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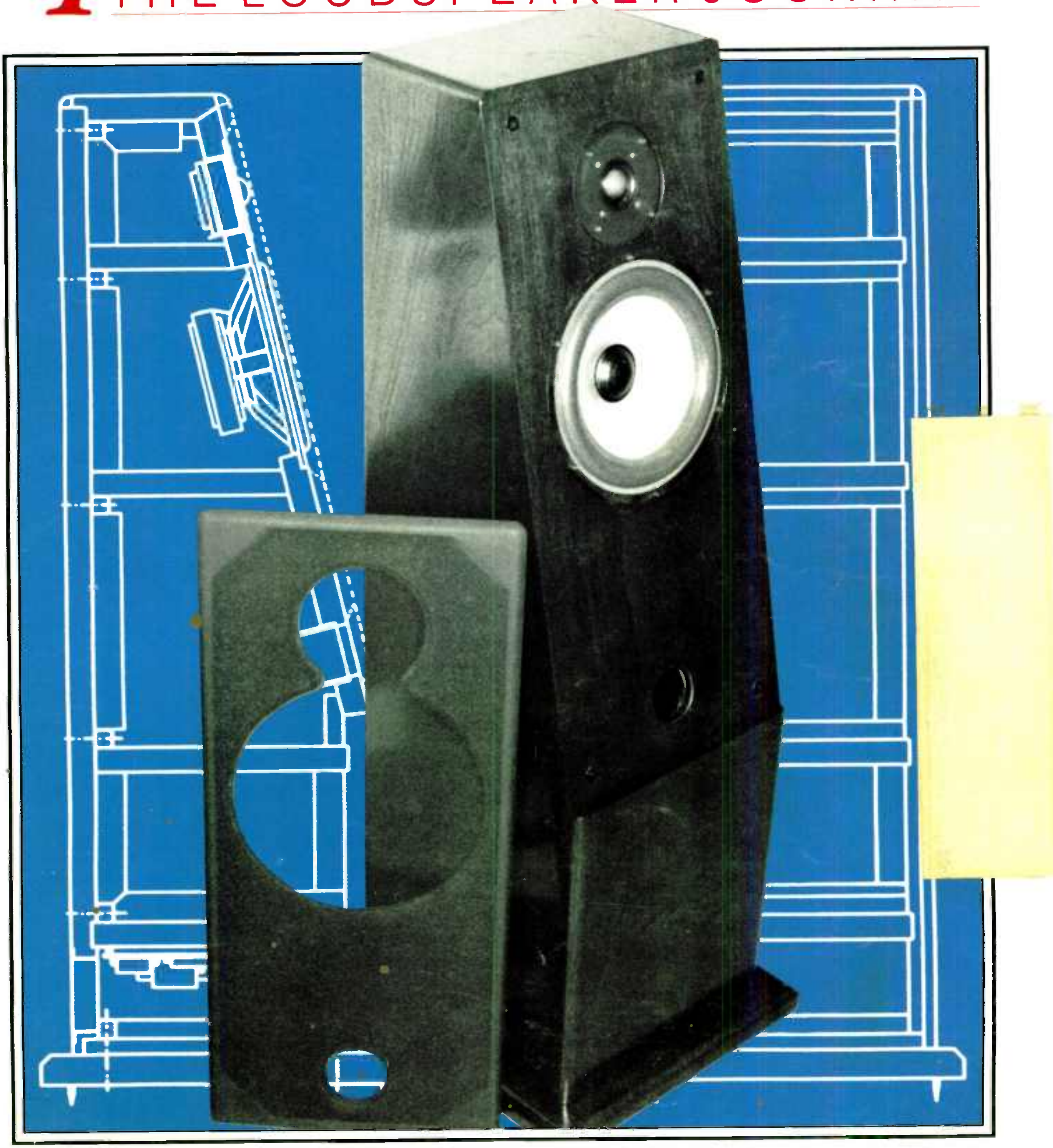
Speaker Builder

THE LOUDSPEAKER JOURNAL



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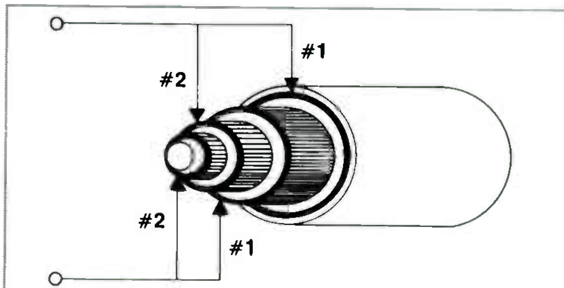

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Reader Service #13

Good News

■ **LINEARX**
Loudspeaker Enclosure Analysis Program (LEAP™) and Loudspeaker Measurement System (LMS™) products are now sold and serviced through LinearX. This corporation has no affiliation with Audio Teknology Inc., but has retained any distributors and/or dealers for the LEAP/LMS product line who were established through ATI. LinearX Systems, Inc., 7556 SW Bridgeport Rd., Portland, OR 97224, (503) 620-3044, FAX (503) 598-9258, BBS (503) 598-9326.

Reader Service #70

▲ **POLYDAX**
Woven Fiberglass cone mid-bass speakers (HT100F0, 4″; HT130F0, 5¼″; HT170F0, 6½″; HT210F0, 8″) feature large magnet structures, high-temperature voice coils wound on aluminum voice coils, and stamped steel chassis. The cone is coupled with a high-loss rubber surround. Polydax Speaker Corp., 10 Upton Dr., Wilmington, MA 01887, (508) 658-0700, FAX (508) 658-0703.

Reader Service #53

▼ **PARTS EXPRESS**
The 1993 catalog includes parts for the electronic hobbyist and home and car audio enthusiasts. Products include raw speaker drivers, crossovers, Mylar® capacitors, air- and bar-core inductors, in-wall speakers, car-amplification products, speaker wire, gold-plated connectors, semiconductors, installation tools, educational books and videotapes, and loudspeaker-design software. Parts Express International, Inc., 340 E. First St., Dayton, OH 45402, (800) 338-0531.

Reader Service #51

◄ **STONECRAFT**
Handmade marble and granite speaker enclosures are available in any size or shape. White marble speaker stands glow with a light installed inside. StoneCraft Speaker Systems Co., c/o SeaRail International, Inc., 1116 Oliver St., Houston, TX 77007, (800) 865-7445, (713) 863-0011, FAX (713) 863-0025.

Reader Service #54

■ **SPEAKER-SCULPTURE**
Transmission-line-loaded loudspeakers are designed to avoid such problems as diffraction, standing waves, crossover anomalies, and lack of coherence. Models include the "Snail" (bookshelf units), the "Sea Horse" (wall hanging), the "Cobra" (free standing), and the "Scorpion" (a subwoofer). Speaker-Sculpture, 2 Division St., New Rochelle, NY 10801, (914) 576-2896.

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■ **SOLO ELECTRONICS**
A new Copper-Foil Air-Core Inductor™ offers 15–50% less power loss, low AC and DC resistance, low Q factor, uniform current density, minimum skin effect resistance (up to 100kHz), and high winding density. Solo Electronics, 2462 Tripaldi Way, Hayward, CA 94545, (510) 887-8016, FAX (510) 887-1657.

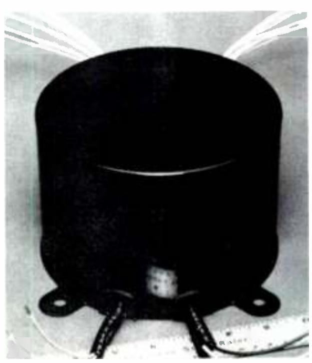
Reader Service #58

■ **ORCA**
TopBox software provides the capability to design and evaluate the expected performance of several loudspeaker system configurations, and requires only a few driver parameters to develop designs (closed-box, bass-reflex, and bandpass). The program synthesizes fourth- and sixth-order band-pass designs directly from your specifications. Available in both PC and Mac versions. ORCA Design & Manufacturing, 1531 Lookout Dr., Agoura, CA 91301, (818) 707-1629, FAX (818) 991-3072.

Reader Service #55

► **TOROID**
"Zero-noise" toroidal transformers are custom designed for amplifier and preamplifier applications. The units incorporate low profile and light weight in addition to low audible noise and low magnetic strayfield emission, and are available with or without encapsulation, with epoxy potted center and threaded inserts, or potted inside a metal can with or without mounting tabs. Toroid Corp. of Maryland, 608 Naylor Mill Rd., Salisbury, MD 21801-9627, (410) 860-0300, FAX (410) 860-0302.

Reader Service #52



■ **PEERLESS**
The RDC 2000 Ring Dome® tweeter for car systems includes such features as high sensitivity and power handling, replaceable ring dome assembly, ferrofluid-cooled voice coil, and laminated metal diaphragm. The unit can be installed in the door or attached to the instrument panel. Peerless of America, Inc., 800 W. Central Rd., Mt. Prospect, IL 60056, (708) 394-9678, FAX (708) 394-5952.

Reader Service #59

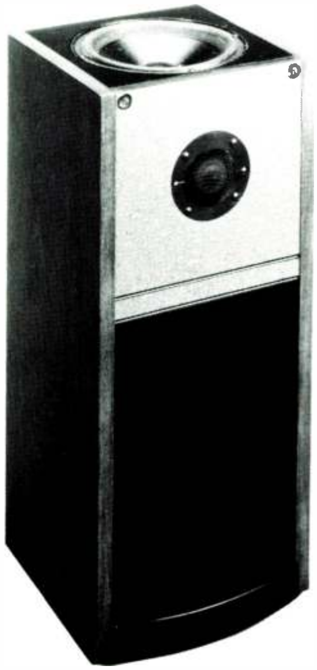
Good News

■ **HERNON**
UV Epoxy 25771 for electronic potting applications combines UV cure mechanism with two-component epoxy. It can be instantly immobilized under UV light, allowing parts to undergo additional assembly operations during the cure process. Full cure is obtained at room temperature or can be accelerated with heat. Hernon Manufacturing Inc., 121 Tech Dr., Sanford, FL 32771, (800) 527-0004, (407) 323-0545, FAX (407) 321-9700.

Reader Service #63

► **RDL**
"Room-Designed" loudspeakers include models FS-1 (a floor-standing unit with both woofer and tweeter mounted on the front panel), F-1 (with the woofer mounted horizontally on the top panel), B-1 (a bookshelf system), and S-1 (same mounting as F-1 but smaller). RDL Acoustics, 26 Pearl St. #15, Bellingham, MA 02019, (508) 966-2200, FAX (508) 966-3645.

Reader Service #64



► **ABILENE**
Texturelac spray-on paint finish was developed for use on speaker boxes, electronic housings, cases, and enclosures. The finish resembles leather, pebble, stone, or stucco. It can be used with conventional air-spray systems, and dries in 15 minutes without seams, stains, or dust. Abilene Research and Development Corp., PO Box 294, Hewlett, NY 11557, (516) 791-6943, FAX (516) 791-6948.

Reader Service #57

■ **RICHARDSON**
Sennheiser Electronic Corp. has named Richardson Electronics as its authorized stocking distributor for microphones, headphones, RF wireless microphones, and other related products. Richardson also supplies power tubes, CRTs, camera tubes, RF components, and capacitors with same-day shipping available on most items. Richardson Electronics, Ltd., LaFox, IL 60147, (708) 208-2200, (800) 348-5580 for US/Canada sales locations.

Reader Service #56

Reader Service #34 →

About This Issue

Good things come in twos, as this issue makes abundantly clear. In our lead article, Australian **Peter Taylor** describes "Two Ways to Realize a Dream" (p. 10). His project demonstrates that part of the satisfaction of a job well done comes from learning and doing rather than simply buying a ready-made product.

Why don't manufacturers' driver sensitivity ratings match calculated ones? Who put the power in power amplifiers? How do you match driver efficiencies in multi-driver systems? **John Lipp** answers these questions and explains his new efficiency parameter, beginning on page 20.

Paul Francis has discovered that using "A Two-Woofer Box System" will increase his system's bass efficiency. The process involves doubling each driver's cone mass. Beginning on page 22, Paul explains the intricacies of cone weighting and describes how the process can even be applied to surplus drivers.

When faced with a lack of bass, **Steven Crosby** put two and two together and designed a dual-voice-coil subwoofer. Judging from the smiles, this trial-and-error project was well worth the effort. The details begin on page 26.

A two-fisted combination returns for a reprise, as **Randy Parker**'s "Prism V Satellite/JBL Subwoofer" (p. 32) concludes with details of cabinet construction.

Finally, what could be better than two speaker projects? **Scott Henion** provides the obvious answer in a tale befitting the Arabian Nights, beginning on page 58.

Speaker Builder

The peculiar evil of silencing the expression of an opinion is, that it is robbing the human race; posterity as well as the exisiting generation; those who dissent from the opinion, still more than those who hold it."
--John Stuart Mill

Speaker Builder is published bi-monthly in the interest of the art and craft of speaker building.

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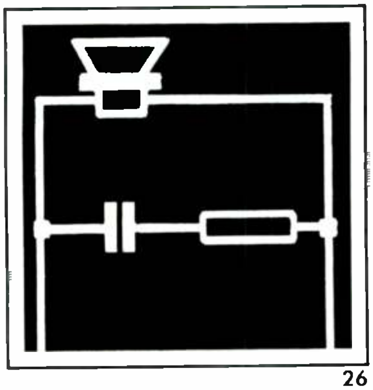

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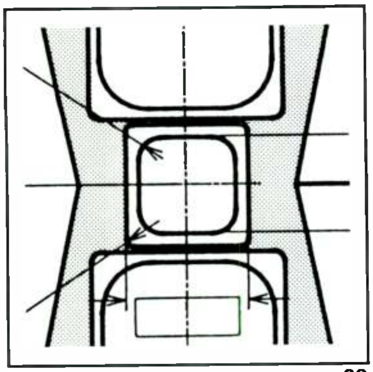

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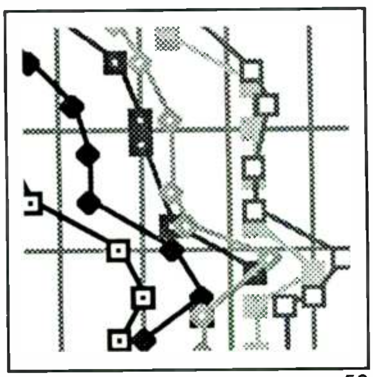

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Speaker Builder

THE LOUDSPEAKER JOURNAL

VOLUME 15 NUMBER 5 OCTOBER 1993

DEPARTMENTS

Editorial

DOES US ENGINEERING EDUCATION NEED A NECK BRACE?

In my view, America's engineering community is suffering from a serious case of sacroiliac damage. Unless something is done to repair its deteriorating backbone's condition, it may become a fully immobilized paraplegic. Fortunately, some folks in influential positions are acknowledging that something is seriously amiss in the engineering establishment, especially in how engineers are educated, and are looking for solutions.

