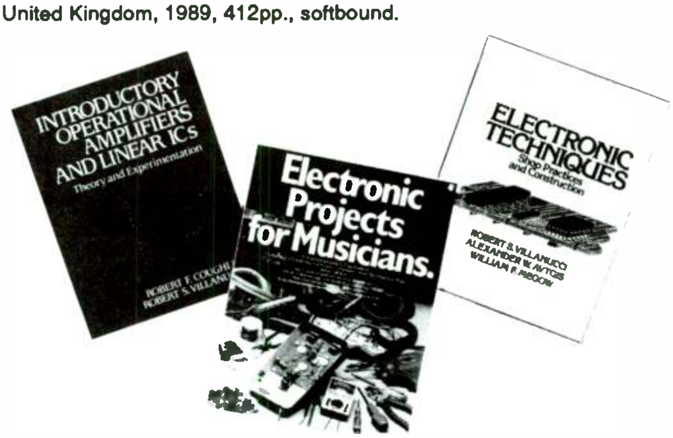
Michael Talbot-Smith — **$44.95**

This comprehensive and easy-to-read account of modern audio technology covers the main items in the broadcast chain: studio acoustics, microphones, loudspeakers, mixing consoles, recording and replay (analog and digital), and the principles of stereo. Chapters include Basic Sound, The Behavior of Sound Waves, Aspects of Hearing, Harming and Charming the Ear, Room Acoustics, Reverberation, Microphones, Phantom Power, Loudspeakers, Basic Stereo, Monitoring the Audio Signal, Processing the Audio Signal, Sockets and Symbols, Sound Desks (Mixing Consoles), Digital Audio, Further Digits, Analog Tape Recording and Reproduction, Digital Recording and Reproduction, Noise Reduction, Public Address, More Uses of Digits, and Further Reading. 1990, 212pp.

MEASURED TONES: THE INTERPLAY OF PHYSICS AND MUSIC — **BKAH1** — **$34.95**

Ian Johnston

From the School of Physics at the University of Sydney, the author takes a nonmathematical look at the physics involved in music, to show that by linking these two subjects, enjoyment of music can be increased–as well as the understanding of physics. Using a completely fresh approach, the physical concepts are developed together with the musical applications and historical development of music. The physical principles underlying music are explained using analogies and examples, rather than mathematical reasoning. Anyone with an interest in music will find that an appreciation of the physics will add to his enjoyment of music. United Kingdom, 1989, 412pp., softbound.



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Tom Mitchell

This program includes a fact-filled, illustrated, easy-to-read guidebook and a 75-minute VHS color videotape. Written in an informal, nontechnical, and entertaining style, the book takes readers on a step-by-step "crash course" in electronics while teaching troubleshooting, servicing, and problem prevention. The videotape helps to drive home key points from the text, demonstrating procedures and illustrating the use of hand tools and test equipment. Contents include an introduction to basic electronics; recognizing electronic components; in-depth coverage of tubes and transformers; detailed coverage of speakers and enclosures; amplifier circuit basics; demystifying biasing; tool and test equipment selection and use; using schematic diagrams; troubleshooting with voltage charts; how not to use an amplifier; voltage charts for most common amplifiers; ten troubleshooting flowcharts; tables and illustrations for international AC; many amplifier modifications; maintenance checklist for troublefree operation; and much useful reference information. Vinyl carrying case for book plus videotape is extremely handsome and durable. 1991, 250pp., 8½ × 11, spiralbound.

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Continued from page 51
both low- and high-pass sections on a single board with common ground traces. Later testing of this network revealed strong cross-coupling of low-frequency woofer signals into the tweeter, with low-frequency attenuation of tweeter drive levels limited to 27dB. The resulting leakage of low-frequency energy into the tweeter greatly aggravated tweeter distortion. The new network mounted on separate low- and high-pass section boards independently wired to the speaker terminals (or, better still, bi-wired) produces low-frequency attenuations in excess of 60dB, completely eliminating this source of coloration in midrange sound.

The original ARIA 5 was designed for flat on-axis response all the way out to 18kHz. Many CD recordings are especially hot in the last octave and can be quite irritating with this type of response. An option has been added to the latest ARIA 5 crossovers which provides a gradual rolloff above 10kHz, amounting to almost 3dB at 20kHz. Although I believe such problems should be corrected at the source, many other designers feel all systems should be built with such a rolloff. The ARIA 5 builder now has the ability to consciously make this choice.

The ARIA 5 in its present form represents a mature design. Hundreds of systems have been built, and the response I get has been both positive and enthusiastic. For a very different view of the current ARIA 5, see Tom Oldfield's letter beginning on page 82 of *SB* 5/91.

Joe D'Appolito
Contributing Editor
Andover, MA 01810

OF CROSSOVER OP AMP SOUND

In response to Wayne Horner's letter, I was asked about the sound of various op amps in my crossover ("A Loudspeaker with Active Crossovers and Delay," *SB* 1/92, p. 36). I would first like to say that I have never found an op amp that sounds as open and natural as a good tube stage. However, many op amps don't get as hot or need high voltages. Besides, while it is possible to implement this crossover with tubes, it would be rather "tube intensive" and not as easy for most people to build. I also use these speakers with a first-order tube crossover (at 3kHz instead of 1.5kHz) and tilt the cabinet back slightly. This has a more open but less spacious sound. The tubes are used basically as buffers to make adjusting the tweeter level easier.

Anyway, I built an A/B comparator and used separate regulated power supplies and a noninverting gain of ten and also of one (as a buffer, as in the crossover). I considered dual op amps because of the application and to keep the number of op amps tested somewhat practical.

The best (dual) op amp I have found so far is the Burr Brown OP 2604. These are, however, difficult to obtain in small quantities. Perhaps Old Colony would consider stocking them. While the differences in sound from op amps are subtle, they do exist. Using a good source and classical music with few instruments can reveal a change in timbre. Sonic differences with op amps are application dependent: Consider the power supply, circuit configuration, and load conditions, among other things. And then you must listen. *(Be sure to limit your music sources to a few, and stay with those same few for testing.)—Ed.*

Interestingly enough Burr Brown, Linear Technology, and Analog Devices have started claiming certain op amps "sound good." Linear Technology maintains their LT1115 (a single) offers a "dramatic improvement in sound quality" over "older audio op amps." Analog Devices' new OP 275 chip, which the company claims "sounds good," is dual unity gain stable and costs only 95¢ in 100s. According to the data sheets, this part works best at higher supply voltages, ±20 as opposed

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to ±15 or even ±18. Newark Electronics, (312) 784-5100, now offers Analog Devices' products. I haven't tried these two (LT1115, OP 275) yet. These days a huge number of new op amps are available.

At a recent Analog Devices' seminar, the speaker joked about how marketing had changed "sounds good" for the OP 275 into "excellent sonic characteristics." Burr Brown (talking about the OP 2604) mentions in their data sheet that a possible reason for the sound quality might be "that bipolar designs generate greater odd-order harmonics than FETs."

As an aside, when designing I-V converters for CD players, try out some current feedback op amps. Companies like Analog Devices, Burr Brown, Comlinear, Elantec, LT, Harris, and others make these. Some of these sound very good and have incredible slew rates, on the order of 1kV/μS. Pay special attention to your power supply bypassing with these. Faster is not easier. They are not appropriate for every application either, especially those with feedback capacitors.

Other "popular" op amps included were the 5532, AD712, LT 1057, OP227 (dual OP27), LF351, LF353, TL072, HA2541, MC34082, etc. In some cases, the metal-cased version sounded better. The OP 2604 sounded the smoothest and most natural of the bunch, and can be used with supply rails up to ±24V DC (maximum). Happy listening!

Mike Somers
Chicago, IL 60657

HAVE A BISCUIT

Regarding Mark Florian's article on cabinet construction, "A High Quality Speaker Enclosure," *SB* 3/92, p. 14), why did he choose to biscuit the vertical panel-to-oak edge connection (*Fig. 1*, p. 14) while using tongue-and-groove for the horizontal connection? I am working on a similar project and intend to use biscuits throughout. Is there an advantage to the t & g?

Thanks for a great article.

Les Winter
New York, NY 10003

Mark Florian replies:

Before building the speakers described in my article, I consulted another source ("Modular Coffee Table and Bar," *The Woodworker's Journal*, Jan/Feb 1985, pp. 50–53) which discussed using continuous plywood splines in place of biscuits. I decided to use biscuits in my project because they are easier to work with and the joints are self-aligning. The *TWJ* article used a tongue-and-groove joint and I decided to retain it here for the Swans. If I were to use biscuits in both places, I would need to offset them so as not to cut a horizontal and vertical slot in the same place, otherwise the lower right-hand corner of the oak hardwood would be removed and ruin the integrity of the joint (*Fig. 1*). The combination of biscuits and tongue-and-groove joints worked well due to the small size of the hardwood.