John Wiley & Sons (founded in 1807) recently hosted a meeting of ten highly qualified people to do some preliminary discussions on the issue. Dr. Joseph Bordogna, the keynote speaker, is assistant director for engineering of the National Science Foundation. The other nine were engineering department heads in universities which included Florida, Missouri-Rolla, Waterloo, Cal Poly, Purdue and Tennessee; plus engineering people from Sun Microsystems and Apple Computer, as well as one director from an engineering firm, Muesser Rutledge.

Among other things, Dr. Bordogna said engineering education needs a "paradigm shift" to enable the next generation to "invent the future." He cautioned against "...trying to solve tomorrow's problems with yesterday's solutions." In addition, he stated that today's engineers are trained with strong analytical skills to "...deal with things the way they are," but are short on relating this discipline to "...deal with things the way they ought to be."

The Wiley organization is coordinating responses to this first move to shift educational values to a broader spectrum. Many others have been commenting for some time on the narrow, almost exclusively mathematical viewpoint of engineers whose philosophical preferences for the scientific approach have serious consequences for society.

Only after the atomic bomb was invented, tested successfully and dropped on Hiroshima did those involved at Los Alamos begin to consider the consequences of their achievement. In another area, the "invention" of the essentially nonrepairable, "throw-away" designs for all manner of electronic equipment was not a matter of thoughtful consideration, but a kind of mindless response to marketing pressures.

One of the editor's old friends, Alan Watling of Colchester, England, recently relayed an apposite story. "I recently bought (for about $25) a telephone answering machine from a 'surplus' company," he says. "They supplied a new IC to replace the one obliterated by British Telecomm (BT), who drill a ¼" hole in the case whenever any machine is returned for *any* fault, and throw it in the trash can. Installing the new IC and repairing the wrecked board was equivalent to putting the cuckoo back into a Swiss clock that has been dropped off the Alps—however, it worked. When I asked around for a circuit diagram I found there isn't one. Nobody ever needs one, do they? There are no real engineers in the repair center, just packers and hole drillers." Mr Watling is a retired BT engineer.

Most of *SB*'s readers will know ahead of time that the editor believes engineering malaise arises from the fact that too many engineering professors apparently cannot build an electronic project. In the electrical engineering world, that is a job for the technician. Not only for the technician—but the lowly technician. The old chestnut about the guerilla warfare that goes on between most engineering departments and the technical development departments, is that the engineer may design the device, but the technician makes it work.

Now that peace has broken out between the Israelis and the Palestine Liberation Organization, perhaps some kind of treaty could bring our engineers and our technicians into some new form of cooperative amity. It would be instructive to compare the original design schematics and the final manufacturing ones to determine whether there is any truth in this widespread rumor. The fact that the magazines Audio Amateur, Inc. publishes are written, to a significant extent, by graduate engineers would seem to contradict my assertion. However, the relatively small circulation of the magazines (this one goes to some 11,500 per issue) could confirm my speculation.

The steady decline of hands-on opportunities for electronic construction in the US has been commented on by others than myself, however. *Electronic Design News* has had editorials recently on this issue, as has the *New York Times*, commenting on Heathkit's discontinuing any electronic kit offerings. The same trend is evident in the fact that, other than the three periodicals we publish, only two general electronics titles survive in the United States, along with the several excellent ham and computer periodicals committed to construction.

Perhaps US electronics engineering suffers from a broken neck. The brains have become disconnected from the hands. This malaise seems not to affect the Europeans or the countries on the Pacific rim. Germany has three periodicals with monthly circulations in excess of 85,000 dedicated almost exclusively to sophisticated, hands-on construction projects. Japan's *MJ* (Audio Technology) dedicates over half of its approximately 250 monthly pages to construction and goes to over 40,000

Continued on page 81

TWO WAYS TO REALIZE A DREAM

BY PETER TAYLOR

Since building a three-transistor radio 35 plus years ago, I have harbored a dream to build speakers, a dream which recurred after I replaced an aging amplifier and added a CD player to my stereo system. My Sonab OA5 speakers had provided faithful service for at least 22 years. The first question was whether I, a rank amateur, could improve them. The second question was how I would tackle the task.

One obvious answer was to purchase a kit, but that seemed too easy a solution. As one which by-passed the learning and understanding phases, it eliminated much of the potential for satisfaction. The alternative was to start from scratch. Locating reference material proved to be a challenge, but I eventually obtained three books which proved to be invaluable.

Having read two of them, and while waiting for the third to arrive, I experimented with the Finnell/Caudle program.[1,2] As I have more experience using Lotus 1-2-3 than BASIC, I began adapting the program to a spreadsheet format. This would utilize the WYSIWYG graphics, and I could build in as many design formulas and rules of thumb as possible from the references.

I found *The Loudspeaker Design Cookbook* invaluable in this regard.[3] I provided for three acoustic-suspension and three bass-reflex designs using either specification or measured data, as well as adding first-, second-, and fourth-order crossover, driver attenuating, and impedance equalizing designs for two- and three-way speakers. In my enthusiasm, I also provided full design details for hand-wound air-core inductors. The finishing touch was the inclusion of low-frequency response plots and all circuit diagrams, complete with component values from the design calculations. After spending considerable time developing and refining the program, I was ready to translate theory into practice.

PHOTO 1: The completed first "final" enclosure. The lower front panel indicates the approximate extent of the lower compartment housing the crossover filters.

THE WITCHING HOUR.

I first carried out trial designs for a wide range of Dynaudio, Peerless, Vifa, Scan-Speak and other drivers. Enclosure size was a major factor. My old Sonabs represented the maximum desirable size in terms of plan dimensions, but greater height would optimize the height of the listening axis. I preferred floor-standing cabinets to stands, and this choice offered some flexibility through the use of a false floor. The other important consideration was cost.

Although my first inclination was to use a three-way design and bass-reflex enclosure, I reasoned that I could achieve a higher-quality end product by using a two-way design. I ultimately decided on Scan-Speak 222 mm 21W/8554 Kevlar® woofers and Scan-Speak 29 mm D2905/9000 tweeters.

To a newcomer, crossovers epitomize the so-called "black art" of speaker design. Vance Dickason's many useful illustrations of crossovers modeled using the LEAP program highlighted the pitfalls. I wished to avoid any potential problems caused by the rising frequency response of the woofers prior to rolloff, and had intended to use a crossover frequency of 1.5kHz with fourth-order Linkwitz-Riley filters. I rethought that strategy on the helpful advice of Arthur Rosenblum from A&S Speakers, who recommended a crossover frequency no lower than 2kHz for the tweeters.

I returned to the drawing board and started plotting frequency responses by hand. The crossover frequencies which came closest to achieving the desired result were 1.8kHz for the woofer and 2kHz for the tweeter.

FIRST "FINAL" DESIGN.

I finalized the design with a tallish enclosure having greater depth than width, which naturally must accommodate the Scan-Speak woofer. I chose the QB3 alignment with

ABOUT THE AUTHOR

Peter Taylor has an honors degree in civil engineering and is the City Engineer of Toowoomba in Queensland, Australia. He also heads a small computer software company which supplies budgeting programs to local government. In his limited spare time, he enjoys listening to a wide range of music.

the following characteristics: V_B = 32.5L, f_B = 34.8Hz, f_3 = 42.4Hz, port diameter of 63 mm, port length of 192 mm, height of 635 mm, width of 230 mm, and depth of 250 mm.

These internal enclosure dimensions were quite tight in terms of satisfying desirable criteria such as driver spacing, woofer and port separation, port and enclosure clearances, and shelf brace locations. The integration of the enclosure and stand provided a separate compartment under the floor. This was more than sufficient for the crossover filters.

I selected 25 mm medium-density fiberboard for the cabinet because of its ready availability, stability, and ease of working. To finish the enclosure, I chose 1.5 mm cedar plywood. (Australian cedar is a traditional furniture timber now in short supply and should not be confused with western red cedar found in the US.) My initial choice of damping material was a nonreticulated, open-cell polyester-polyurethane foam with 80 cells/25 mm and 25 mm thick.

I used good quality resistors, capacitors, 14 AWG air-core inductors, and wiring throughout. Most of these components and the drivers were obtained from A&S Speakers, and I am very grateful for the efficient and friendly service provided by Arthur Rosenblum and his staff.

I sealed the speakers and the enclosure rear panels with polyurethane foam strips, and secured them with machine cap screws and either T-nuts or brass blind nuts. I used heavier cap screws to secure the base plinths, and T-nuts for ease of access to the crossovers. Four adjustable spikes support each enclosure just above carpet level.

The grilles consist of a 12 mm quarter-round (quad) wood frame bonded to a sheet of plastic laminate 1 mm thick. The laminate stiffened an otherwise flimsy frame. I glued 12-mm-thick reticulated foam to the laminate so it covered the entire surface within the frame. The laminate and foam, cut at 45°, provide openings for the drivers and the port. For the grille cloth, I used black chiffon, which proved to be virtually transparent in both the visual and acoustic senses. The finished product is shown in *Photo 1*.

TESTING TIME. As the time approached to test the finished speakers, I experienced mounting excitement and apprehension. Initial listening tests with a variety of music produced a warm inner glow, which no doubt all amateur speaker builders experience. A-B comparisons with the Sonabs confirmed initial impressions. While the new speakers were not as bright as the Sonabs, the more mellow sound provided very easy listening, and stereo imaging was much more precise.

Then the nagging questions arose: Were the Sonabs overly bright because of their four tweeters? Did the new speakers lack brightness? Was I detecting peaks and troughs in response during the sine wave sweep on the test CD?

Fortunately, I was able to borrow some test gear, including an old but adequate signal generator. Impedance measurements (*Fig. 1*) indicated an f_B of approximately 29Hz. Further analysis gave a Q_L close to three compared with seven assumed for design. Using the same sine wave signal and a Brüel and Kjaer sound level meter, frequency response showed fairly rapid roll-off after 10kHz.

I was eager to test an alternative damping material before making further adjustments to the speakers. Reports indicated that a reticulated foam would be superior to the nonreticulated variety. I chose another polyester-polyurethane foam with reticulated open cells at 45/25 mm, the same I had used for the grilles but 25 mm thick. At the same time, I disconnected the C-R impedance equalizers from the high-pass filters. Further testing indicated these modifications had very little effect on either impedance or frequency response.

Connecting an X-Y plotter to the sound level meter and using a test CD simpli-

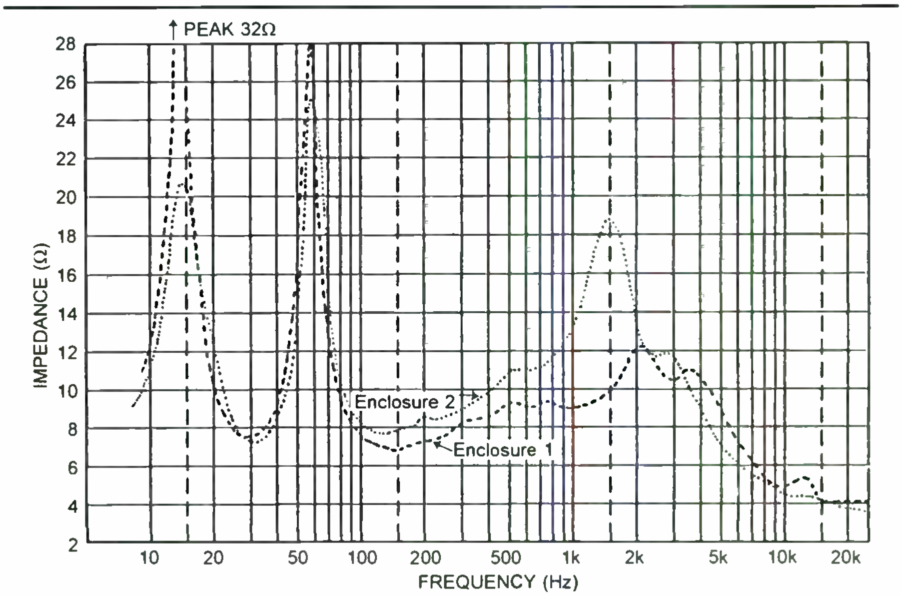


FIGURE 1: The dashed line plots the impedance of the first "final" design; the dotted line plots the impedance of the final design.

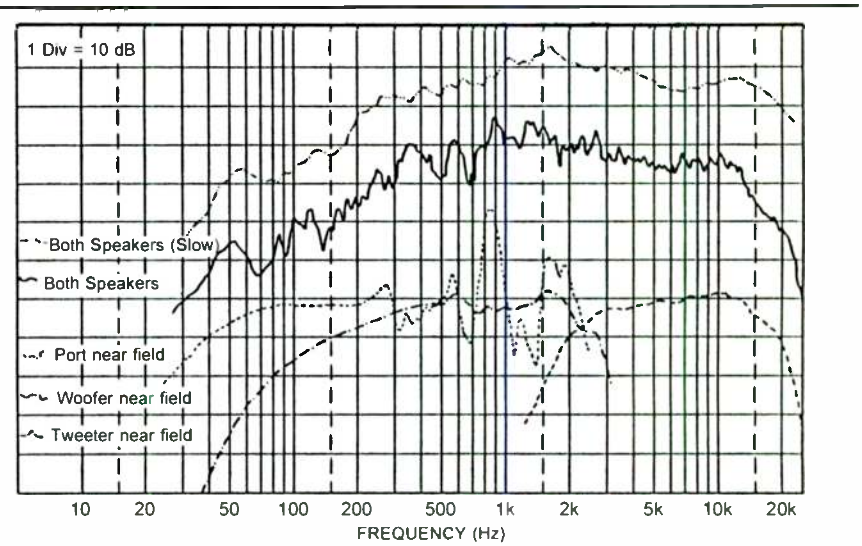


FIGURE 2: In-room, on-axis frequency responses of the first "final" enclosures with second-order low-pass filters and 63-mm-diameter ports. The speakers were 2.4 meters apart; the listening position was 3.4 meters from each speaker; and the signals were sine wave sweeps on a Denon Audio Technical CD (tracks 36 and 65). Note the near-field port spike around 850Hz.

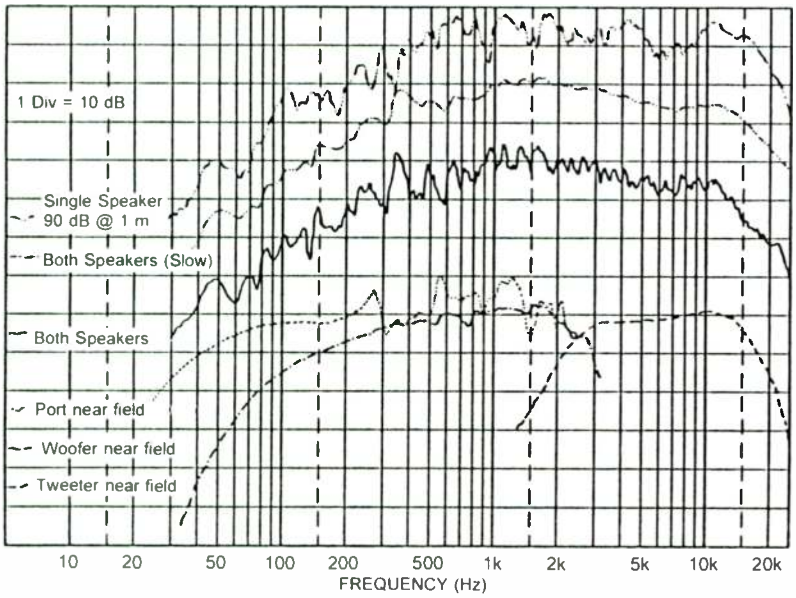


FIGURE 3: In-room, on-axis frequency responses of the modified first "final" enclosures with second-order low-pass filters and 51-mm-diameter ports. Note absence of major near-field port spikes.

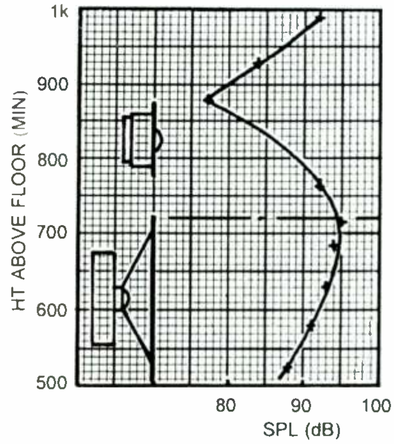


FIGURE 4: Extent of lobing at listening position for modified first "final" enclosure. The relative vertical and horizontal positions of the two drivers are superimposed on the plot.

fied and accelerated the frequency response testing process. I performed a series of tests from my normal listening position for both speakers, each speaker, and the speakers with and without grilles. (The room is less than ideal for this purpose, with an asymmetric setup and a ceiling which steps from 2.35–3.20 meters approximately midway between the speakers.)

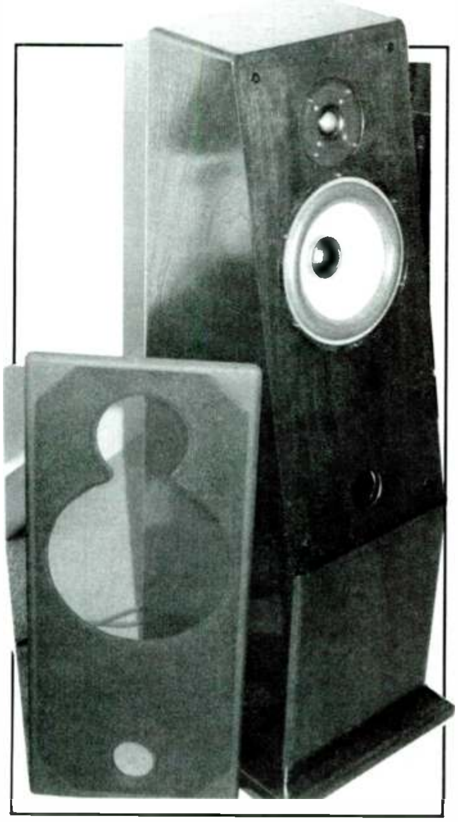


PHOTO 2: The completed final enclosure. The lower compartment housing the crossover filters is approximately 100 mm high.

The plots showed increased response levels around 1–2kHz and some dips in the 3–6kHz range. One speaker was more severe than the other, suggesting some room effects, but I could not entirely blame the room. Ralph Gonzales' crossover article ("Real-World Two-Way Crossovers: A Design Method, *SB* 2/92, p. 18) provided food for thought. The response rises were somewhere near the prerolloff lift shown in the woofer specification sheet. My crossover design seemed to follow Gonzales' "real-world" approach through the use of different high- and low-pass crossover frequencies.

The frequency of the response dip was higher than either crossover frequency, but perhaps reversing the tweeter polarity would help. More tests revealed no dramatic effects. The plots indicated, however, that the conventional polarity for even-order crossovers was correct in my case. I had also read that dips were easier to live with than humps, so I decided to concentrate on the latter.

Further hand plotting indicated a second-order Linkwitz-Riley low-pass filter might make some improvements without the need to alter the high-pass filter. So, I ordered new Solen capacitors and inductors, and the soldering iron was once again in action.

LOUDSPEAKERS AND PIPES. Listening tests suggested that while some improvements had been achieved, there were still a hump and a hint of a dip (*Fig. 2*). I recalled a review by Holt and Atkinson in *Stereophile* in which near-field testing had been used to locate a problem.[4] I wondered whether it would work for me. The tweeter and woofer responses were straightforward, but those peaks in the port response were another matter. Converting the frequencies of the peaks to wavelengths, and then calculating fractions and multiples of those wavelengths, resulted in some recurring values. They looked suspiciously like some of the internal dimensions of my enclosures.

I thought I must be paying the price for ignoring the golden ratio rule as it should be applied to enclosure dimensions. My conclusion that a resonance problem existed in the height of the box led me to place pieces of damping material in strategic locations. Further testing once again revealed that only minor improvements had been made.

After rereading Dickason's chapter on vented boxes, I found the answer in one of the simulation plots: pipe resonance—not in the enclosure but in the port. A further check on the wavelength calculations confirmed it. Values ranging from 188–196 mm were aplenty. The port length was 192 mm.

I now faced a further problem. My port at 63 mm diameter was already minimal according to theory. The next plastic pipe size, nominally 50 mm, was too small. Further examination of Dickason's simulations seemed to suggest that a vent with a length-to-diameter ratio of approximately two might have fewer problems. The ratio for my port was 3.0 whereas a 51-mm-diameter port would have a ratio of 2.3. I decided it was time to ignore the theoretical min-

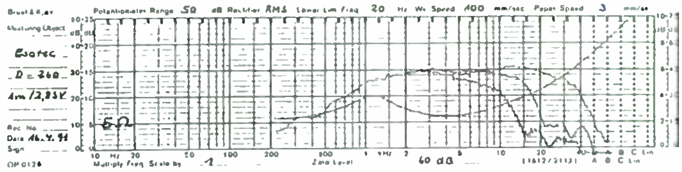
Continued on page 14

ESOTEC *Speakers by Dynaudio*

The Dynaudio Esotec loudspeakers represent a breakthrough in transducer technology with each stage of development aimed at creating ideal performance for a loudspeaker. The Esotec D-260 high frequency transducer is a culmination of thousands of hours of research and hundreds of thousands of dollars in tooling and dedicated instrumentation. The finished product was required to have the same precision tolerances as the now legendary ESOTAR series, but at a moderate finished cost. The end result is a tweeter with clear and accurate resolution, yet without a trace of sharpness even at highest output levels. Continuing this standard are three new cone transducers: the 15W75 midwoofer, utilizing a 5 inch cone and a 3 inch voice coil; the 17WLQ, a 6.5 inch woofer with a 3 inch coil, which can be used in either sealed or vented enclosures; and the latest development, the 20W75, an 8 inch woofer that also has a 3 inch voice coil and can develop very low bass (below 35 Hz) in moderate vented enclosures. All woofers feature cast frames, magnesium silicate impregnated polypropylene cones, butyl rubber surrounds, vented pole pieces, and laser cut precision spiders. These precision technologies incorporated into the ESOTEC drive units produce extremely smooth frequency response with the control and attack that is possible only with large voice coil design.

ESOTEC D-260

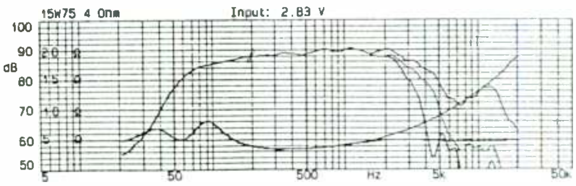
The D-260 is a 1" damped soft dome tweeter with a transmission line rear chamber. This new design gives this tweeter a very musical sound, clear and accurate. This driver will not compress, at loud volume it still reproduces a crystal clear sound.



Theile-Small Parameters:						Voice coil:		
Q, mechanical	Q_{ms}	0.83	eff. cone area	S_D	7.7 cm2	diameter	d	28 mm
Q, electrical	Q_{es}	1.14	moving mass	M_{ms}	0.51 g	length	h	2.8 mm
Q, total	Q_{ts}	0.48	lin. excursion (p-p)	X_{max}	0.3 mm	layers	n	2
Resonance, free air	fs	1000 Hz	max. excursion (p-p)		3.2 mm	inductance (10 KHz)	L_e	0.063 mH
force factor	BxL	3.9 Tm	**Power handling:**			nom. impedance	Z_{vc}	8 Ω
Equivalent volume	Vas	-	nominal (long term)	IEC	130 W	DC resistance	R_e	5.2 Ω
			transient	10ms	1,000 W			

ESOTEC 15W75

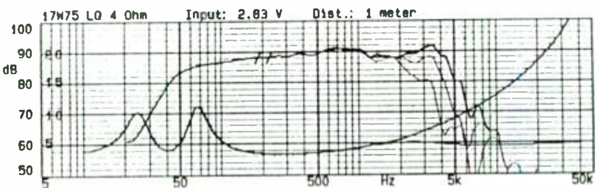
The 15W75 5" woofer with a 3" voice coil is a very fast midbass driver. The sound reproduction from this driver is very smooth and accurate. We have used this driver in 2-ways, MTM designs, autosound and as a midrange. The results were exceptional.



Theile-Small Parameters:		4Ω / 8Ω				Voice coil:		
Q, mechanical	Q_{ms}	1.7	eff. cone area	S_D	87 cm2	diameter	d	75 mm
Q, electrical	Q_{es}	0.6	moving mass	M_{ms}	12 g	length	h	10.5 / 10 mm
Q, total	Q_{ts}	0.4	lin. excursion (p-p)	X_{max}	5.5 mm	layers	n	2
Resonance, free air	fs	55 Hz	max. excursion (p-p)		15 mm	inductance (10 KHz)	L_e	0.15 / 0.19 mH
force factor	BxL	4.7 / 6.0 Tm	**Power handling:**			nom. impedance	Z_{vc}	4 / 8 Ω
Equivalent volume	Vas	7.5 l	nominal (long term)	IEC	130 W	DC resistance	R_e	3.0 / 4.9 Ω
			transient	10ms	1,000 W			

ESOTEC 17WLQ

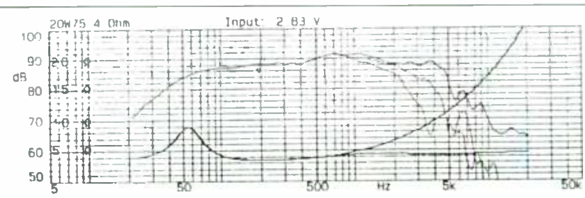
This driver should be in stock by Sept. so we don't have personal experience with it yet. It looks as if it should get down to 43Hz in .6ft^3 and 70Hz in a .4ft^3 sealed enclosure. If this driver is anything like its brothers, it will be worth waiting for.



Theile-Small Parameters:		4Ω / 8Ω				Voice coil:		
Q, mechanical	Q_{ms}	1.8	eff. cone area	S_D	120 cm2	diameter	d	75 mm
Q, electrical	Q_{es}	0.5	moving mass	M_{ms}	15 g	length	h	11.5 / 10.5 mm
Q, total	Q_{ts}	0.4	lin. excursion (p-p)	X_{max}	6.5 / 5.5 mm	layers	n	2
Resonance, free air	fs	40Hz	max. excursion (p-p)		17 mm	inductance (10 KHz)	L_e	0.15 / 0.19 mH
force factor	BxL	5.0 / 6.0 Tm	**Power handling:**			nom. impedance	Z_{vc}	4 / 8 Ω
Equivalent volume	Vas	22 l	nominal (long term)	IEC	130W	DC resistance	R_e	3.0 / 4.9 Ω
			transient	10ms	1,000W			

ESOTEC 20W75

The 20W75 has en extremely smooth roll off for an 8" woofer. This driver works well sealed or vented, with low F_3's in moderate sized boxes. The 4ohm driver has an f3 of 32Hz in a 1.8ft3 vented enclosure. Grills are available for autosound.



Theile-Small Parameters:		4Ω / 8Ω				Voice coil:		
Q, mechanical	Q_{ms}	1.5 / 1.8	eff. cone area	S_D	180 cm2	diameter	d	75 mm
Q, electrical	Q_{es}	0.5 / 0.7	moving mass	M_{ms}	20 g	length	h	13.6 / 14.2 mm
Q, total	Q_{ts}	0.4 / 0.5	lin. excursion (p-p)	X_{max}	8.6 / 9.2 mm	layers	n	2
Resonance, free air	fs	30 Hz	max. excursion (p-p)		15 mm	inductance (10 KHz)	L_e	0.2 / 0.3 mH
force factor	BxL	4.8 / 5.0 Tm	**Power handling:**			nom. impedance	Z_{vc}	4 / 8 Ω
Equivalent volume	Vas	64 / 65 l	nominal (long term)	IEC	130W	DC resistance	R_e	3.15 / 5.0 Ω
			transient	10ms	1,000W			

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Reader Service #1

Continued from page 12

imum diameter and try the smaller tube. Besides, many higher quality commercial speakers have relatively small vents. I was able to fit the new port neatly into sleeves of the 63-mm-diameter material, thus avoiding an untidy modification to the enclosures.

When I reviewed the near-field response plot for the new port (*Fig. 3*), I was like a kid with a new toy and settled back for some well-deserved listening enjoyment. Alas, there was still a dip around 6kHz and the high-frequency response seemed a little disappointing, though much of that disappointment appeared only on paper.

Gonzales referred to phase relationships—a bit complicated for me, though I understood the implications. His frequency response plots showed dips like mine and he eliminated them, in simulation, by moving the woofer. I now concentrated on testing frequency responses with the enclosure tilted backwards to varying degrees. The dip was virtually eliminated with the base 60 mm above the floor at the front edge. Measurement of sound levels for a 1kHz tone at various heights at the listening position confirmed the extent of lobing (*Fig. 4*), which was readily apparent during "normal" listening by slowly rising from a sitting to a standing position.

LAST "FINAL" DESIGN. Simulations by Dickason indicated that aligning driver zero delay phases (ZDP) in the same vertical plane by means of a sloping front baffle might not produce the same result as a time delay. While I could see the advantages of active crossovers with time delays, I opted for the simplicity of my existing passive filters. Logically, it seemed a stepped baffle might be a better solution when used in conjunction with Linkwitz-Riley crossovers. A practicable design given other constraints such as driver spacings, avoidance of reflections, diffractions and the like, was difficult to achieve. I soon realized that a sloping baffle was indeed a sensible compromise.

The new design (*Fig. 5*) was very similar to the original one, apart from the enclosure shape: $V_B = 31.5L$, $f_B = 35.5Hz$, $f_3 = 43.6Hz$, port diameter of 51 mm, port length of 117 mm. The slight differences were caused by changes to Q_{TS} following the use of second-order low-pass filters and subsequent lower series resistances. I retained the reticulated polyester-polyurethane foam as the damping material, but increased its thickness slightly to 30 mm. For convenience, I finished the 25 mm medium-density fiberboard with iron-on cedar veneer instead of the 1.5 mm plywood previously used.