RIGHT ANSWER

Is it possible to modify the "Mitey Mike" output circuit to convert from AC to DC? Recording DC potentiometers are readily available at relatively low cost; recording AC units are both rare and expensive. The ability to record output makes spectrum analysis an automatic operation.

Clive E. Sadler
Dover, DE 19903

Contributing Editor Joe D'Appolito replies:

It makes much more sense and would be simpler to add a wideband rectifier to your chart recorder than to modify the Mitey Mike. This addition would give you a versatile instrument useful for all types of AC measurements.

Microphones are inherently AC output devices. In addition to frequency response measurements,

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124pp., softbound

HEATH NOSTALGIA by Terry Perdue

Millions of people worldwide have enjoyed the special experience of assembling a quality Heath product with their own hands, and often learned something useful in the process. And many a youngster went on to pursue a career in the electronics field due to an interest sparked by a Heathkit. As we know, Heath has recently announced that it is going out of the kit business. Still, many people have fond memories of their Heathkit experiences and will enjoy renewing them through this book, as well as learning more about the company's heritage. With 24 pages of photos, *Heath Nostalgia* will be an addition of timeless value to any bookshelf.

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you can—if you have a scope and signal generator, for example—observe speaker response to various waveforms. Using tone bursts you can observe your system's max SPL capability before overload or clipping. Many *SB* readers use Mitey Mike with Siegfried Linkwitz's ⅓-octave tone-burst generator for quasi-anechoic response measurements. You can also record with it. Converting Mitey Mike to a DC output would greatly limit its utility.

Because Mitey Mike output is in the millivolt to tens of millivolts range, an active op amp type rectifier circuit is required. If you wish it to be effective over the entire audio band, you'll need a wide bandwidth unit. Putting this circuitry on the Mitey Mike board seems like an unnecessary complication and it would also more than double battery drain.

On the other hand, it would be relatively straightforward to add an op amp-based, wideband AC rectifier outboard of your recording potentiometer with an appropriate power supply run off the AC mains. Op amp-based rectifier circuits are widely published in the applications literature supplied by the manufacturers.

QUASI SECONDS

Randall Bradley's experience with the "Quasi Second-Order" crossover ("Tools, Tips & Techniques" *SB* 3/92, p. 64) led me to investigate further. He said "the crossover behaved differently depending on the load presented. It was a true crossover chameleon." This is true for any passive crossover. Bradley didn't state whether his drivers had impedance correction or not. Other factors to consider would be the drivers natural acoustic rolloff and driver offset. All of these (plus others) must be considered to arrive at the actual acoustic response.

Using a "Quasi Second-Order" crossover with a Zeta of 0.5, I ran it through a computer program similar to PSPICE. The crossover frequency is 2kHz and the load is 8Ω. *Table 1* is the frequency and phase response of the low-pass section. *Table 2* is the high-pass and *Table 3* is the summation of *Tables 1* and *2*. In *Table 1*, the response is only down −8.13dB at 4kHz instead of the −12dB predicted by Kaminsky. In fact, the rolloff rate continues at about −8dB/octave for several more octaves.

In the paper presented by Ashley and Kaminsky, *Fig. 8* seems to bear this out. How they arrived at an initial rolloff of −12dB/octave, I don't understand. Also notice the rise in output of each section to 1.8dB. *Table 3* shows that it does sum flat if you have pure resistive load drivers, have no offset, and have flat frequency responses extending two octaves or more on either side of the crossover frequency. No problem, right? As Bradley discovered, the "Quasi Second-Order" is difficult to use with "real world" drivers.

For those interested in experimenting with this crossover, I have included the formulas to determine L & C when Zeta is 0.5.

$$L = (Z \times T_o)/2 \quad C = (T_o/Z)^2$$

Where $T_o = 1{,}000{,}000/(2 \times 3.1415 \times F)$ and L = μH and C = μF.

David Long
Dalton, GA 30721

Randall Bradley replies:

Let me try to clarify my position regarding these "Quasi Second-Order" crossovers. The point I was attempting to make is: As presented, the crossovers do not behave in a way which can be predicted solely from the Ashley and Kaminsky chart, computer generated or not. That means that grabbing two "8Ω" speakers off the shelf or from the catalog, and picking crossover component values from the Ashley and Kaminsky *JAES* article will almost certainly *not* give you a 12dB/octave *slope* crossover.

Unless all the complex driver and system parameters are known and reduced to a valid electrical and mathematical model, any computer predictions generated may not be quite so accurate. This is one good reason for always testing the real speaker and then listening to it.

In these discussions, I refer only to the electrical characteristics of the crossover filter sections. The combined electrical/acoustic response almost certainly needs separate consideration.

Continued on page 59

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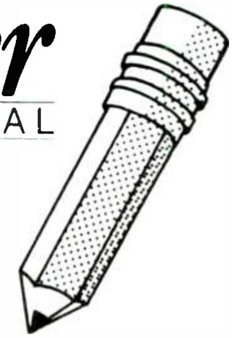

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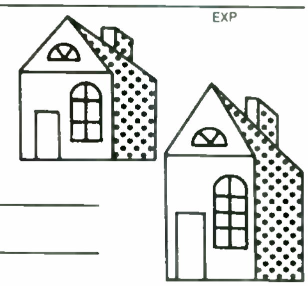

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Continued from page 57

The assertion that *any* passive crossover behaves in the same manner as this series quasi 12dB crossover is, in my opinion, incorrect. While crossover frequency will change with load impedance variation, I don't know of any parallel passive crossover that changes in *slope* as well as frequency as a function of load impedance. Perhaps I've simply missed something in the literature about this.

It is clear that the relationships in the quasi 12dB between Zeta, the component values you select, and the load is very critical. My point is in the real world, this relationship is difficult to predict, can-

TABLE 1

LOW-PASS FREQUENCY & PHASE RESPONSE

FREQUENCY Hz	AMPLITUDE dB	PHASE DEGREE
250	0.08	– 3.7
375	0.19	– 5.6
500	0.33	– 7.8
625	0.51	– 10.2
750	0.71	– 13.0
875	0.93	– 16.1
1,000	1.17	– 19.7
1,125	1.39	– 23.7
1,250	1.59	– 28.4
1,375	1.73	– 33.5
1,500	1.80	– 39.2
1,625	1.77	– 45.2
1,750	1.62	– 51.4
1,875	1.35	– 57.5
2,000	0.97	– 63.4
2,125	0.49	– 68.9
2,250	– 0.06	– 73.9
2,375	– 0.67	– 78.4
2,500	– 1.31	– 82.2
2,625	– 1.96	– 85.6
2,750	– 2.61	– 88.4
2,875	– 3.25	– 90.9
3,000	– 3.87	– 92.9
3,125	– 4.48	– 94.7
3,250	– 5.07	– 96.2
3,375	– 5.63	– 97.4
3,500	– 6.17	– 98.5
3,625	– 6.69	– 99.4
3,750	– 7.19	– 100.1
3,875	– 7.67	– 100.8
4,000	– 8.13	– 101.3
4,500	– 9.79	– 102.7
5,000	– 11.20	– 103.2
5,500	– 12.43	– 103.3
6,000	– 13.51	– 103.1
6,500	– 14.47	– 102.8
7,000	– 15.34	– 102.5
7,500	– 16.12	– 102.1
8,000	– 16.83	– 101.6
8,500	– 17.49	– 101.2
9,000	– 18.09	– 100.8
9,500	– 18.66	– 100.4
10,000	– 19.19	– 100.0
10,500	– 19.68	– 99.7
11,000	– 20.15	– 99.3
11,500	– 20.59	– 99.0
12,000	– 21.01	– 98.7
12,500	– 21.41	– 98.4
13,000	– 21.78	– 98.1
13,500	– 22.15	– 97.9
14,000	– 22.49	– 97.6
14,500	– 22.83	– 97.4
15,000	– 23.15	– 97.2
15,500	– 23.45	– 97.0
16,000	– 23.75	– 96.8

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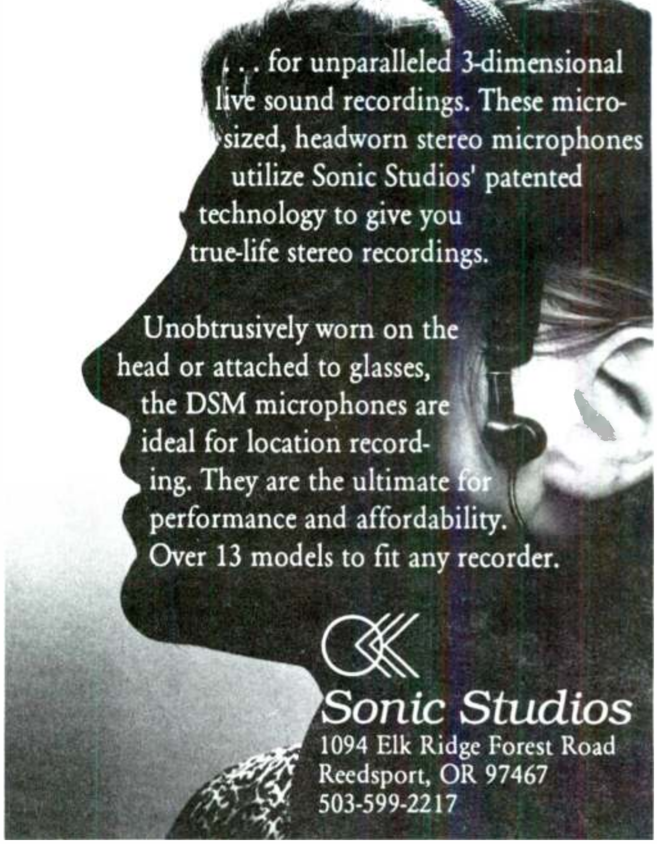