Photo 2 shows the end result. While far less space was available in the lower compartment for the crossovers, careful

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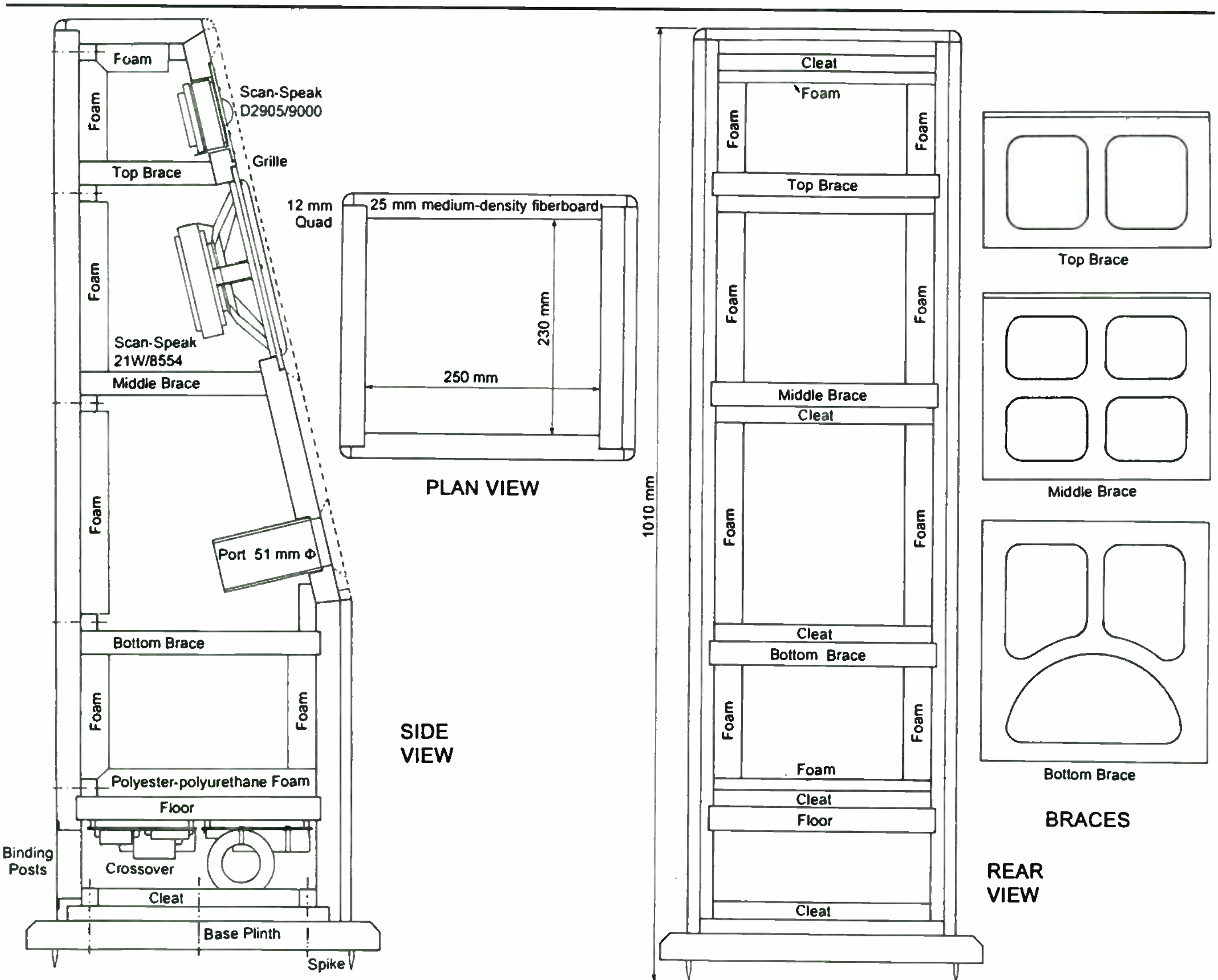

FIGURE 5: The final design. Note shelf bracing detail.

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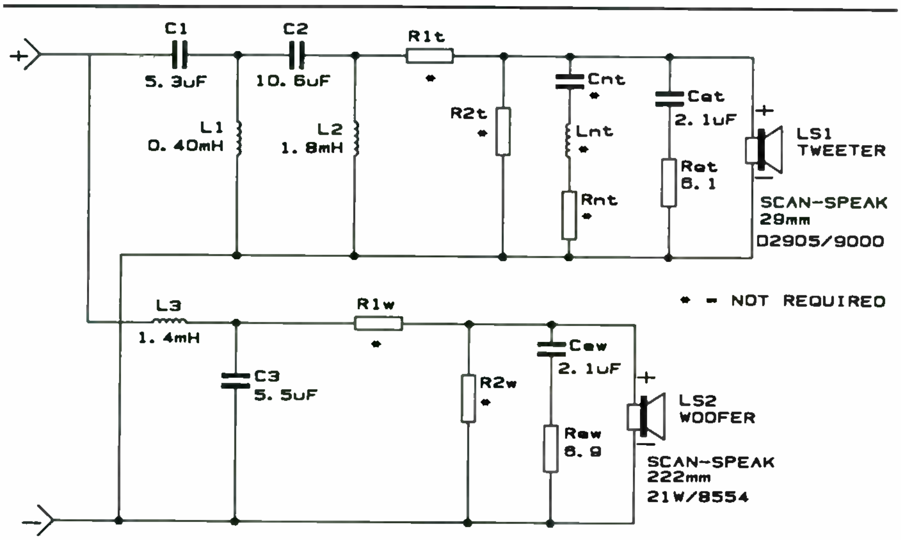

FIGURE 6: Two-way fourth-order HF and second-order LF crossover, attenuation and driver load compensating circuits. The final crossover design, with filters separated for bi-wiring. Neither the tweeter C-R filter nor the woofer notch filter were used. Conventional electrical symbols are not used due to software limitations.

Continued from page 14

planning ensured a neat fit. The final crossover circuits are shown in *Fig. 6*.

Subjective listening tests gave an immediate impression of a cleaner sound and more accurate soundstage. I detected the all too familiar low-frequency room effects during the sine wave sweep, but the high-frequency dip seemed to have disappeared. A friend who had shared the subjective listening thought the speakers were brighter than before.

What would the measurements show? I obtained the plots shown in *Fig. 7* from the sound level meter. They confirmed a significant improvement in the high-frequency response, including extension of the top end and virtual elimination of the 6kHz dip.

The box resonance frequency is still a little lower than design, f_3 probably higher, and Q_L is still low. All of which suggests there is still some misalignment and room for improvement—but I think I'll just sit back and enjoy the music.

POSTSCRIPT. I enjoyed the challenges of designing and building my own speakers, of testing them and analyzing the results. Perhaps, as a novice, I might be permitted one observation which appears to contradict established wisdom: the length of a port in vented enclosures should not be much greater than twice its diameter if significant pipe resonances are to be avoided, even if this requires a diameter smaller than that calculated as a minimum by other methods.

Having enjoyed the music for several months, I resumed the quest for perfection. My efforts were initially directed to finding the best room layout, compatible with other sensible requirements such as aesthetics and practicability. This exercise resulted in some loss of bass response, therefore, before looking further into room and cable aspects I decided to tune the speaker enclosures to their design frequency.

In an attempt to minimize trial and error, I looked to more scientific approaches. Analysis of the impedance curve indicated a Q_L closer to three than seven, and f_B approximately 31Hz instead of 35.5Hz. Redesigning the enclosures for Q_L of three gave a port length of 75 mm for the 51-mm-diameter port. This design increased V_B and f_B, but, as I did not intend to alter the boxes at this stage, I looked for an alternative approach which might confirm the new port dimension.

I tried the tuning formula in David Weems' book:

$$\Delta L_V = \frac{-\Delta f_B \times 2L_V}{f_B}$$

which gave a new port length of 87 mm—not very close to 75 mm. I could not establish a mathematical basis for Weems' approach. Since I intended to vary frequency with port length without altering box volume or port diameter, simple mathematics suggested I should differentiate Dickason's port length equation with respect to frequency. This gives:

$$\Delta L_V = \frac{-2 \times 9438.7 \times R^2}{V_B \times f_B^3} \times \Delta f_B$$

for V_B in liters, and L_V and R in millimeters. ΔL_V and Δf_B are changes in port length and box frequency, respectively. The new port length calculated by this method was 78 mm.

I opted for a port length of 80 mm as a first try, resulting in a new f_B of 34.5Hz, only 1Hz below design. Reapplying my formula suggested a further shortening to 70 mm. This time, the tuned box frequency was 35.5Hz. As might be expected, bass response improved as a result of this tweaking.

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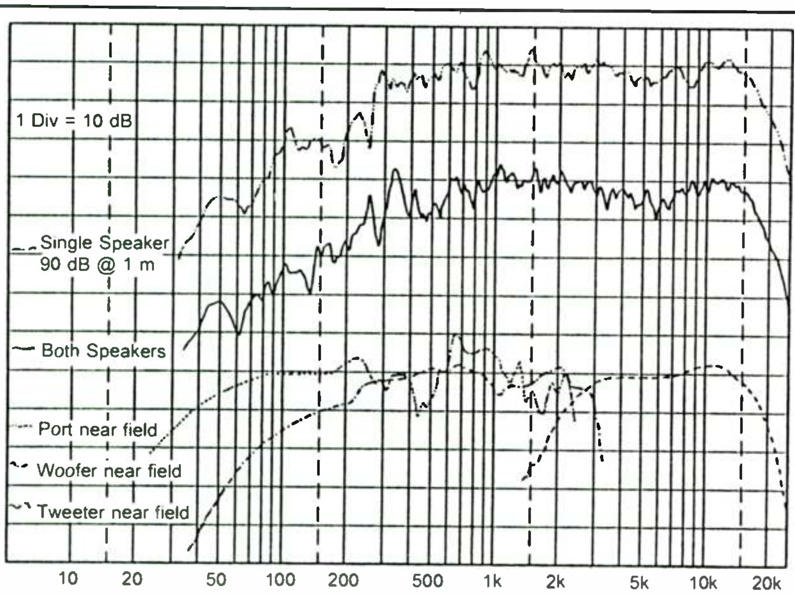

FIGURE 7: In-room, on-axis frequency responses of the final enclosures with second-order low-pass filters, vertically aligned driver ZDPs, and 51-mm-diameter ports. Note the high-frequency extension and elimination of the 6kHz dip.

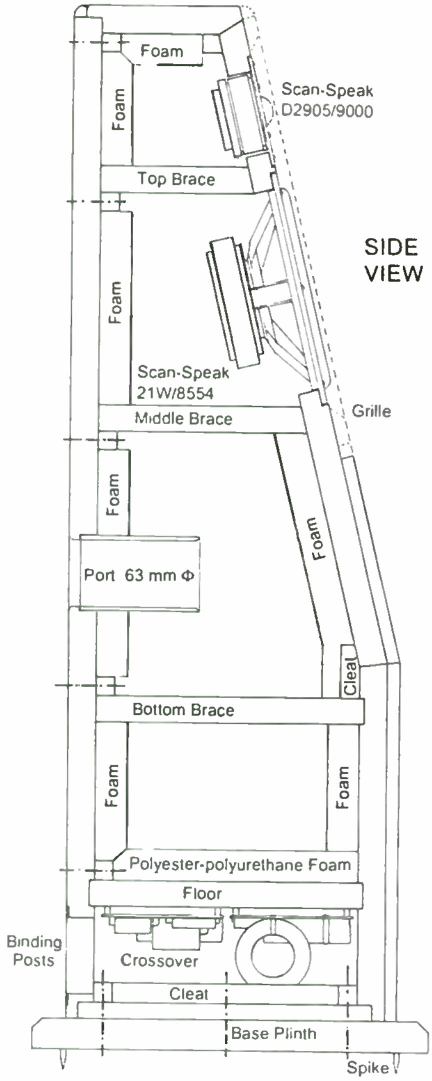

FIGURE 8: The modified final design.

Continued from page 16

HEAVY BREATHING. My family must have thought I was now ready for some serious listening, because they presented me with a magnificent reclining chair for my birthday. It was duly located on the "sweet spot"—but, alas, no bass!

After all my hard work, I decided it had to be the room. Testing with 40 and 80Hz tones confirmed my suspicions. An enormous black hole existed in a band where the chair was sitting. Moving the speakers closer to and farther from the wall seemed to change the black hole's location only slightly. Fortunately, I was able to move the chair to a new position closer to the speakers and restore my faith in my craftsmanship.

The low-frequency testing revealed the 51-mm-diameter port was having some breathing difficulties at higher listening levels. Because I had shortened the port to tune the enclosure, perhaps I could revert to the 63-mm-diameter tube without reintroducing the resonance problems which had plagued the prototype.

Using the same approach to determine the correct length, I calculated that the larger port should be between 125-130 mm long. As this resulted in a length-to-diameter ratio of about two, I was fairly confident that resonance should not be a problem.

ABOUT FACE. Installing a larger port in the same place as the existing one without damaging or spoiling the enclosure was almost impossible. The rear

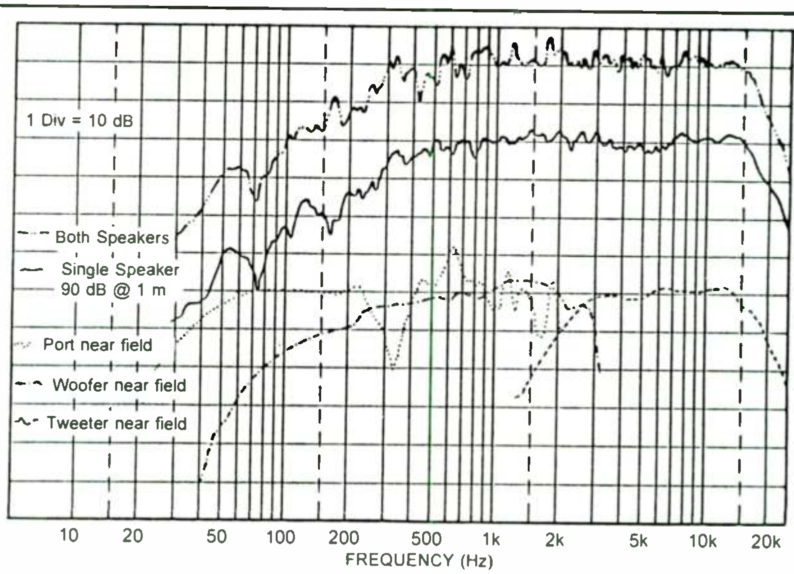

FIGURE 9: In-room, on-axis frequency response of the modified final enclosure with second-order low-pass filters, vertically aligned driver ZDPs, and 63-mm-diameter ports. The speakers were 1.9 meters apart; the listening position was 2.7 meters from each speaker. The signals were sine wave sweeps on a Denon Audio Technical CD (tracks 36 and 65). Note the high- and low-frequency improvements.

panel offered a solution, but I was wary. In his book, Vance Dickason suggested that a rear vent was an acceptable alternative. I carried out a survey of recommended speakers in several respected hi-fi journals. The overwhelming majority of those with vented enclosures had ports in the back panel. So I proceeded.

I was glad I had decided to fix the back panel with cap-screws and T-nuts. I plugged the hole where the 51 mm port had been in each enclosure, and then extended the extra thickness of 12 mm plywood and cedar veneer of the lower baffle to conceal the plug. I shortened the grille by 200 mm, as shown in *Fig. 8*.

Fitting the new port to the back panel without damaging the previously finished surface was a relatively simple matter. One test run resulted in the ports being trimmed to a final length of 123 mm to achieve the tuned box frequency of 35.5Hz.

During all this testing, I rediscovered that one of the tweeters was 8dB down over the 3–6kHz range. This was undoubtedly contributing to the slight dip in response evident in the plot in *Fig. 7*. With Arthur Rosenblum's help, I replaced the tweeters within a week. The improvement was immediately obvious during listening tests. There was more precise imaging and far greater clarity, particularly in the higher frequencies in orchestral works. I was also able to measure an improvement, as *Fig. 9* shows. Back to the serious listening. . . .

SOURCES

A&S Speakers
3170 23rd St.
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(Scan-Speak speakers, crossover components, miscellaneous hardware)

Caxton Street Audio
18 Caxton St.
Brisbane QLD 4000
Australia
(cables, banana plugs)

REFERENCES

1. Weems, David B., *Designing, Building and Testing Your Own Speaker System—With Projects*, 3rd Ed., TAB Books, 1990.
2. McComb, Gordon, *Building Speaker Systems*, Master Publishing Inc., 1988.
3. Dickason, Vance, *The Loudspeaker Design Cookbook*, 4th Ed., Audio Amateur Press, 1991.
4. Holt, J. Gordon and John Atkinson, "Nelson-Reed 804-CM Loudspeaker," *Stereophile* (March 1992): 99–103.

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MATCHING DRIVER EFFICIENCIES

BY JOHN I. LIPP

I have long wondered why the driver sensitivity ratings provided by many manufacturers never seem to match the calculated efficiency. In particular, the frequency response graphs of 4Ω drivers typically show them close to 3dB more efficient than predicted by Small's equation.[1] How could Small's driver analysis, which is so accurate for predicting low-frequency response, be so inaccurate elsewhere?

Small's expression for power efficiency, where V_{AS} is in cubic feet, is:

$$\eta_O = \frac{2.77 \times 10^{-8} f_S^3 V_{AS}}{Q_{ES}}$$

or, where V_{AS} is in liters:

$$\eta_O = \frac{9.78 \times 10^{-10} f_S^3 V_{AS}}{Q_{ES}}$$

The equation commonly used by driver manufacturers to estimate efficiency, often called sensitivity, at 1W/1M is:

$$\eta_O \text{ (in decibels)} = 112.2 + 10\log_{10}(\eta_O)$$

While correct, it fails to take amplifier reality into account.

MISLEADING MISSIVES. The parameter η_O is a driver's *power* efficiency. Although we refer to "power amplifiers" in a stereo system, they do not amplify power. Rather, they amplify the voltage output from CD players and such devices to a higher voltage which can drive a loudspeaker. This process draws a substantial amount of power from the amplifier, so the term "power amplifier" is applied to them. While not inaccurate, the term is misleading.

Manufacturers and reviewers test every driver and loudspeaker system using the same voltage level. "At 1W/1M" translates into "at a voltage which produces 1W into a typical loudspeaker load at 1M distance." For an 8Ω driver, that voltage is approximately 2.83V RMS. A few manufacturers use 1W inputs for testing. In this case, every driver's input test voltage is calibrated to produce 1W of input power. The moral is: always read the fine print on test procedures, since they are inconsistent.

The power produced by a voltage V_{REF} into a resistor of value R is equal to V_{REF}^2/R. Since an amplifier produces a voltage output, drivers with different DC resistance values (R_E) will be driven by different amounts of power. More power is required for drivers with lower, rather than higher, R_E. When both are connected to the same amplifier, the former will be louder, even with identical η_O. If the lower-R_E driver is a woofer and the other a midrange, the resulting loudspeaker system will be bass heavy. Pronounced treble (very unpleasant) will result if the situation is reversed. To balance the system, either an attenuator on the midrange or a more efficiently rated woofer will be necessary.

TABLE 1

η_O AND η_E COMPARISONS

Driver		Manufacturer's Parameters					Efficiencies	
Brand	Model	f_S	R_E	Q_{ES}	V_{AS}	η_O	η_O	η_E
Morel	MW142	52	5.2	0.62	0.25	86	84.1	86.0
	MW1275	22	6.4	1.00	9.6	89	86.6	87.6
Focal	5N313	43.8	5.3	0.23	0.67	91	90.4	92.2
	7K011-DBL	33.1	3.0	0.26	1.77	93	90.5	94.7
Seas	11 F-M	150	6.5	1.2	0.04	89	86.5	87.4
	CB 17 RCY	41	5.7	0.35	1.10	91	89.9	91.4
Dynaudio	17M-75	74	5.5	2.13	0.21	87	82.6	84.2
	24W-75	33	5.5	1.11	3.12	89	86.6	88.2
Vifa	P21W0-12	33	5.8	0.39	3.00	92	91.0	92.4
	P25W0	24	5.7	0.30	6.29	90	91.2	92.6
Zalytron	10 inch	25	6.0	0.31	5.40	92	90.9	92.1
	12 inch DVC	20	2.9	0.51	9.57	93	88.3	92.7
McCauley	6334	64	6.0	0.26	1.84	101	99.2	100.5
	6224	42	6.0	0.33	6.47	100	98.2	99.4

The efficiency η_O, under manufacturer's parameters, is that provided by the manufacturer unless frequency response graphs indicate otherwise. All efficiencies are in decibels; V_{AS} is specified in cubic feet.

ABOUT THE AUTHOR

John Lipp's interest in loudspeaker building began when he rebuilt a pair with a bad tweeter. This led him to study loudspeaker design while earning a BS in electrical engineering at Michigan Technological University. John is currently working on his doctorate in electrical engineering in the area of image and signal processing. He enjoys writing computer software to aid in loudspeaker design and assists other amateur loudspeaker builders in the MTU Student Chapter of the Audio Engineering Society.

EFFICIENCY EXPERT. In order to successfully match driver efficiencies in multi-driver systems using η_O, you must take into account power level differences resulting from different R_Es. Otherwise, you will be comparing apples to oranges. To facilitate an accurate accounting, I have created a new efficiency parameter which I call η_E, the driver voltage efficiency:

$$\eta_E = \frac{V_{REF}^2 \, \eta_O}{R_E}$$

where V_{REF} is the RMS voltage value used in testing all of the drivers.

Typically, V_{REF} is 2.82843V RMS (1W into an 8Ω load). The voltage efficiency expression is then:

$$\eta_E = \frac{8}{R_E}\,\eta_O = \frac{K \, f_S^3 \, V_{AS}}{Q_{ES} \, R_E}$$

where $K = 2.22 \times 10^{-7}$ for V_{AS} in cubic feet, or $K = 7.83 \times 10^{-9}$ for V_{AS} in liters.

This will correct the power differences in any driver, including woofers, midranges, and tweeters which are dynamic, direct radiators. Be forewarned that η_E is not a true efficiency—it is a fictitious parameter. If R_E is very low or V_{REF} high, it is possible for η_E to be greater than 100%. This is, of course, impossible, emphasizing the fictitious nature of the parameter.

Table 1 lists data for drivers from several manufacturers chosen at random. Consider the Morel MW142. The calculated efficiency η_O is 84.0dB, which is 2.0dB off from Morel's claim and response graph indications. This apparent discrepancy is significant. Calculating η_E results in an efficiency rating of 86.0dB—right on the money! From the trend evident in *Table 1*, we see that η_E is the more accurate estimate of driver efficiency.

NO FREE LUNCH. The voltage efficiency equation also explains several loudspeaker phenomena. Two identical drivers connected electrically in parallel and mounted on the same baffle, for example, have half the R_E of a single driver (they are connected in parallel), but they have twice the V_{AS} because both are mounted on the same baffle. Thus:

$$\eta_E \text{ (two drivers)} = \frac{K \, f_S^3 \, (2V_{AS})}{Q_{ES}\,(0.5R_E)} = 4\,\frac{K \, f_S^3 \, V_{AS}}{Q_{ES} \, R_E} = 4\eta_E \text{ (one driver)}$$

The two drivers in parallel are four times (6dB) more efficient than a single driver; however, you cannot correctly predict this result with η_O. An Isobarik system with two woofers similarly connected has the same efficiency as a single woofer, with both R_E and V_{AS} half that of a single driver. Obviously, you don't get a smaller box for free. Two identical drivers connected electrically in series (twice the R_E and V_{AS}) also have the same efficiency as a single driver. All other factors being equal, a given driver's 4Ω version will be more efficient than its 8Ω version. (The lower Q_{ES} will further increase the efficiency.) Consequently, if you have found an excellent driver, but it is too inefficient for your design, its lower-impedance twin might work.

I hope this discussion of loudspeaker efficiencies will enhance your efforts to build a better loudspeaker. Besides explaining the difference in calculated efficiencies and those actually measured under typical operating conditions, it allows you to compute efficiency gains when using combinations of identical drivers, including Isobarik driver loading.

REFERENCE

Small, Richard H., "Direct-Radiator Loudspeaker System Analysis," *JAES*, Vol. 20, No. 5 (June 1972): 383–395.

A TWO-WOOFER BOX SYSTEM

BY PAUL T. FRANCIS

In *SB* 2/90 ("Woofer Alternatives," p. 50), Ralph Gonzalez presents a dual-woofer alternative to the compound (Isobarik) configuration. He suggests doubling each driver's cone mass by adding weights, connecting the voice coils in parallel, and mounting them on the front panel in the standard configuration.

Compared to a single unmodified driver, F_S drops to $1/\sqrt{2}$ times normal value (0.707), and Q_{TS} rises to $\sqrt{2}$ times normal (1.4144). Impedance halves and V_{AS} doubles. Overall sensitivity is the same, because the parallel connection offers increased sensitivity which balances the loss incurred by the added cone mass. In effect, this combination creates a "duo driver" with unique parameters.

With four idle 6½" Peerless drivers on hand ("surplus" cast-frame, poly-cone units, now unavailable), I thought it might be worthwhile to try this approach, because the lower F_S and higher Q_{TS} would shift their parameters into closed-box territory. Using averaged Thiele/Small (T/S) parameters, the calculated performance showed bass response below 40Hz in acceptably small boxes. (Two similar drivers in small, stuffed, closed boxes had smooth response to 3.5kHz, but F_C was just under 80Hz.)

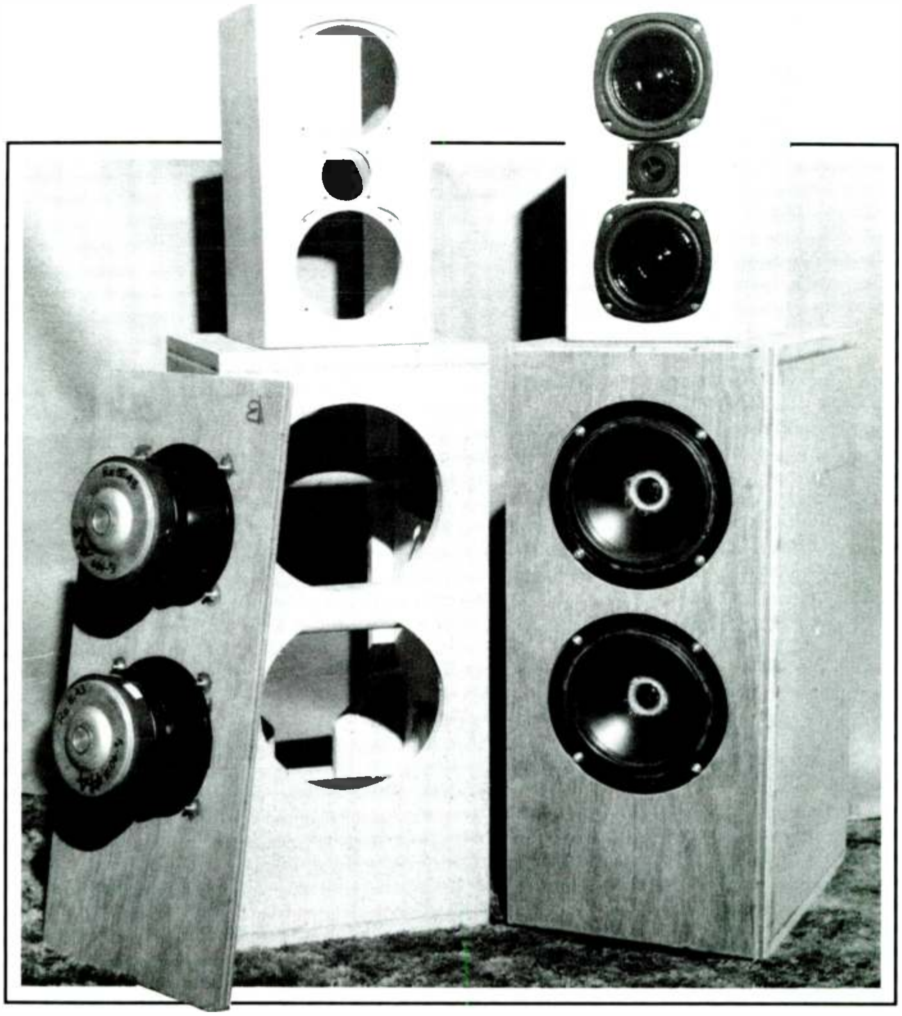

PHOTO 1: Original test system with its minimum-cost mid-high module, now replaced with multi-directional, eight-driver (per side) unit. The woofer itself was inverted to make use of the Allison effect, and the side panels were modified by attaching extra half-inch-thick plywood panels to the outside surfaces.

The "duo driver" would have an F_S of 28Hz, Q_{TS} of 0.54, V_{AS} of 1.62 ft.^{3}, cone area equal to a 9" driver, smooth response to 3.2kHz, and good dispersion to near 3kHz with vertical driver placement. It would be suitable for both two- and three-way systems and a natural for the D'Appolito (MTM) configuration.

RINGMASTER. For cone weights, I trimmed ¼" strips from a sheet of lead roof flashing and formed them into rings which fit around the dust cap. Monitoring F_S, I taped them to the cone until I was within about 2Hz of the target frequency (0.707), then embedded the rings in a bead of silicone sealer around the dust cap, and attached any small pieces symmetrically around the rings. When the sealer cured, I made final adjustments with additional sealer and a bit more lead. (I took all measurements with the speaker in its normal vertical position.)