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TABLE 2

HIGH-PASS FREQUENCY & PHASE RESPONSE

FREQUENCY Hz	AMPLITUDE dB	PHASE DEGREE
250	−23.75	96.8
375	−19.84	99.6
500	−16.83	101.6
625	−14.29	102.9
750	−12.04	103.3
875	−10.00	102.8
1,000	− 8.13	101.3
1,125	− 6.41	98.9
1,250	− 4.84	95.6
1,375	− 3.42	91.5
1,500	− 2.17	86.6
1,625	− 1.11	81.1
1,750	0.23	75.3
1,875	0.45	69.3
2,000	0.97	63.4
2,125	1.33	57.9
2,250	1.57	52.8
2,375	1.71	48.1
2,500	1.78	44.0
2,625	1.80	40.3
2,750	1.78	37.1
2,875	1.74	34.3
3,000	1.69	31.8
3,125	1.63	29.6
3,250	1.56	27.6
3,375	1.49	25.9
3,500	1.42	24.4
3,625	1.35	23.0
3,750	1.29	21.8
3,875	1.22	20.7
4,000	1.17	19.7

TABLE 3

SUMMATION OF FREQUENCY & PHASE RESPONSE

FREQUENCY Hz	AMPLITUDE dB	PHASE DEGREE
250	0.0	100.5
375	0.0	105.2
500	0.0	109.4
625	0.01	113.1
750	0.0	116.3
875	−0.01	118.9
1,000	0.0	121.0
1,125	0.01	122.0
1,250	0.0	124.0
1,375	0.0	125.0
1,500	0.0	125.8
1,625	0.0	126.3
1,750	−0.01	126.7
1,875	0.0	126.8
2,000	0.01	126.8
2,125	0.0	126.8
2,250	0.0	126.7
2,375	−0.01	126.5
2,500	0.0	126.2
2,625	0.0	125.9
2,750	0.0	125.5
2,875	−0.01	125.2
3,000	0.0	124.7
3,125	0.0	124.3
3,250	0.0	123.8
3,375	0.0	123.3
3,500	0.0	122.9
3,625	0.0	122.4
3,750	0.0	121.9
3,875	−0.01	121.5
4,000	0.0	121.0

not be assumed, and therefore requires empirical testing.

As you point out, the closer your drivers get to presenting a pure resistive load, the closer they'll be to the predicted values of crossover network response. So, impedance correction and/or Zobels might provide the advantage of bringing performance closer to the ideal.

In fact, this basic configuration of a coil and a capacitor in series with a tweeter across the coil and a woofer across the cap is found most often as a 6dB/octave (first-order) series crossover, not a 12dB/octave (second-order). This is why the crossover is a "chameleon."

If memory serves, the article mentioned that the 12dB slope was only over a very small area, and was associated with the peaking effect your calculations correctly showed. A clue to this unique quasi 12dB crossover's behavior and slope might be found in your tables.

Without taking the time to review the original article, your equations and the actual computer program used, I can only assume your simulation results are valid. Your tables show a maximum phase shift of about 100°. Normally, a 12dB/octave filter is expected to exhibit a 180° shift. Perhaps this 100° phase shift explains why you only measured about an 8dB/octave slope over most of the curve.

REFERENCE

1. Ashley, J. Robert and Allan L. Kaminsky, "Active and Passive Filters as Loudspeaker Crossover Networks," 39th Convention of the Audio Engineering Society, New York, October 12, 1970.

In any event, this crossover is a "best buy" when it comes to combining simplicity of alignment between two drivers, and lowest parts count per crossover "order." So, it bears some consideration, especially when parts are dear. But so far, I have not liked the way that it sounds. However the potential is still there.

Anyone for figuring out how to do a quasi 24dB/octave crossover? Is it possible?

DRIVING TLs

I have been reviewing Craig Cushing's article ("A More Compact Transmission Line Subwoofer," *SB* 1/87, p. 9) because I plan to build a pair of his enclosures. Would Meniscus Eclipse 10" drivers be a workable alternative? (I have a pair of these already that are performing well in Galo TL-10 enclosures (*SB* 1/82, p. 7 & 2/82, p. 20). Would the reduction in cone area of this driver be a problem due to the critical nature of line cross-section?

Michael Short
Hazel Green, AL 35750

Craig Cushing replies:

Use the Meniscus Eclipse 10" driver in my design as is—no cabinet modifications are needed at all. In fact, I've experimented with a low-resonance-frequency 8" driver in the same box with excellent results. With most intelligently-designed TLs, if you don't crowd the line with a driver whose cone area

World Radio History

exceeds the early cross-section of the line proper (not the area immediately behind the driver), it should work fairly well, and usually better than that.

A BIGGER CONE

Although Mr. Sanders did not direct his letter to me ("Efficiency Alignments," Mailbox, *SB* 3/92, p. 79), I have some comments to add. Since my article "Symmetrical Loading for Auto Subwoofers" (*SB* 6/90, p. 20), I have built six more bandpass subwoofers for my vehicles and believe I may offer additional insight on Mr. Sanders' goals.

To raise the reference efficiency of a given driver, you can reduce the mass of the cone, raising its resonance as well. Or, you can add more magnet (flux) to increase efficiency while lowering the speaker's Q_T. Lastly, you can increase the "grip" on the air by making the cone larger. Both the light cone and the big magnet will unfortunately raise the F_S/Q_T value and make a poor sealed bandpass system. A larger driver, or multiple drivers, will give you a higher efficiency but at the expense of a large enclosure.

Using a loudspeaker modeling program, I found the reference efficiency of a given bandpass system continues to rise until it closely emulates a resonant pipe. My program depicts the limit at about +14dB, but the resulting bandwidth is essentially worthless. More importantly, these conditions reduce the loading on the driver and the excursions become a problem.

Several available programs predict normalized responses for various enclosure alignments on a screen or printer. Speak-Easy [46 Cook St., Newton, MA 02158, (617) 969-1460] sells an excellent program that models many types of designs and performs multiple iterations simultaneously for comparisons. These powerful programs provide the only practical means for home experimenters to achieve successful bandpass designs.

My project was based on a sealed-bandpass design which I believe still sounds the best for home systems. For the car, however, I now advise vented systems for their enhanced efficiency and far greater power handling capability. For example, I have modeled the responses and relative excursions for both a sealed and vented bandpass systems (*Figs. 1* and *2*). The enclosure and driver is the same for both plots; the only difference is I added a series vent between the two enclosure cavities.

For the record, the driver is an old Speakerlab 5″ woofer. The Q_T measured 0.67, F_S is 66Hz, and V_{AS} is 0.18 ft.^{3} The model is 0.2 ft.^{3} per cavity; the output vent is tuned to 90Hz, the series vent to 45Hz. The subwoofer in my Voyager uses dual drivers in push/pull and a slightly revised alignment for deeper response. When I initially tested it as a sealed sys-

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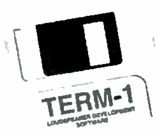

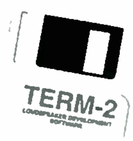

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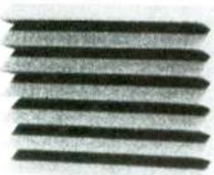

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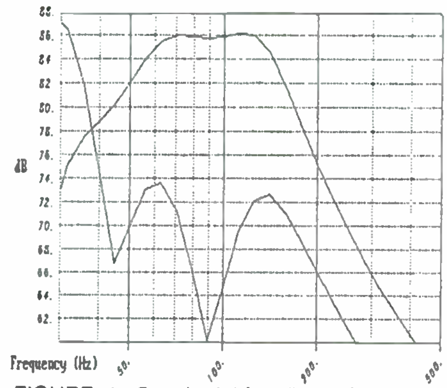

FIGURE 1: Speakerlab's 5″ woofer series vented bandpass.