While this procedure may seem somewhat tedious, it provides a safety factor. Besides, things tend to go quickly once you know the approximate strip length you'll need. You can correct accidental

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ABOUT THE AUTHOR

Paul Francis' interest in "hi-fi" reproduction became an avocation in the early '50s with the advent of test instrument kits. He constructed all of his amps, preamps, and other gadgets, several of proprietary design, but speakers were always his main interest. In a brief memory review, he counted 28 projects accomplished. Now retired, he enjoys writing essays on audio-related subjects.

BLACK HOLE

High efficiency dampening products from ORCA

A better speaker damping material...

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.

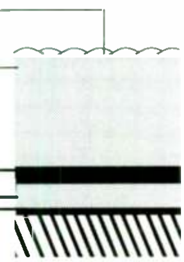
First, THE PAD. It's a thin (1/16 inch) black flexible viscoelastic damping material (filled vinyl copolymer) with maximum performance between 50 and 100 degrees F (we hope that that covers the temperature range of your listening room) and excellent flame resistance - it meets UL94 V-O. Thanks to its 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!***

orca 1531 Lookout Drive
Agoura, CA 91301 U.S.A
818-707-1629
FAX 818-991-3072

AΞON Cables

New from ORCA!

AX-ON (Greek axon, axis): that part of a nerve cell through which impulses travel away from the cell body. AXON 8 speaker cable combines outstanding design features with component quality usually associated with the most expensive cable. With eight AXON 1 solid-core conductors and utilizing mylar/ polypropylene construction, AXON 8 offers outstanding performance for amp-speaker connections and perfectionist internal speaker wiring. Our superb AXON 1 AWG 20 solid core conductor is also available separately. Oxygen-free and 99.997% pure, it is ideal for most internal wiring applications.

Outer insulation: UL approved TPE
Cable geometry: non interleaved spiral
Individual conductor insulation: 105 degree Celsius, UL approved PVC
Cable equivalent gauge: total - AWG 11, 2 conductors - AWG 17, 4 conductors - AWG 14
Individual conductors: solid core AWG 20 copper, long-grain and ultra-soft, free of all contaminants and oxygen.
Cable core: crushed polypropylene
Inner envelope: mylar film

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overweighting by snipping V-cuts in the ring. No matter what method you use, it helps to first measure the F_S and determine each driver's target frequency. (I taped this information to the frame to avoid confusion.)

For those of you who hesitate to alter permanently four valuable drivers, an alternative is to attach styrofoam pads around the dust cap with a minimum of silicone sealer. Attach the weights to the foam, which you can easily remove with a small brush dipped in acetone. This dissolves the styrofoam almost instantly, and the small amount of remaining sealer will insignificantly affect the cone's performance. Just be certain you have styrofoam in the first place.

After determining that small errors in V_{AS} measurement would have little effect on final performance (*Fig. 1*), I chose a system Q of 0.8. The boxes are ¾″ particleboard with panel and crossbracing, plus a double-thick speaker panel. I applied two coats of acoustic damping to all interior surfaces and filled the 1.3 ft.^{3} net volume with 9 oz. of Acousta-Stuf. The average F_C was 41.5Hz and near-field measurements indicated an f_3 at exactly 37Hz (*Photo 1*).

As this was only a trial system, I modified a small, experimental, two-way box system to suit the purpose. With two Pioneer 4½″ (modified) woofers and one Audax TW51A tweeter per side, they produced a sound which belied their modest cost.

An Audio Concepts G2 (aperiodic) and two proprietary closed-box systems were available for comparative listening tests. One of the latter used an Audio Concepts 10″ woofer, and the other an Eminence EM40. Each was capable of excellent bass reproduction, although the older Eminence didn't reach quite as deep as the others due to a size/bass tradeoff. Each produced very good full-range sound.

TABLE 1

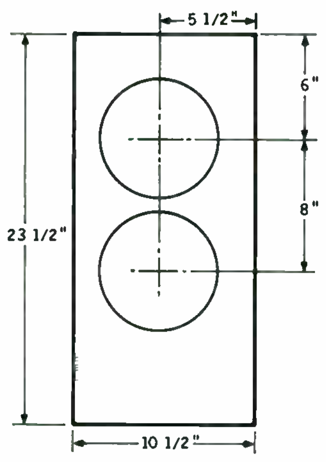
AVERAGED DRIVER PARAMETERS

	F_S	Q_{TS}	V_{AS} (ft.^{3})
Unweighted	39.6	0.381	0.81
Weighted	28.0	0.54	1.62

TABLE 2

CLOSED BOX RESPONSE

Q_C	F_C	f_3	VOLUME (ft.^{3})
0.7	36.7	36.7	2.27
0.8	41.5	37.2	1.35
0.9	46.6	38.7	0.91
1.0	51.8	40.8	0.67



BOX DIMENSIONS

INSIDE: 9 x 22 x 12 1/4"
OUTSIDE: 10 1/2 x 23 1/2 x 14 1/2"*
*DOUBLE-THICK SPEAKER PANEL

FIGURE 1: Box dimensions. Driver placements were chosen to avoid equal distances from top or side panels while allowing space for a heavy edge-on brace between drivers. The box is over-volumed to allow for additional bracing.

WCA W/O DOUBT. Listening tests soon revealed that, in terms of sound quality, the Weighted Cone Alternative (WCA) conceded nothing to the other systems. Very low organ tones were reproduced with an ease and clarity which implied bass capability far below f_3. From symphony orchestra to solo piano, the WCA's sound was open and detailed with truly outstanding transients. I could hear no change in quality at loud volumes, mid-bass heaviness or any particular coloration, and they passed the male-voice test with ease. The bass range sounded more realistic than with any comparative system, regardless of music source.

While the halved impedance may be uncomfortable for some, any reasonably good amplifier should easily handle a 4Ω load and provide more output watts as well. If you insist on 8Ω, use a dual 8/8Ω voice coil driver, with the voice coils connected in series and the drivers in parallel. Impedance will be 8Ω, and sensitivity will equal that of a single, unmodified driver with the same voice coil connection. (The Madisound 1027, 1052DVC, and Seas P-21REQ/DC allow reasonable box volumes in this application.) Another option, albeit expensive, would be to use two series-connected pairs per side.

Drivers can also be connected in series, but impedance doubles and sensitivity drops 6dB. You might use this configuration with high-output 4Ω drivers, such as those found in auto applications.

Since the WCA approach alters only driver parameters and sensitivity, it can be applied to any enclosure type. It may take a bit of searching to find the driver best suited to your purpose. If all other factors are more or less equal, choose the driver with the greatest linear excursion (X_{MAX}), especially with 6½″ or 8″ units.

In closed boxes, the WCA requires at least twice the volume of a similar system using unmodified drivers, but you gain an octave of bass. This is a tradeoff worth considering for new systems or woofer upgrades. I'm aware of no other technique which significantly lowers driver resonant frequency and maintains single-driver sensitivity.

This project delivers the deepest, most authentic bass I've yet heard from any system of such simplicity, size or cost. Its deep-bass potential opens exciting possibilities for two-way systems using 6½″ or 8″ drivers that are well worthy of "full-range" designation. A driver which reaches below 40Hz in just 1 ft.^{3}, plus an appropriate tweeter in the D'Appolito arrangement, should get any such effort off to a good start.

TABLE 3

TYPICAL DUAL-WOOFER DRIVERS

DRIVER	SIZE (″)	Q_{TC}	f_3 (Hz)
Eclipse 6518R	6½	0.9	37
Madisound 6102	6½	1.0	31
Seas PI7RE	6½	0.75	38
Vifa PI7WJ	6½	0.85	39
Zalytron Model 14	6½	1.1	33
Eclipse W0838R	8	1.1	30
Madisound 81524DVC	8	0.85	35
Madisound 8154	8	0.7	38
Seas CA21RE4X/DC	8	0.9	39
Madisound 10207DVC	10	0.95	36

Above is a sampling of readily available dual-woofer drivers having a typical variety of parameters and cone/surround materials. The calculated F_S and Q_{TC} figures indicate their performance in a 1.3 ft.^{3} box in the dual-woofer configuration. For your own calculations, multiply the driver's F_S by 0.707, the Q_{TS} by 1.4144, and the V_{AS} by 2. Then proceed as usual.

SOURCES

Madisound Speaker Components
8608 University Green
Box 44283
Madison, WI 53744-4283
(608) 831-3433
FAX (608) 831-3771

Meniscus
2442 28th St. SW
Wyoming, MI 49509
(616) 534-9121
FAX (616) 534-7676

Zalytron Industries Corp.
469 Jericho Tpk.
Mineola, NY 11501
(516) 747-3515
FAX (516) 294-1943

DESIGNING A DUAL-VOICE-COIL SUBWOOFER

BY STEVEN A. CROSBY

This project originated when a discussion with my friend Sam turned into an offer to build a subwoofer for his speakers, which had disappointing bass. His listening room was a converted garage about 12′ × 20′. The only listening position was at his desk, which was in the middle of one of the long walls.

The stereo was directly across from the desk. A cabinet housed the electronics, with both speakers on top and angled outward. A quick listen confirmed Sam's complaint: very little bass.

BASS RIDDLE. The speakers, 6½″ ported two-ways, should have produced better bass. I thought they might be wired out of phase; however, when I reversed the connections at one speaker, the bass was eliminated altogether. As all the drivers were operating, I abandoned trying to find a cause and instead sought a cure.

Since room boundaries reinforce the bass, and since most reinforcement comes from corner placement, I suggested we first try positioning the speakers in the corners of the long wall. That solved the lost-bass riddle. It wasn't thunderous, but it was there. As I expected, however, placing the speakers that far apart caused a thinness of the center image, analogous to an aisle down the middle of an orchestra. When the image went full right or left, it spread to the sides.

The room decor prevented positioning the speakers against any other wall. Finally, we decided a subwoofer was the best recourse. It would allow us to bring the main speakers in from the corners, filling the hole in the center, and provide a good deal more bass than the main speakers ever could.

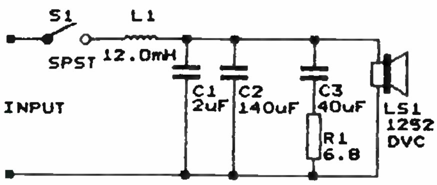


FIGURE 1: Crossover schematic (for each voice coil; a total of two are required).

Since cost was a factor and high SPLs were unnecessary, we settled on a single enclosure, dual-voice-coil design. We planned on running the right and left channels to their respective voice coils, and quickly eliminated the vented and horn enclosures in favor of a sealed one for its small size and ease of construction. Sam liked a Butterworth response (Q_{TC} = 0.707) or a little above that if we needed to keep the enclosure to a manageable size. We later decided to go with aperiodic loading for reduced ringing and impedance peak. I also planned to use driver impedance compensation to optimize the crossover performance (*Fig. 1*).

DRIVER'S TEST. One driver seemed particularly well-suited for our project: the Madisound 1252 DVC (*Table 1*). When I plugged the manufacturer's specifications (f_S = 19Hz, Q_{TS} = 0.36, V_{AS} = 318 ltrs.) into my computer program, I arrived at an f_3 of 37Hz in a 3.9 ft.^{3} enclosure for a Q_{TC} of 0.707.

For testing purposes, I had the equipment to measure f_S and Q_{TS}, but not V_{AS}. According to Joe D'Appolito (*SB* 4/82, p. 41), a 25% variation in V_{AS} will produce less than a 1dB variation in bandpass response. I decided to test the two measurable parameters and use the manufacturer's specification for V_{AS}.

I was also interested in finding how the parameters would change during the break-in period. This would require making tests every hour until the readings stabilized. As this was my first experience with a dual-voice-coil driver, I was also curious to see how the parameters would change with the coils driven in series, in parallel, with one coil driven, and with each coil driven by separate amplifier channels, as in the finished system.

After mounting the driver by taping the magnet to the paint shelf of my 6′ step ladder, I set up the test equipment on a table in the corner and ran cables to the driver in the middle of the room. I applied the testing procedure in *The Loudspeaker Design Cookbook* for f_S and Q_{TS}, using an oscilloscope, a digital multimeter (DMM), a sine wave generator, and a 40W/channel amplifier.[1]

I measured the voice coil DC resistances (although not directly using the multimeter as I thought errors were likely at such low values) by first measuring a 150Ω resistor. This value kept me

TABLE 1

SUBWOOFER PARTS LIST

QTY.	DESCRIPTION
2	140µF bipolar electrolytic capacitor
2	40µF bipolar electrolytic capacitor
2	2µF Châteauroux capacitor
2	12.0mH Sledgehammer audio inductor
2	LP100 L-pad
2	6.8Ω 5% 25W resistor
1	Dynaudio Variovent
1	1252 DVC 12″ woofer
	Terminal blocks, spade lugs*

*Available from Radio Shack. All other parts may be obtained through Madisound.

ABOUT THE AUTHOR

Steven A. Crosby has been an electronics technician in the USAF since 1983, and has been studying audio and speaker building for 15 years. His ultimate goal is to design and build all components in his audio system except the signal sources. He lives with his wife and two daughters in rural England.

in the DMM's lowest range, but was high enough to stabilize the reading. I then connected the resistor to one driver terminal and measured it and the voice coil in series. I subtracted the previous reading and was left with the voice coil's DC resistance. This method eliminates any resistance of the test leads. Since the soundwaves from any noise cause the cone to move slightly, causing fluctuations in the meter reading, a quiet room is essential. The DC resistance (R_E) of both coils was identical at 5.9Ω.

TABLE 2

TEST RESULTS WITH ONE-HOUR BREAK-IN PERIOD

	TEST 3	TEST 4	TEST 5
F_S (Hz)	15.2	15.2	15.2
I_C (mA)	43.7	43.4	43.6
I_E (mA)	37.0	36.8	36.9
I_O (mA)	3.0	3.1	3.0
R_O	12.3	11.9	12.3
I_R (mA)	10.5	10.7	10.5
F1 (Hz)	10.6	10.6	10.6
F2 (Hz)	20.8	21.0	20.8
Q_{MS}	5.23	5.03	5.22
Q_{ES}	0.46	0.46	0.46
Q_{TS}	0.42	0.42	0.42

I wired the two voice coils in series because this configuration supposedly gives better results than a parallel connection. I then ran the signal generator output into the amplifier inputs. (I was using the amp to provide enough power to drive the speaker for the break-in period.) I ran the amp's negative output directly to the driver, and the positive output through the DMM (set for current) to the driver. The oscilloscope, connected to the driver terminals, monitored the voltage and signal frequency to obtain the optimum signal voltage of 0.2–0.7V. The amp output level, which I adjusted for 0.424V RMS at the driver, equaled 1.2V PP.

To find the free-air resonance (f_S)—the point of highest impedance, hence the lowest current—I adjusted the signal generator frequency until I found the lowest current reading on the DMM. The oscilloscope showed a frequency of 64ms or 15.6Hz. When I raised the frequency, the current increased, indicating this value was correct.

Using the same method I had used to measure the voice coil DC resistance, I set a potentiometer (R_C) to 5.9Ω. When I placed it in the circuit, the current through it (I_C) at 15.6Hz measured 81mA. Since $R_C = R_E$, then $I_C = I_E$, thus I_E = 81mA. I reconnected the driver and the current through it (I_O) measured 3mA. Then $R_O = I_E/I_O$, or R_O = 27. Next, $I_R = \sqrt{I_E} \times I_O$, so I_R = 15.6mA.

The frequencies above and below 15.6Hz where the current equaled 15.6mA were approximately 8Hz and 25Hz. I paid strict attention to the oscilloscope, because as frequency decreased, so did the output level of the amplifier. The voltage level at the driver must be the same for all measurements. The formulas in *The Loudspeaker Design Cookbook* gave me a Q_{MS} of 4.74, a Q_{ES} of 0.21, and a Q_{TS} of 0.20. I decided the break-in would raise these values, so I increased the output level until the driver cone moved a good amount and ran it that way for an hour.

The next set of measurements again resulted in an f_S of 15.6Hz. Substituting the potentiometer (R_C), set for 5.9Ω, for the driver resulted in a reading of 68.5mA (I_C) at 15.6Hz. This caused me some concern, because if the resistance and voltage remained the same, the current should have been 81mA. A quick check with a calculator showed the 68.5mA reading was probably correct. I must have accidentally moved the potentiometer shaft before the first test.

Again, since $R_C = R_E$, then I_E = 68.5mA. After reconnecting the driver, I_O = 3mA. R_O = 22.8, and I_R = 14.3mA. Current equaled 14.3mA at approximately 9.6Hz and 23.8Hz. The formulas gave me Q_{MS} = 5.25, Q_{ES} = 0.24, and Q_{TS} = 0.23. Since these values were still very low, I ran another break-in cycle and reviewed the procedure. I discovered I had been using 5.9Ω as equal to the voice coil DC resistance; however, since the voice coils were wired in series, I should have used 11.8Ω.

I took three more series of tests, alternating them with one hour break-in periods (*Table 2*). The only change was to a 10Ω resistor (R_C) instead of the potentiometer, because it was closer to the 11.8Ω voice coil resistance (R_E). I used the formula $I_E = (I_C \times R_C)/R_E$.

As the values seemed to be changing very little, I surmised that I was not allowing a sufficient break-in period between tests. I ran the driver at f_S with a good amount of cone travel for four hours and conducted the final four tests: the voice coils wired in series (#6) and in parallel (#7), one coil driven (#8), and driven by separate amplifier channels with one coil measured (#9). For test #7, I used two 10Ω resistors in parallel for R_C. *Table 3* lists the results.

I decided to use the results from test #6 as the correct values. As for my break-in time experiment, I could find no appreciable differences within ten hours of testing, so I couldn't draw any conclusions. The other tests worked out well and gave the predicted results, although I questioned the validity of test #9. Plugging the two measured (f_S and Q_{TS}) and one manufacturer's (V_{AS}) values into my computer program resulted in an f_3 of 26Hz in a 6.1 ft.^{3} enclosure (Q_{TC} = 0.707). We decided to go with an 18″ cube (internally) for 3.375 ft.^{3}, which resulted in a Q_{TC} of approximately 0.87 and an f_3 of approximately 27Hz.

THE PLOTS THICKEN. I turned the driver over to Sam, as he was to build the enclosure. I simply told him to make it as rigid as possible. He planned to use 1.5-inch-thick particleboard. When he dropped off the completed enclosure, I found he had used ⅝″ plywood instead. The internal dimensions were 18 × 18 × 16 for a 3 ft.^{3} volume. He used butt joints which were glued and screwed together.

He mounted the driver in the center of the front baffle, and ran the speaker wires out a small hole in the back of the enclosure. The driver was secured to the front panel with drywall mounts which he had inserted into holes drilled into the baffle. As the screws are tightened, the interior portion of the mount collapses so it can't come back through the hole.

I removed the driver and applied some clear silicone caulk to the baffle. I then replaced the driver, tightened the screws until the caulk began oozing out, and let it dry overnight. I also caulked the hole in the back of the enclosure for the speaker wires.

I planned to run some impedance plots with the driver in the enclosure. The results would indicate the accuracy of my Thiele/Small predictions and allow me to calculate the impedance compensation circuit components (zobel) values. I made these measurements at the end of the speaker wires, feeding the sine wave generator into the amplifier, then the amp output through the DMM (set for current) to the driver. I used the oscilloscope to

Continued on page 30

TABLE 3

FINAL TEST RESULTS

	TEST 6	TEST 7	TEST 8	TEST 9
R_E (Ω)	11.8	2.95	5.9	5.9
F_S (Hz)	15.6	15.6	15.6	15.6
I_C (mA)	43.5	83.2	43.0	43.0
I_E (mA)	36.9	147.0	72.9	72.9
I_O (mA)	3.7	14.3	12.8	13.1
R_O	10.0	10.3	5.7	5.6
I_R (mA)	11.7	45.8	30.5	30.9
F1 (Hz)	10.0	10.3	11.5	8.3
F2 (Hz)	21.7	21.7	20.0	25.6
Q_{MS}	4.21	4.37	4.37	2.13
Q_{ES}	0.47	0.47	0.93	0.48
Q_{TS}	0.42	0.42	0.77	0.39

Sound Reinforcement Handbook — BKHL1 — $34.95

Sound reinforcement is the use of audio amplification systems. This book is the first and only one of its kind to cover all aspects of designing and using such systems for public address and musical performance. It features the audio theory involved, as well as practical applications, and covers everything from microphones to loudspeakers. Revised second edition has almost 40 new pages; index; new material on MIDI and synchronization; and a new appendix on logorithms. By Gary Davis and Ralph Jones, for Yamaha. 1987, 1989, 418pp., 8½ x 11, softbound.

IASCA Official Judging Rules — BKIA1 — $19.95

A must for all car audio aficionados--as well as handy for audiophiles of all types--this handbook outlines the competition criteria of the International Auto Sound Challenge Association. Packed with tips and techniques and written by real pros, a unique and interesting addition to any audio shelf. By IASCA. 191pp.

Mobile Electronics Certification Program Study Guide — BKBO1 — $34.95

The MECP is designed to test autosound, cellular, and mobile security installers at different levels of ability, allowing them to earn and display increasingly presitigious certificates. This guide covers basic as well as advanced topics, and also includes an 11-page glossary. Edited by Mary Ann Giorgio, MECP. 1993, 256pp., 8½ x 11, softbound.

Alternator Whine — BKNA1 — $19.95

Everything you or anyone else ever needed to know about detecting and curing the causes of car audio's biggest nemesis. Illustrated. By David Navone. 52pp.

Autosound 2000 Troubleshooting Flowchart — BKNA2 — $9.95

Two-color wall poster traces all car audio mysteries. By Autosound 2000.

Digital Audio Engineering: An Anthology — BKAR1 — $29.95

Includes "An Introduction to Digital Recording and Reproduction"; "Limitations on the Dynamic Range of Digitized Audio"; "Architectural Issues in the Design of the System Concepts Digital Synthesizer"; "The FRMbox--A Modular Digital Music Synthesizer"; "The Lucasfilm Digital Audio Facility." Volume 3 in A-R Editions' Computer Music and Digital Audio Series; edited by John Strawn. 144pp., 6 x 9, hardbound.

The Compact Disc Handbook — BKAR2 — $49.95

For audio and multimedia enthusiasts, CD owners, recording engineers, and manufacturers, this second edition remains the most comprehensive and detailed reference book on this technology. Contents include: Introduction to the Compact Disc; Fundamentals of Digital Audio; The Compact Disc System; CD Player Design; Practical Concerns; Diverse Disc Formats; Disc Manufacturing. Volume 5 in A-R Editions' CMDA Series (see above); by Ken C. Pohlmann. 339pp., 6 x 9, hardbound.

Synthesizer Performance and Real Time Techniques — BKAR3 — $49.95

Volume 8 in A-R Editions' CMDA Series (see above), this book presents a complete orientation to synthesized music. Combining detailed technical advice with instruction on live performance in many musical styles, it begins with a historical perspective and then traces the evolution of synthesizer technology up through its current vanguard performance practices. Terminology is standardized and explained, and a comprehensive set of performance exercises is included. By Jeff Pressing. 1992, 400pp., 6 x 9, hardbound.

Das Lautsprecherbuch #7 — BKHF1 — $29.95

NEW THIS ISSUE

WRITTEN COMPLETELY IN GERMAN, *The Loudspeaker Book #7* is one of the world's best collections of up-to-date loudspeaker data. Starting with in-depth reviews of speaker CAD programs such as LMP (Loudspeaker Modeling Program), XOPT, and CALSOD (Computer-Aided Loudspeaker System Optimization and Design), it proceeds to discussion of the definition and use of the most important loudspeaker parameters and data. Next come 2-page spec sheets on 65 tweeters, 39 midranges, and 105 woofers, each containing numerous specs and stats, 3 graphs, and a photo. Driver makers include Audax, Beyma, Davis, Dynaudio, Eton, Harwood, KEF, McFarlow, Seas, Vifa, and many more. The book concludes with detailed reviews of 12 ready-made speakers, including ones by Harwood, Jordan, Seas, and Strathearn--each entry complete with photo, blueprints, and crossover schematic. By Michael Gaedtke. 1992, 624pp., 5¾ x 8¼, softbound.

Euro Pop Book — BKRI2 — $64.95

Third edition of the preeminent international rock and pop music directory, including 20,000 contacts in 29 countries. Edited by Stéphane Davet, CIR (Centre d'Information du Rock) Publishing. 1993, 789pp., 6¾ x 9½, softbound.

The Audio Designer's Tube Register, Volume 1 — BKMC2 — $24.95

This brand-new book, based on fresh data from author Tom Mitchell's lab, features complete electrical and mechanical specifications for the 6C4, 6C10, 6CG7, 6DJ8, 6EU7, 6K11, 12AT7, 12AU7, 12AX7, 12AY7, 12BH7, 12DW7, 5751, and 6922. Each tube type is illustrated by eleven separate graphs: plate characteristic curves; transfer characteristic curves; μ and gm for both Ec and Ib; rp for both Eb and Ib; and three useful graphs not given by any manufacturer--constant current curves, Rdc(Eb), and Rdc(Ib). These graphs can be cross-referenced to seven different data tables for quick analysis. 1993, 144pp., 8½ x 11, spiralbound.

The Science of Sound — BKAW1 — $49.95

This beautiful second edition builds upon its predecessor's reputation as the most authoritative textbook on acoustics and musical acoustics. After thoroughly covering these basic principles, author Thomas D. Rossing comprehensively explains a number of more advanced topics, including the perception and measurement of sound, the human voice, and environmental noise. Over 550 figures; references, glossary, questions, exercises at the end of each chapter. 1990, 686pp., 7¾ x 9½, hardbound.

The Ultimate Sound Blaster Book--Including CD-ROM — BKS46 — $34.95

This book/disk combination provides complete coverage of installing, configuring, and troubleshooting Sound Blaster audio boards--the best-selling audio adapter. Further, it also features the addition of other multimedia peripherals such as CD-ROM drives, MIDI equipment, and full-motion video adapters. Covering Sound Blaster, Sound Blaster Pro, and Sound Blaster 16, the disk is packed with sound files, shareware audio board utilities, and fun shareware games. By Que Development Group. 1993, 512pp., 7⅜ x 9⅛, softbound, plus CD-ROM.

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NEW THIS ISSUE

History of the British Radio Valve to 1940 — BKAE2 — $24.95

This well-illustrated volume is a comprehensive history of vacuum tube (valve) development in England from 1904 to 1940, including sketches of the major manufacturers. A great resource for identifying and dating early British tubes, the book includes tube data as well as tube equivalent tables. By Keith R. Thrower. 210 pages, softbound.

Vintage Hi-Fi Spotter's Guide, Volume 1 — BKAE3/1 — $14.95

Copies of catalog pages and advertisements for 1947-1963 hi-fi components, including Fisher, Eico, Heathkit, McIntosh, Scott, Harman-Kardon, Marantz, Pilot, Dynaco, Radio Craftsmen, and others. Compiled by Charles Kittleson. 87 pages.

Vintage Hi-Fi Spotter's Guide, Volume 2 — BKAE3/2 — $14.95

As above, containing more ads and catalog pages dating from 1929-1963 and also including Speaker Spotter. Includes amps, preamps, speakers, phonographs, receivers, and other equipment not covered in volume 1. Compiled by Charles Kittleson. 88 pages.

Vintage Hi-Fi Spotter's Guide, 2-Volume Set — BKAE3/S — $24.95

As above, both BKAE3/1 and BKAE3/2, at a savings of $4.95!

Wood Engineering Handbook — BKPH5 — $59.95

Of great value to enclosure builders everywhere, this is the newly updated and expanded second edition of the standard reference on the best use of wood for strength and beauty. Its 23 chapters contain insights into the physical and mechanical properties of wood; different types of native and foreign hard- and softwoods; effective methods of drying, fastening, finishing, and preserving wood; types and properties of commercial lumber; new advances in wood products; and much, much more. By the Forest Products Laboratory, U.S. Department of Agriculture. 1990, 457pp., $8\frac{1}{2}$ x $11\frac{1}{4}$, hardbound.

Optional Mitey Mike Flexible Cable and Wand

This add-on to our popular KD-2 Mitey Mike test microphone replaces the standard 18" brass wand with a 6" brass wand and 6' shielded cable terminated in an RCA phono plug. Entire wand subassembly is heat-shrink covered for protection. Fully assembled, including mike capsule. Gold-plated RCA phono jack and instructions also supplied for easy conversion of standard Mitey Mike enclosure. Purchasing options available:

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KD-2AMICI	Flexible Cable and Wand calibrated for IMP, $3\frac{1}{2}$" IBM disk	60.00
KD-2AMICMI	Flexible Cable and Wand calibrated for both MLSSA and IMP, $3\frac{1}{2}$" IBM disk	65.00

Tage Frid Teaches Woodworking Joinery, Shaping, Veneering, Finishing — BKTN3 — $29.95

Published by popular demand, this great volume is a combination of Frid's previous two books (series volume 1 and 2) on these subjects. Easy-to-understand, well-illustrated instruction by a true master craftsman. 1993, 468pp., softbound.

Troubleshooting & Repairing Audio & Video Cassette Players & Recorders — BKT35 — $19.95

This is an all-in-one, illustrated guide for consumers and hobbyists, covering everything from microcassettes, portables, and stereo/auto cassettes and CDs to VCRs, camcorders, and digital audio tape. Techniques included range from basic cleaning and maintenance to common repairs. Glossary and list of manufacturer's addresses. By Homer L. Davidson. 1992, 464pp., 7 x 10, softbound.

Perfectionist's Stylus Sweep — BRSSW — $3.95

A must for quality vinyl lovers, this soft, bushy nylon brush cleans the diamond tip and cantilever for less distortion and better sound. Short, flat handle is easy to hold and use. $2\frac{1}{8}$" overall length.