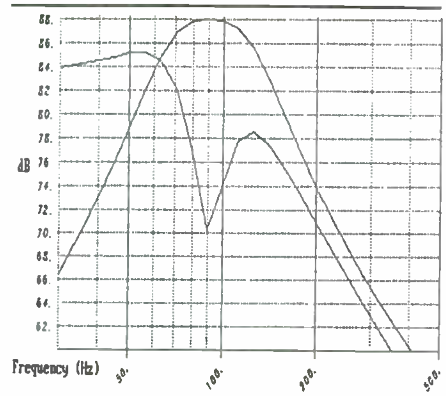

FIGURE 2: Speakerlab's 5″ woofer sealed bandpass.

tem, the cones bottomed very easily. Adding the series vent increased the power output immensely with plenty of thump.

A few practical notes include: For multiple drivers of the same type, simply multiply V_{AS} and all box volumes by the number of drivers; keep Q_T, F_S, and vent frequencies the same. Programs provide only approximations for the actual vent dimensions; you still must tune them. While the output and dual vents are usually very close, a series vent is way off. You may tune via impedance troughs, although an S-Y scope is far more accurate and faster.

I have found that net volumes are close enough and I compensate for the vent, driver, and braces. For driver volumes, I measure the dimensions and calculate cone, magnet, and cutout volumes. If you do not use an electronic crossover in conjunction with the power amplifier, considerable midrange output will be present along with the bass. Line the output cavity with foam or fiberglass; it also helps to aim the port away from the listening position. If you overlook this step, imaging suffers.

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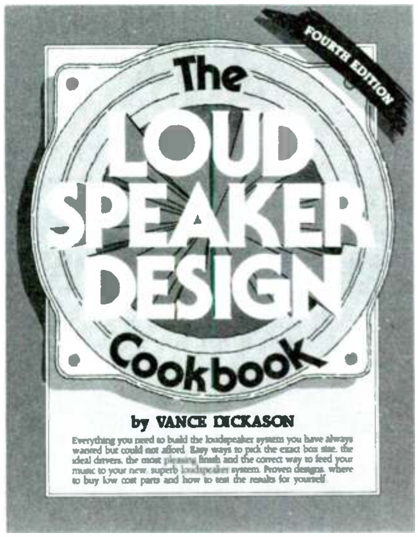

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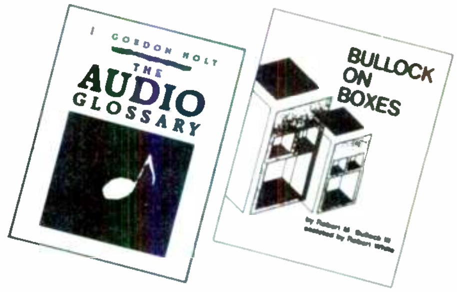

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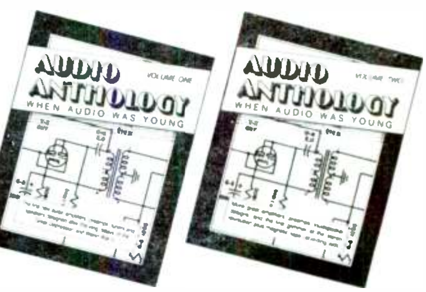

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information on bandpass boxes. Mr. Margerand provided tables in his article "The Third Dimension: Symmetrically Loaded," (*SB* 6/88, p. 29). I am trying an alignment which apparently is outside the limits of his tables. He clearly generated these tables using his computer. Therefore, somebody must have the formulas used to compute these values. As an alternative, it may be possible to construct the formulas from the information in his articles. In the sidebar on page 30, he provided an almost complete discussion of the theory. Below the response graph, he includes several formulas including $p = j\Omega$. I just can't seem to find any reference to "j."

R. A. Nixon
Atlanta, GA 30324

UP, DOWN, ALL AROUND

The article on damping factor ("Damping Factor Reviewed," Galo, *SB* 3/92, p. 26) was very informative, but I'm having trouble figuring out my amp source impedance because I have a 4Ω speaker. The amp has a 100 damping factor at 8Ω. Does this go up or down with a 4Ω load? Could you tell me what the damping would be for a 4Ω load? Does it remain at 100?

Lance Weller
Mount Lake Terrace, WA 98043

Contributing Editor Gary Galo replies:

Damping factor decreases as the loudspeaker impedance goes down. Most amplifiers specify damping factor into an 8Ω load. If an amplifier has a DF of 100 into 8Ω, then the DF will be 50 into 4Ω. The ratio of 8:100 is the same regardless of the load. If the loudspeaker impedance is cut in half, the DF is also cut in half. Double the loudspeaker Z and you also double the DF.

OUTRAGEOUS

Having built hundreds of speaker systems for friends and customers, I have had to deal with some unusual requests. The latest one was for a speaker system that would sound as close as possible to a live heavy metal concert. It was obvious that over-designed ported 8" or 10" woofer systems would not do, so I brought in the big boys.

Some of the constraints were box size and over-all costs. The box size had to be no bigger than 3.5'^{3}. I chose a closed box and Q_{TC} of 1.1 and I wanted f_3 around 30Hz. Looking through the catalogs for likely woofer candidates in the 15" or 18" range, it became increasingly apparent I was faced with an impossible mission. Then, while flipping through an OREVOX

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catalog, I found it—an 18″ woofer with 125 oz. magnet, 3″ voice coil, 400W$_{RMS}$/800W peak, and sensitivity of 98dB @ 1W/1M. The most important specs were just right: F_0 of 15Hz, V_{AS} of 9.738, Q_{MS} of 5.240, Q_{FS} of 0.485, Q_{TS} of 0.444.

A quick look at the charts showed that for Q_{TC} of 1.1 alignment the box size needed to be 1.957 ft.³ The F_C would be 36.666Hz and the f_3 would be 27.745Hz. (I used *The Loudspeaker Design Cookbook*, 4th Ed., by Vance Dickason.)

So there you have it! 18″ woofer, box size of 2 ft.³, f_3 of 28Hz, with high sensitivity and high power to go along with it.

Of course I made the box a little bit bigger to make up for volume losses due to bracing and the volume of the huge driver itself. I made the internal dimensions of the box 18.5″ × 30″ × 11″, which comes to 3.53 ft.³

Construction was straightforward. I used ¾″ MDF, butt joints, and lots of glue and screws. For bracing, I used 2″-wide MDF scrap (two braces lengthwise on the back and two braces front to back, one above and one below the woofer, which was mounted approximately in the middle of the baffle).

I am leaving crossover design, mids, and tweeter combinations up to the prospective builder, since the possible combinations are too numerous to describe. In my case, I am using two 3″ dome mids and a 1″ dome tweeter (OREVOX MD 7509T and Morel MDT28). Crossover is second-order 750/5000. The mids and the tweeter are mounted on a separate pedestal that sits on top of the woofer boxes.

How does it sound? Crank up PANTERA with a couple of hundred watts and stand back!

For those who wish to build this project, order WC 18125 woofer(s) from OREVOX, 248 North Puente Ave., City of Industry, CA 91746, (800) 237-0700.

Peter P. Manchev
Oklahoma City, OK 73135

MAC REVIEW VAC

I'm finally ready to invest in a speaker design program, but think I'm working from a position of ignorance. I am a Mac user, and would prefer not to buy into a whole new technology. I always shop through the ads in *Speaker Builder* and read the reviews, but this is a piecemeal approach at best. Even a review per issue, useful as that would be, would leave us ever further behind the rapid progress in the field.

In view of the massive interest in these products by your subscribers, would you consider a survey article (or articles: PC and Mac) that would help us deal with this most important purchase in an informed manner? I realize *SB* is no *Consumer's Guide*, but at this point CAD is the

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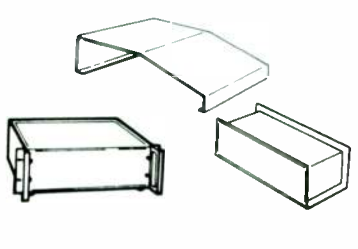

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HEAD TO HEAD

I must take issue with the accuracy of a few of Gary Galo's comments in his review of *The Audio Glossary* (*SB* 2/92, p. 32). For example, he lauds the book for its definition of RMS, but the book's definition and Galo's commentary give erroneous and misleading info. First, the book states that RMS is "the square root of the average of two or more squared values." It would be more accurate to say ". . . one or more squared values," even though for just one value, the RMS is of course the same as the value itself.

Even worse, he states (and claims the book does also) that RMS "equals the peak value multiplied by 0.707." I have two problems with this statement: First, although the RMS value of a sine wave is indeed 0.707 of its peak, this is not true of most other waveforms, of which there are an infinite number. *(This latter is, I remind readers, an unprovable assumption on Mr. Sharpe's part.)—Ed.*

Second, one must ask, "The value of what?" Galo means the value of a continuous and repetitive waveform, though he doesn't state it. His confusion reveals another problem with *The Audio Glossary*'s definition. The definition refers to values, which in the definition's context, means discrete numbers, and a waveform is a continuous signal. In the audio field (with the exception of digital signal processing), RMS is usually discussed in relationship to continuous signals and not discrete values. Thus for the book to define RMS in terms of such values will do nothing but confuse the reader. Gary describes this definition as "well done." Half-baked is more like it.

Galo also likes the book's definition of sound. I don't. It is so simplistic as to be uninformative and almost tautological. By defining sound as nothing more than air vibration you can hear, the book gives no richness or intuition as to the physical or perceptual nature of sound. Instead it states what most fourth graders know.

Galo also commends the book for its definition of current flow. This definition unfortunately gives evidence of what must be author Holt's ignorance of science and math. Holt seems to believe that because electrons flow from negative to positive, defining current as flowing from positive to negative is somehow wrong. First of all, other particles besides electrons can carry current. Some of them have positive charge (e.g. positive ions), and travel from positive to negative. What neither Holt nor Galo seems to understand is that the *definition* of current is, in part, a mathematical abstraction of a physical phenomenon: The direction of its flow can be described arbitrarily as long as the signs of other physical constants are defined so as to be consistent.

In general, Galo's review misses the mark and Sutheim's review (*TAA* 1/91, p. 35) is more accurate and reliable. I hope I have not been too "nitpicky," but so much misunderstanding of scientific issues among the general public abounds that those endeavoring to write reference material must use great care and rigor when using and defining technical terms.

Tom Sharpe
Bedford, MA 01730

Contributing Editor Gary Galo replies:

In his definition of RMS, Holt clearly states that 0.707 times the peak value refers only to sine waves. (Has Mr. Sharpe actually read the book, or is he relying strictly on my comments to form an opinion?) Given that, Holt is correct in stating that two or more squared values must be involved. A discussion of the RMS values of complex waveforms was beyond the scope of his concise definition, and I personally do not have a problem with that. I think Mr. Sharpe is really nitpicking when he criticizes me for not specifically stating that the waveform is continuous and repetitive. Given the scope of the definition, I don't think this is necessary. Besides, to identify the peak, average and RMS values of any *symmetrical* wave form, one only needs to look at *one-half* of one complete cycle.

Regarding my enthusiasm for Holt's definition of sound, Mr. Sharpe seems to have missed my point: A listener isn't required in order for sound to exist. Mr. Holt addresses this nicely. Again, this is a short, concise definition, and is not intended to be a complete tutorial on the subject. For a bit more insight, readers may wish to look up Holt's definitions of *compression*, *rarefaction*, *frequency*, *pitch* and *loudness*.

Regarding current flow, the teaching of "conventional current flow" gets in the way of a practical understanding of how electron devices operate. The movement of positive ions is of little use in practical audio electronics. I wrote at length about this subject in my column, "Ask TAA," (*TAA* 2/90, p. 47). The respected engineering sources I quoted admit we now know conventional current flow to be incorrect, but we're stuck with it due to decades, if not centuries, of use. Insufficient space here prevents repeating my defense of this position. Instead, I'll refer interested readers to the aforementioned column.

Mr. Sharpe has missed the point of Holt's book. To paraphrase Anna Russell, from her marvelous analysis of Wagner's *Ring*, Holt's isn't a book written "by some great expert for the edification of other great experts." It is a glossary written by someone known for his ability to explain audio terminology in language lay readers can understand. His in-

Continued on page 68

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SpeakerBuilder

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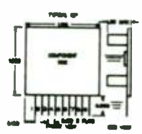

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tended audience are readers of *Stereophile*, *The Absolute Sound*, and other magazines which review audio equipment. These people have little technical background, but wish to understand the terminology used in equipment reviews. If each definition were of sufficient scope to satisfy Mr. Sharpe, *The Audio Glossary* would consume volumes.

I certainly never implied that *The Audio Glossary* would be the last word on technical matters. Readers will eventually move on to sources offering more in-depth analyses of these topics. Glenn D. White's *The Audio Dictionary* (*SB* 3/92, p. 69) is an excellent companion, offering a logical "next step" for readers interested in greater technical detail. These two books complement each other, and shouldn't be viewed as competitors.

Electrical engineers are often unrealistic when it comes to assessing the needs of non-technical individuals. *(EEs are also notorious for designing devices which cannot be built until some experienced technician modifies them to a practical implentation.)— Ed.* What seems like knowledge known to every fourth grader to those of us who work in the audio field may actually be a foreign language to an audio novice. Holt's book targets that audience, and accomplishes its task very well.

MERCI

Thanks to everyone, especially Jim Hunter of Klipsch & Associates, who responded to my letter (*SB* 1/92, p. 75) seeking information regarding modifications and updates to vintage Klipschorn crossovers. Jim's lengthy discussion and guidance was very helpful and much appreciated. With the updates applied, my pair of 1973 K-horns never sounded better and confirm my admiration for what I believe to be one of the best speaker designs ever.

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Les Winter
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A LITTLER OPTION

Roy Littler's "A ⅓-Octave Noise Source" (*SB* 3/92, p. 10) takes me back a few years when I considered building a poor man's spectrum analyzer. Inexpensive overseas products using ⅓-octave analysis or true spectrum analysis never matured.

I did some minor research in using MF-10s and wasn't convinced I could accomplish what I was trying to do. To sweep the MF-10s a wide-range VCO (voltage controlled oscillation) would be required or else division of the spectrum into bands was needed. I wasn't quite sure how to set up the MF-10 and I knew very narrow bandwidths would require slower sweep rates.

In its simplest implementation, Roy's circuit could be used. Replace the pink noise section with a buffer amplifier section. Sufficient drive is necessary to overcome circuit noise, too much will saturate the MF-10. The output could drive an optional log amplifier stage which could drive a storage oscilloscope. By disconnecting the final op amp filter and using the second section of the rotary switch tied to a voltage divider, its drive could go to the DC-coupled horizontal section

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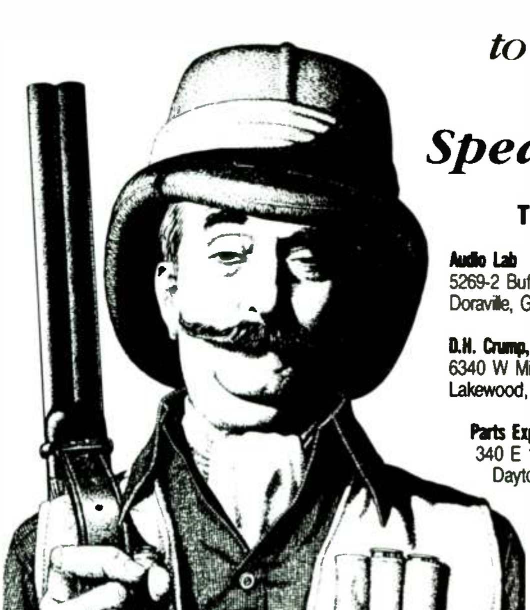

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of our scope. Switch S1 would also need a second section divider.

What we have here is a manually step swept spectrum analyzer. Unfortunately, this is not cheap if a storage scope is required; its manual operation leaves a lot to be desired. A single indicator such as a meter or LED display might help, although its decay characteristics would have to be fairly fast.

To go the full route, the circuit should be fully automatic. The output would drive a multisection LED display, each section with its own sample-and-hold. I think this would be a bit too much for simplicity's sake. However, the spectrum might be broken down into three selectable scans of 10 segments each.

Greg Szekeres
Pittsburgh, PA 15236

The Danielle

continued from page 42

parable in quality and timbre to B&W 802s, but with approximately one-eighth of the cost and 8″ more in box height.

The taut bass is not for everyone—in fact, it may not be as saleable as "punchy" bass to the general public. However, the speakers seem to disappear, reproducing sound with very little addition. That particular "timbre soup" (to quote Dickason in the *LDC*) pleases me. If you acquire the LDP, those of you with different tastes can build from this article to produce your own custom bass response by using the same crossover for the MTM and combining higher-Q_{TC} woofer/midranges with lower-S bandpass enclosures.

Eventually, I intend to build smaller subwoofers using the same TA-305F clones with compound loading in true Helmholtz resonators and to move the MTM section to satellites for better looks. With computer modeling programs to take the drudgery out of calculations and guarantee excellent results, speaker building has really become fun.

REQUEST. One final note to *SB* readers: I welcome suggestions from LDP purchasers regarding improvements and/or modifications for future versions. My intent in writing the software was to make "cookbook" speaker calculations available to everybody at a low price while still covering the widest possible range of knowledge, except for system optimization. I hope the LDP will become yet another useful tool for better speaker design.

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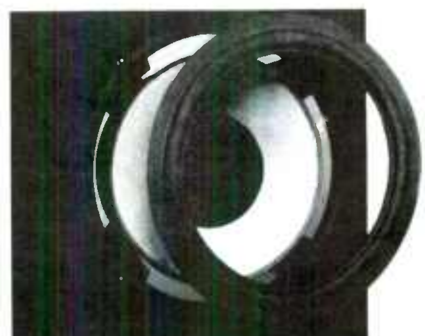

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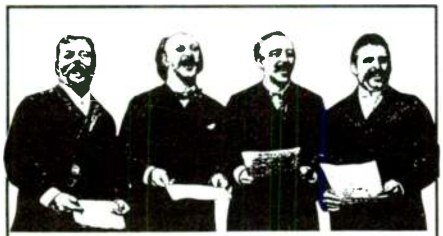

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World Radio History

Moran in the Market

BAFFLES WITH BOWERS & WILKINS

By David R. Moran

R-E-S-P-E-C-T

Bowers & Wilkins (B&W) is perhaps the most respected—and high-end-favored—of major consumer loudspeaker companies, at least of those who make expensive, conventionally forward-facing, multiway dynamic-driver systems. More consistently than competing products from their English colleagues Celestion and KEF (who recently were wed, after a Polk takeover of the latter evidently was abandoned), and also more consistently than competing products from American high-enders Snell, Vandersteen, Thiel or Infinity, B&W Matrix 801s or 802s are the current pick of eminent classical companies, musicians, and music critics, and recording engineers and even loudspeaker reviewers.

These fussy listeners have voted with their checkbooks, and that's most impressive. I myself know architectural acousticians and wealthy audiophiles alike who have installed those very models in their custom dedicated listening rooms. And just the other day a pro-speaker designer mentioned to me that he wanted to buy a pair of 802s as much for their elegant robot looks as for anything else—adding "if they sound bad, I'll just EQ them."

Ten years ago, when dbx engineering was measuring the horizontal radiation pattern of practically any loudspeaker we could get our hands on, the B&W 802 stood out as having a "really nice polar plot" for its conventional type of dispersion. The careful matching of driver to rounded baffle of almost minimal width, resulting in that cabinet-with-tiny-head(s) look, seemed to be the cause. (While KEF may have pioneered this baffle-matching robotic look, followed eventually by topline Vandersteen and Dahlquist and inexpensive Ohm models, no one has refined it so consistently or executed it so precisely as B&W.)

None of us ever thought those early-'80s 802s sounded exactly excellent, howver. Not bad, by any means, and yes, they did have superior standard imaging, with considerably more "floaty" airiness than most everyone else. But they did not produce startling, superb playback.

More recently, and much more forcefully, a sharp-eared audio-journalist colleague stated that none of the many B&Ws he has heard over the years has *ever* sounded right, or even particularly good: there always was something off—colored, nasal—in the crucial midrange. A second journalist recalled at least that he had never heard the company demonstrate them successfully at audio shows.

So what's the story? Are the topline, much revered B&Ws good speakers or not—and why? I have always been eager to find out for myself, and a month ago the opportunity arose to spend some time with the $4,000 802.2s (they were quasi 802.3s, actually, the latest version, as they included the new series 3 tweeter if not every other new detail). In the signal path was the B&W bass-boost EQ box ($250). Each vented cabinet comprises two 8″ woofers, one 5″ midrange, and one 1″ tweeter, with steep (24dB/octave) crossovers at 400Hz and 3kHz.

Judgment Day

A perfectionist audio-engineer friend asked me to join him in evaluating these 802s' performance in his custom-designed home theater. He was unhappy with the sound, specifically a honk in the midrange and boom in the midbass. After a brief listen I concurred in his dissatisfaction, noting that the imaging was steady and tight despite the sonics. He had done some crude tonal adjusting with an octave equalizer, which we refined to an almost acceptable degree calling on the dbx RTA-1 to quantify the changes.

Much better than that, using the kilobuck SigTech AEC 1000 (Acoustic Environment Correction, from Cambridge Signal Technologies) adaptive DSP unit to adjust the first 50msec of sound in the room, he obtained fine EQ results, as the AEC 1000 is the fanciest of the new digital equalization systems coming to market these days. Lately he has been experimenting with a good analog ⅓-octave equalizer, to see how that less-expensive correction audibly compares with the digital EQ, which by definition is more,

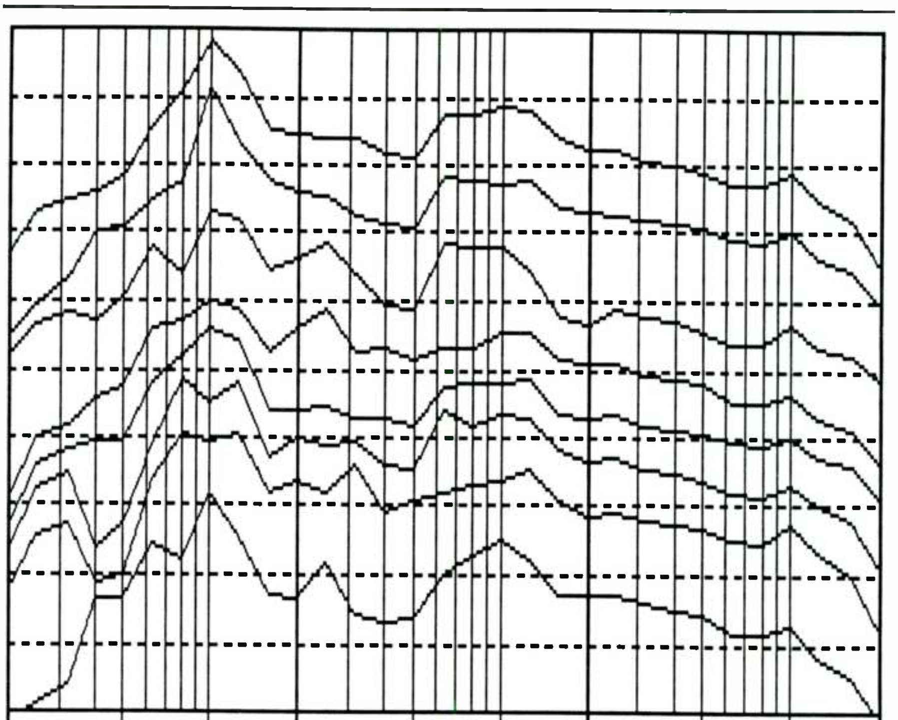

FIGURE 1: Various B&W 802.2 (but with the series 3 tweeter) room responses, of each speaker individually and the pair together, located as the owner prefers. Mono and stereo pink noise was used, measured at the sweet spot on different days, with doors and windows both open and closed. The dbx RTA-1 was fed by an AKG microphone compensated to instrumentation flatness, with continuous time and some small spatial averaging. All plots are 5dB per division and 20Hz–20kHz.

World Radio History

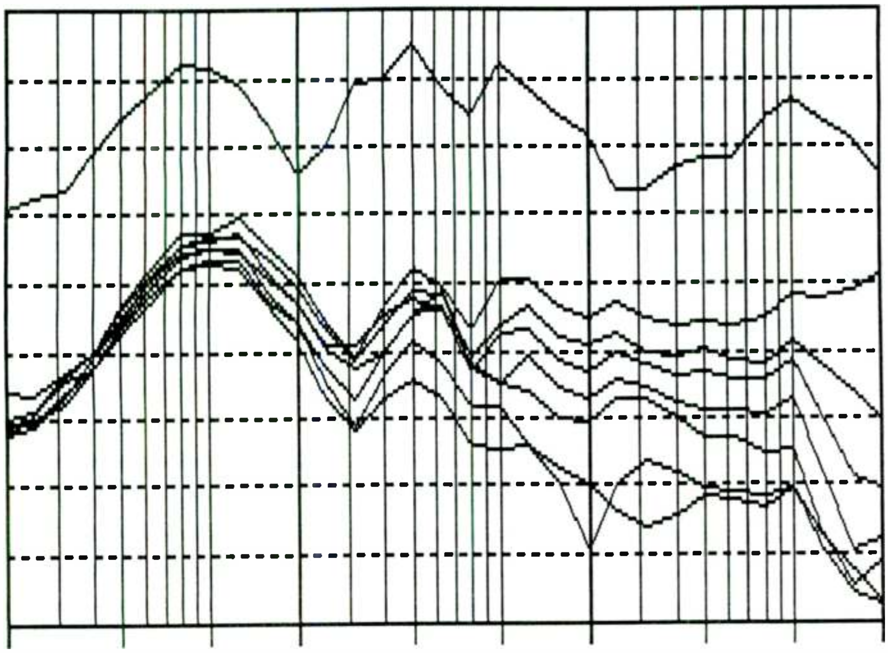

FIGURE 2: Outdoor measurements. At bottom are axis, −30°, −45°, −60°, −90°, −135°, and −180° angular responses. Usually I do not include the −45° response, but this loudspeaker is so exemplary in the levels, spacing and evenness of its dispersion that I took an extra angular measurement just for the beauty of it. At top is vertical response, 45° upward and in front of the speaker, to gauge the spectrum of a typical room's ceiling reflection; note lobing right where the horizontal stitching is so seamless. For the record, the two individual speakers matched within a dB or two across the entire audio band.

and extremely, precise—well beyond what can be heard.

An aside: One claim for digital EQ concerns how analog equalization is "seldom audibly satisfactory," as SigTech's literature blithely alleges, which will come as news to everyone who has done careful work with a good ⅓-octave equalizer and a precision ⅓-octave RTA, or even who has performed elaborate, successful crossover design. No doubt digital EQ is fine, much finer than anything analog filters can accomplish; further, much is made of its superior "time-domain" performance and lower phase distortion. Whether any of these achievements count to the human ear, which in so many ways is sorely limited and in some other ways is exquisitely sensitive, is another matter altogether, and another column.

Suffice to say here only that the SigTech-EQed 802s now sound very nice and image even better. Oddly, while my RTA measurements of the unimproved B&Ws in this home-theater environment closely (and gratifyingly) match ones made with TEF, Neutrik, and the SigTech systems, the measurement of the speakers as corrected by the SigTech, unsurprisingly smooth everywhere else across the audio band, showed one time a broad 4dB bump around 600Hz, another time a narrower 3dB bump at 2.5kHz. This has me intrigued, that instrumentation-grade ⅓-octave pink-noise assessments could be missing something important. The dbx RTA-1 also measured some modest lumpiness between 70 and 300Hz which I am not so concerned about, given the very different time windows of the two measuring systems. Naturally I will report the ongoing investigation into discrepancies and any audible consequences.

Analytic Work

Assuming reasonable correlation of the dbx RTA-1 results with audibility, let's turn to its data. *Figure 1*, which displays eight room responses of the speakers separately and together, reproducing mono and stereo pink noise and including B&W's own bass-EQ component, seems to show clearly why the owner felt as he did about his 802s' sound. Observe the fairly consistent thickness (elevated output) around 100Hz, the depressed response across the octave-plus above that point, and the broad Monet-like grainstack centered in the octave just below 1kHz.

My friend's theater/listening room is large and well-proportioned with a slop-

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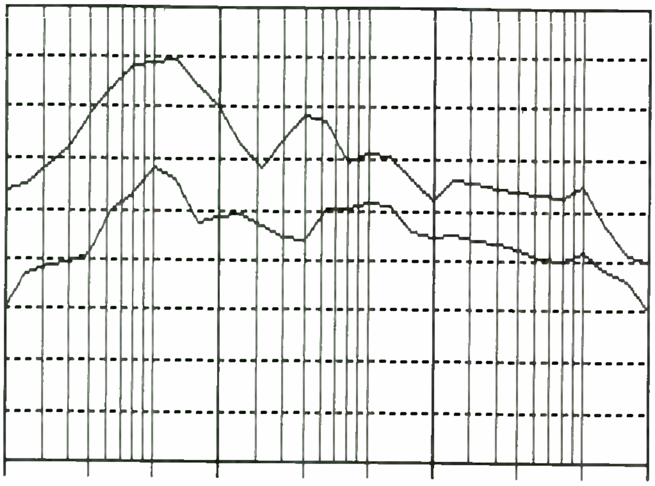

FIGURE 3: At top is the total average of the *Figure 2* curves, properly weighted. At bottom is the total average of the *Figure 1* room responses. See text for interpretations.

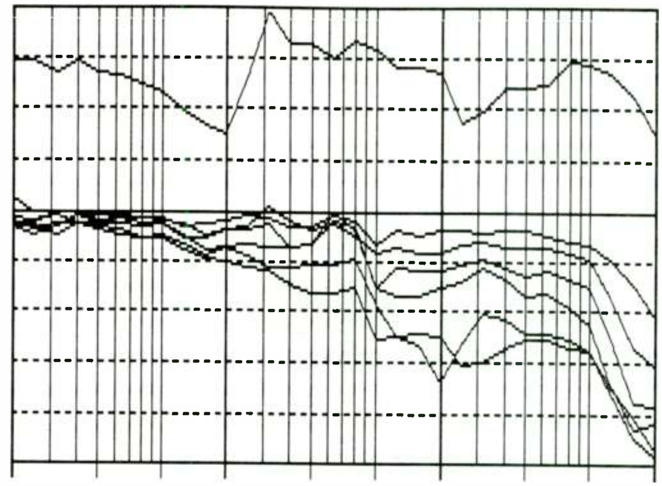

FIGURE 4: Differential curves. At top is the deviation from flat of that forward vertical response. At bottom is the difference with angle of the horizontal output, which I suggest help form the playback images. The straight line is the axis response; a beautiful set of almost parallel curves lies below it, with imaging to match. See text and *Figure 2* caption for details on the angles and for further interpretation. There is hardly any sign of an upper crossover, and none whatsoever frontally! The tweeter is oddly beamy above 10kHz, given its small mounting load.

ing ceiling, and is fairly absorptive sonically, unusually so in the bass, with actual lossy bass traps. As so often is the case with audiophile systems, the speakers have been positioned for best imaging, not calculatingly staggered for smoothest boundary augmentation and response below 500Hz.

I must point out that in the 801 and 802, with their rather highly positioned woofers, B&W makes it almost impossible for an end user to get smooth response below 500Hz, and only too easy for the midrange output to be prominent and, in relief, excessive. Refer to *Fig. 2*'s curve set. As usual, it displays frequency response outdoors, at listening distance away and listening height, by horizontal angle—from directly in front to directly behind. At top by itself is the vertical frequency response, 45 degrees up and in front of the speaker. *Figure 3*'s top curve is the total of *Fig. 2, averaged.*

All of these anechoic-with-floor responses show the upper-bass/lower-midrange notch resulting from ground-reflection interference which is exhibited by *every* loudspeaker system with a woofer located not near enough to the floor. (Compare with the curves for the Allison AL130, which lack the notch, in *SB* 2/92 p. 80, *Fig. 2.*) If a system has its woofer(s) up off the floor, you have to be extremely conscientious and shrewd about proper distancing to the front and side walls, in order to fill the notch in. B&W 801 and 802 manuals are strikingly poor in this regard. Aside from their hype ("How do you improve on a masterpiece?") and self-contradiction ("If the acoustic landscape of your room is unable to satisfactorily absorb low frequencies and produce an acceptable balance, then the use of the B&W Bass Alignment Filter accessory will extend the bass response..."), the entire advice for "Placement of Loudspeakers" merely consists of the casual observation that "...the position of your loudspeakers within the available environment will have a greater effect than any other variable under your control," period. That's it. Unbelievable. Nothing even of the usual yawns about getting more bass close to corners, less bass away from them—much less about how equidistant, and least-equidistant, spacing from front and side walls so drastically affects the smoothness of the sound.

Indeed the 801, whose 12″ woofer is strangely high off the floor in the first place, commonly is sold and used with stands!

Of course, a great many listeners, even experienced ones, prefer the sound with this notch—to an uneducated ear, its thinning effect seems to make the midrange and sometimes the treble "clearer." Evidently, if you are to live with a hole in the octave below middle C, you must conclude that it does not matter or does no harm to faithful reproduction. Or you must fool yourself into thinking it causes a euphonious decrease in "heaviness" in the lower midrange.

Notch Repercussions

In the case of these 802s, the upper-bass valley made the midrange stick out, as noted: if the 150–600Hz dip were filled in (after all, this is where most of music's energy lies), the sound would be smooth and full, not honked. Further, refer to the bottom of *Fig. 3*, the total of all the *Fig. 1* room responses, averaged, and again to *Fig. 3* top, the total of all the outdoor responses, averaged. Note how an octave or so above the valley, that is starting at 1.4kHz or so, the shelving downward to the smooth treble does not help that 500Hz–1kHz honk either.

While I am wagging my finger at B&W, let me reiterate a secret for all you speaker builders:

If you assume "audiophile" (serious) speakers are going to be used between 2.5 and 4 feet from the front and side walls, then for natural sound, any woofer used in such a system *must be less than a foot from the floor.* Otherwise there will be a suckout in the upper bass/lower midrange, in the 90–180Hz octave. There is absolutely no getting around this; it cannot be wished or hoped away "due to room acoustics."

In a 3-way, this low-placed woofer should be cut off at or preferably before 400Hz. In a 2-way you are going to have a tough time of it, obviously. Either the woofer and the ear-height tweeter are going to be a ways apart (nearly two feet, less for a low-rise loudspeaker), which is hardly fatal but will perhaps bother the true-blue audiophile; or you are going to have to compromise by putting the 2-way on a stand but close to a wall, presumably the front wall.

Or you can put the 2-way on a stand out in the room and equalize in a 5–10dB boost at the right spot within the 90–180Hz octave.

Thus speak the laws of physics.

My bafflement apropos B&W, since they advise an equalizer for boosting the low end and since they appear unwilling to design the problem out by getting the woofer(s) closer to the floor, is: Why not include with the equalizer a few precise boost settings in the 90–180Hz octave,

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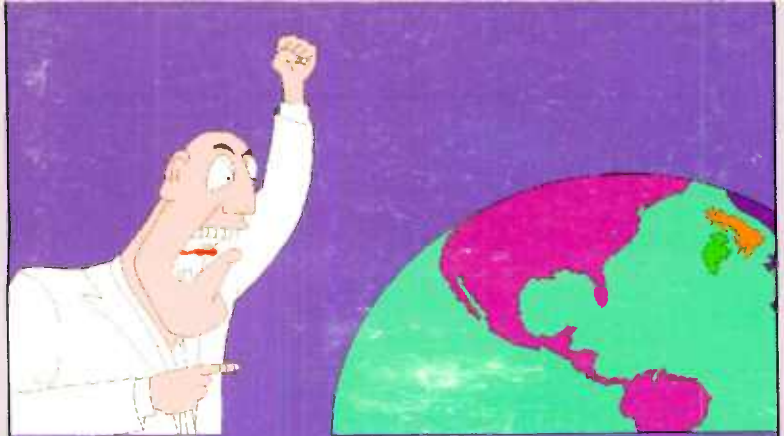
Fast Reply #JG1428

World Radio History



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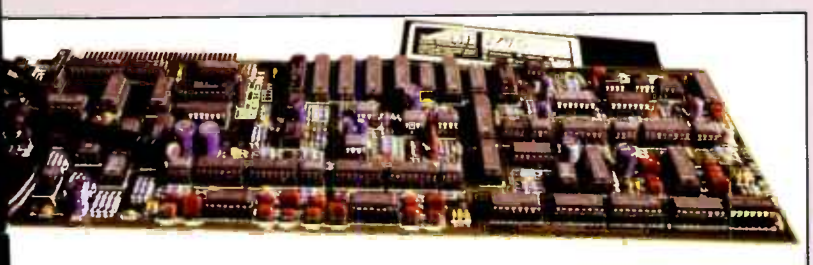

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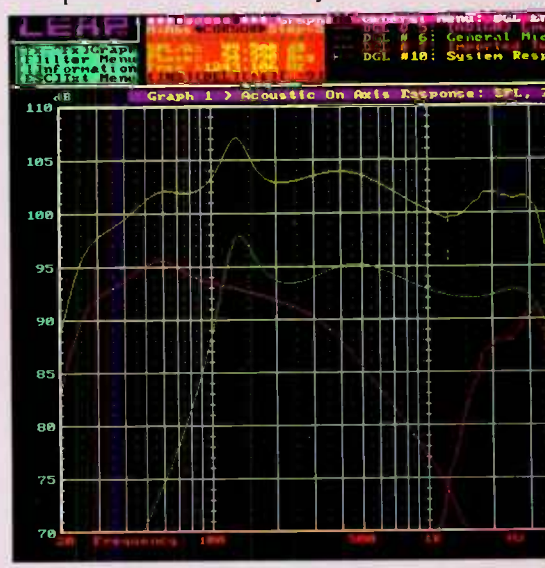

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World Radio History

Continued from page 76
calculated for various boundary placements, to achieve flat, unnotched response? I mean, I hear tell that the Bose Corporation had the good sense and interest in fidelity to do just that in one release of their dedicated 901 equalizer. If B&W did it, it would revolutionize the industry—especially the high end. Not to mention that the playback of a $4,000 pair of speakers would be of higher fidelity.

All of the calculations necessary for solving this common, real and audible problem can be performed with the free Allison Boundary Augmentation software I have mentioned in previous columns. In other words, it can also be a tool for speaker designers. If you experiment with various distances to the floor and front and side walls, you immediately see from the curve graphs what your range of compromise (and possible perfection) is.

The Good News

Now. Turning to *Figure 4*, which shows the B&W 802's horizontal output by angle normalized to a perfectly flat axis response, there is really tremendous performance above the midrange, from below 1kHz on up. Holy moly, I say: I have never seen anything like it, such amazing—smooth—3kHz midrange/tweeter crossover work. The result is as seamless and as ideally, congruently "striated" as I have measured. Only the KEF Uni-Q (see *SB* 5/91 p. 94, *Figs. 5a* and *b* and *6a* and *b*) had as uniform horizontal directivity—but with much less spaciousness to the treble and upper treble. To my hearing, both that driver and this B&W midrange/tweeter combination image with unequaled focus. Curiously, even with the 802s' large, smooth-surfaced grapefruit-and-golfball-size baffles, these distinguished drivers do not have as much off-axis output as the more widely and roughly baffled Allison midrange and tweeter, especially the latter above 10kHz. Again see *SB* 2/92, this time p. 82, *Fig.3*.

Vertical output approximately 45° above and in front of the 802 is shown at the top of *Figures 2* (raw response), as mentioned, and 4 (plotted as deviation from normalized, straight-line axis response). Nothing untoward is going on, but a strong cancellation occurs at 2.5kHz, showing that with two drivers and one crossover you can't have everything, and that if you were standing close to and in front of the speakers, the upper-midrange sound would worsen. Fortunately, human ears are on the sides of the head, so vertical-response anomalies are not crippling.

Get Out the Chainsaw

What to conclude? We have good sound with superlative imaging from the upper midrange up, serious and common problems from the lower midrange down. If I were a lazy speaker builder with a lot of dough and a big woodworking shop, I would try cutting in half the B&W 802.3 and the Allison AL130 horizontally, gluing the latter's bottom to the former's top, and then seeing how delightful and satisfying the sound (perhaps still needing a little EQ) and imaging was. Or something like that. Doubtless, readers will have more practical ideas and experiences about baffle width and smoothness, crossover timbral voicing, and proper boundary augmentation. Let me know what they are.

SOURCES

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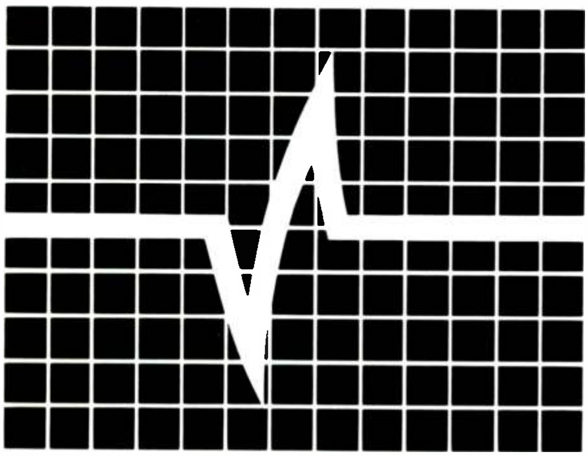

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ligh Power Woofer

igh power woofer features a cone reinforced with Kevlar and coated with a polymer or added stiffness. A Kapton coil former is edgewound eavy gauge ribbon wire and ed pole piece allows um heat dispersion to keep ce coil cool and increase handling. The special reinforced steel basket ns as well a die cast, but at a fraction of the cost. Power handling: 250 MS, 350 watts maximum. Resonant frequency: 48.5 Hz. Frequency se: 30-3,000 Hz. SPL= 88 dB 1W/1M. 2" voice coil. 50 oz. magnet. impedance. VAS= .5 cu ft. QTS= .39, QMS= 13.4, QES= .41. ions: A= 8-1/8", B= 5-1/2", C= 2-3/4", D= 1-1/2". Net weight: 9 lbs.

295-020	$65.95 (1-3)	$59.50 (4-up)

10" High Power Woofer

High power woofer featuring a Kevlar reinforced paper cone and coated with a polymer resin for added stiffness. A Kapton voice coil former is edgewound with heavy gauge ribbon wire and a vented pole piece allows for maximum heat dispersion to keep the voice coil cool and increase power handling. The special double reinforced steel basket is as rigid as diecast, but at a fraction of the cost. Power handling: 375 watts RMS, 530 watts maximum. Resonant frequency: 31.5 Hz. Frequency response: 25-3,000 Hz. SPL= 92.3 dB 1W/1M. 2" voice coil. 50 oz. magnet. 8 ohm impedance. VAS= 4.6 cu ft., QTS= .38, QMS= 11.3, QES= .39. Dimensions: A= 10-1/8", B= 5-3/4", C=3-1/2", D=1-3/4". Net weight: 10 lbs.

#SH-295-030	$79.50 (1-3)	$71.50 (4-up)

Surface Mount Piezo Super Tweeter Pair

This extremely small tweeter incorporates all the advantages of piezo tweeters into a small package that can be mounted almost anywhere. Ideal for mounting on the back of rearview mirrors in car stereo installations. Frequency response: 5,000-20,000 Hz. SPL: 97 dB 1W/1M. Power handling: 80 watts RMS, when used with a 4.7 microfarad capacitor. When power exceeds 25 watts RMS, a 15 ohm, 20 watt resistor can be used in series. Sold in pairs. Net weight: 1/2 lb.

#SH-265-267	$24.00 (1-3 prs.)	$22.50 (4 prs-up)

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Dimensions: 8" (L) x 3-1/8" (W) x 2-1/4" (H). Net weight: 2 lbs.

#SH-240-075	$29.95 (1-5)	$27.90 (6-up)

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