Loudspeaker Design Cookbook: Foreign-Language Editions

Vance Dickason's worldwide best-seller in English now available in two additional languages: German and Portuguese. (BKAA2, English edition, 1991, 154pp., 8 x 11, softbound, $29.95.) Purchasing options available:

BKAA2/G	Loudspeaker Design Cookbook, German edition, 1993, 300pp., 6 3/4 x 9, hardbound	$49.95
BKAA2/P	Loudspeaker Design Cookbook, Portuguese edition, 1993, 152pp., 8 x 11, softbound	49.95

Operating Features of the Audion — BKAA26 — $6.95

First published in 1917, this essay first appeared in the *Journal of the New York Academy of Sciences* and is now reprinted as a 32-page illustrated pamphlet. Major Armstrong was the inventor of the superheterodyne circuit, FM broadcasting, and dozens of other modern engineering designs. Included is the very first authoritative report on the triode vacuum tube's capabilities. By Edwin H. Armstrong. 1993, 32pp., softbound.

Mullard Circuits for Audio Amplifiers — BKAA27 — $16.95

This book is a complete guide to building eleven power and control amps for a sound system with vacuum tubes, featuring a four-chapter tutorial on sound quality which is fabled guidance on achieving the best sound with tubes. First published in 1959 by Mullard, one of Britain's premier "valve" manufacturers, this is a do-it-yourself classic, with sheet metal diagrams, parts lists, and performance data. 1993, 144pp., 8 x 10, softbound.

SONGWORKS Software — SOF-SNG1M3G — $114.95

Write your own scores! This amazing package is the world's best music composition software for the Macintosh. It produces a single staff of music with optional chords and text (as in songbooks or leadsheets), and notates your melody for you either automatically or as you enter it note by note. Allowing you to play on the letter keys of the computer, on the screen piano or guitar, or through MIDI, it plays chords simultaneously with melody, using a variety of built-in accompaniment patterns. SONGWORKS, among many other things, will invent song ideas to stimulate your imagination; transpose your own work to any key; suggest chords to go with your tune; or suggest a melody to go with your chords. It is MIDI-compatible, but MIDI is not required. Usable with any Macintosh and prints to any Apple printer. By Jeffrey Evans. Includes operating manual. 1992, Macintosh only.

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Continued from page 27
monitor frequency and voltage level (0.424V RMS). By keeping a constant voltage across the driver and recording the current through the voice coil, I could calculate the impedance. I took readings at 20 frequencies from 10Hz-20kHz.

Since separate amplifier channels drove the voice coils, each required its own zobel circuit. I connected the voice coils in series, ran the impedance plot, and attributed half the impedance to each voice coil. To ensure the impedances would be equal, I also ran an impedance plot on each voice coil, driving the two coils by separate amplifier channels. I predicted a system resonance of around 34Hz.

I first tested the voice coils connected in series. They showed a resonance peak at 37.4Hz, otherwise the plot was pretty much as expected (*Table 4*). I ran the next tests while separate amplifier channels drove the voice coils, but measured only the right voice coil (I had arbitrarily labeled them right and left). It became immediately apparent that the values were not half of the series-connected values; however, the resonance peak was the same frequency, and the rest of the plot was as expected. The left voice coil plot was nearly identical to the right at first, but the current began dropping very rapidly when I got close to the resonance peak. It dropped to 0.5mA which equaled 848Ω! From resonance up, the left voice coil measured a slightly higher impedance than the right one.

When I asked the folks at Madisound, they said they had never heard of such a high impedance peak at resonance and suggested I switch the amplifier channels to the voice coils. I reran the tests with the left amplifier channel driving the right voice coil, and vice versa. The large impedance peak remained in the left amplifier channel and the right voice coil now measured 0.9mA or 471Ω. I took another complete set of readings using the right amplifier channel to drive the voice coil under test (*Table 5*). The voice coils now measured very similarly.

TABLE 4

VOICE COILS CONNECTED IN SERIES

FREQUENCY	SERIES	RIGHT	LEFT
10	12.0	8.1	8.2
20	15.3	10.0	10.0
30	29.9	17.8	17.8
37.4	115	36.3	848
40	70.7	30.3	57.3
50	21.0	12.8	13.6
60	16.0	10.0	10.9
70	14.0	8.9	9.9
80	13.6	8.7	9.8
90	13.6	8.7	9.8
100	13.4	8.6	9.7
150	14.5	9.2	10.4
200	15.2	9.7	10.9
300	17.7	11.1	12.3
400	20.1	12.3	13.6
500	22.6	13.5	15.0
1k	33.4	18.6	21.9
5k	103	40.0	64.3
10k	303	48.8	118
20k	---	84.9	530

TABLE 5

RIGHT AMPLIFIER CHANNEL DRIVING THE VOICE COIL

FREQUENCY	RIGHT	LEFT
10	6.0	6.1
20	8.0	8.1
30	15.7	15.5
37.4	35.1	33.9
40	29.1	28.3
50	11.4	11.1
60	8.2	8.2
70	6.9	7.1
80	6.8	6.9
90	6.9	6.9
100	6.7	6.8
150	7.1	7.1
200	7.6	7.8
300	9.0	9.2
400	10.1	10.4
500	11.3	11.6
1k	15.7	16.6
5k	30.5	35.7
10k	40.4	51.1
20k	67.3	106

DOWN TO BASICS. A short program in BASIC allowed me to easily change the zobel component values and observe the effect on the impedances. I finally settled on 40μF and 6.8Ω in parallel with each voice coil. In theory, this combination kept the impedance for each channel within 1Ω from 65Hz-20kHz.

I was also curious about the difference between the predicted system resonance of 34Hz and the measured 37.6Hz. By putting different V_{AS} values into my program, I found that a V_{AS} of 375 liters and my measured values for f_S (15.6Hz) and Q_{TS} (0.42) resulted in predictions exactly as measured for the actual system. The driver was more compliant than rated, and this would result in lowered free-air resonance. The computer predicted a Q_{TC} of about 0.97 and f_3 of 29Hz, as well as a 1.1dB peak in the response curve at approximately 53Hz.

Many three-way (subwoofer/satellite) speaker systems have crossovers in the 120–160Hz range. In an effort to keep costs down, I had planned to use a 6dB/octave crossover, although I was worried about sonically locating the subwoofer with such a shallow slope.

I used two 100W L-Pads to adjust the satellite levels, and one Dynaudio Variovent (although Dynaudio recommends using three for volumes over 80 liters). I planned to make all electrical connections on two 8-position terminal blocks mounted on the back of the enclosure.

I connected the zobel components and ran new impedance curves (*Table 6*). The values weren't exactly as predicted, but they were close enough. The zobel ciruit caused a slight shift in the system resonance to 36.4Hz.

I cut the required 4¼" Variovent hole in the back panel with my sabre saw and glued it with Elmer's woodworking glue. Another set of impedance curves (*Table 6*) showed the Variovent did not affect the resonance frequency, but did reduce the impedance at resonance. It appeared to have no other effect. Had I used three Variovents, as Dynaudio recommended, the impedance at resonance would probably have been further reduced.

The Loudspeaker Design Cookbook provides formulas to determine crossover component values.[2] I used 6.5Ω for the approximate impedance in the 100–150Hz range, and calculated the component values required for first- and second-order Butterworth crossovers at 120Hz and 160Hz. The closest available coil value was 12mH, which gave a crossover frequency of 122Hz (second order).

The formulas also determined the capacitor value. I planned to use a 140μF bipolar electrolytic bypassed by a 2μF Châteauroux polypropylene. I wanted to try the system without a high-pass crossover on the satellites, which would have impedance peaks just below the 120Hz crossover frequency. These peaks would

TABLE 6

IMPEDANCE CURVES WITH ZOBELS

	ZOBEL		ZOBEL & VARIOVENT	
FREQ.	RIGHT	LEFT	RIGHT	LEFT
10	6.0	6.2	6.2	6.4
20	8.1	8.4	8.4	8.7
30	16.4	17.1	16.2	16.8
36.4	31.4	32.9	26.4	27.7
40	23.4	24.2	21.4	22.3
50	10.0	10.2	10.0	10.4
60	7.5	7.8	7.6	7.8
70	6.5	6.7	6.5	6.7
80	6.4	6.6	6.4	6.5
90	6.4	6.6	6.4	6.7
100	6.2	6.4	6.2	6.4
150	6.6	6.8	6.6	6.8
200	7.0	7.2	7.0	7.3
300	7.5	7.9	7.6	7.9
400	7.7	7.9	7.7	8.0
500	7.5	7.8	7.6	7.8
1k	6.9	7.1	6.9	7.2
5k	6.9	7.1	6.8	7.2
10k	7.2	7.4	7.1	7.4
20k	7.8	8.0	7.7	8.0

interfere with any attempt at a crossover in that region.

I had been considering how to mount the crossover parts to the back of the enclosure. The easiest way would have been to wire them together, then glue them to the back panel with caulk or Liquid Nails. Instead, I etched circuit boards to hold the capacitors and resistors, and bolted the inductor coils to the back panel.

I first drew the layout of the circuit board on a piece of paper, then cut a large board into two smaller ones and drilled the holes. I drew the runs with an etch-resist pen, and placed the boards in a pan of etchant. Although the etching process supposedly takes 15-20 minutes, half an hour later the boards looked the same. I removed one and tried to rub the copper parts with a scrub pad without removing the ink traces. When I returned the board to the etchant, it began to make slow progress. I scrubbed the copper areas of the remaining board, and, after about four hours, they were finally done to my satisfaction. *(Etching occurs faster at 120°F and with the boards floated, copper side down, in the ferric chloride.—Ed.)*

After I soldered the capacitors and resistors to the circuit boards, I mounted them, along with inductor coils and L-pads, to the back panel. I used wood screws through the circuit boards, and rubber grommets which raised them off the back panel and provided vibration isolation. I bolted the inductor coils to the back panel using large lag screws, and mounted the L-pads with Liquid Nails. I also wired a double-pole double-throw (DPDT) switch into the subwoofer inputs so I could easily switch it on and off.

Extended listening revealed one problem with the subwoofer and my Allison Four speakers. The Allisons have a bass response to about 50Hz. Since I didn't include a high-pass crossover for the satellites, there was an overlap in the 50-120Hz range. The result was a slight overemphasis in the upper-bass range, which couldn't be removed without also removing the low bass. I would have needed an equalizer.

After connecting the subwoofer to Sam's system, I placed my sound level meter on a tripod at his listening position and fed my sine wave generator into his amp. The generator has a range switch that changes the frequency by decades. I wanted to feed a signal into the subwoofer and satellite ranges, and adjust the L-pads for the same SPL reading at the two frequencies (60 and 600Hz). With the voltage from the amplifier the same at both frequencies, the sound level was about the same with the L-pads completely turned up.

The sound was outstanding. The subwoofer blended very well with Sam's speakers. We were both very pleased with the results and didn't hear one sound we didn't like. We used terms such as balanced, impact, and foundation more than once. At one point, I noticed that my eyes had closed and a continuous smile was on my face. I looked at Sam, who had the same smile on his face. I started laughing. If anyone saw us through the window, we would look pretty foolish. Neither of us cared at the moment, so we went back to listening—and smiling.

SOURCE

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REFERENCES

1. Dickason, Vance, *The Loudspeaker Design Cookbook*, 4th ed., Audio Amateur Press, 1991, Section 8.80.
2. ibid., pp. 56, 57.

Part II

THE PRISM V SATELLITE/JBL SUBWOOFER

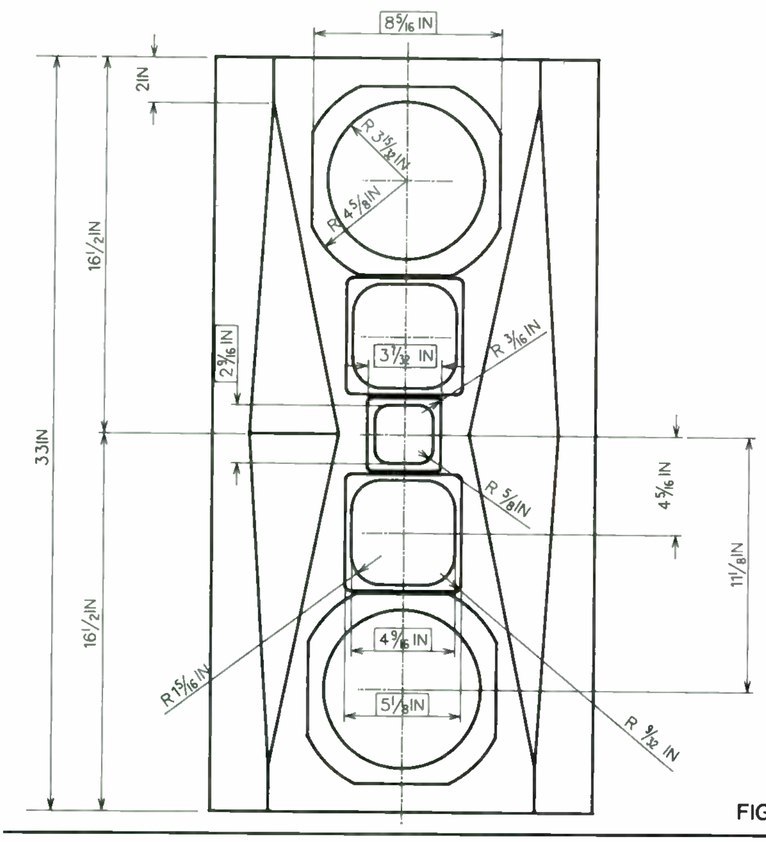
BY RANDY PARKER

In designing the Prism V's cabinet, I paid great attention to reducing the types of distortions frequently attributed to cabinet speakers: enclosure panel vibration, resonances caused by the mechanical coupling of driver motor reaction forces into the enclosure walls, and internal standing waves. You can minimize these problems in several ways.

Commonly used methods include: using 1″ MDF particleboard for the enclosure walls; constructing a triple-thick front baffle for added mass and resistance to flexing; incorporating horizontal shelf, vertical front-to-back, and corner braces; using Polydax "Norsorex" gaskets on bass drivers; and isolating the midrange and tweeter from the bass drivers' backwave. Other methods involve the liberal use of double-thick layers of auto body damping pads (used to damp sheet metal panels in cars), especially for the midrange and tweeter self-contained rear enclosures.

DAMPER SAMPLER. I obtained two different brands of auto body damping material from auto parts dealers. "Q-Pads" are manufactured by FibreGlass Evercoat (part #116). One package contains six 12″ × 12″ self-adhesive panels. Although each pad is only about ⅛″ thick, they are surprisingly heavy—roughly one pound. They appear to be made of a flexible rubber/fiberglass composite and are extremely inert. Use one package per enclosure, cutting them with a utility knife to fit the panels. They have a heavy self-adhesive coating on one side, but I also used a staple gun to ensure secure bonding and peeled off the plastic backing to allow adhesion of an additional layer of damping material.

The second layer is 3M brand "Silencer Strips" (part #08585), which come in 3-inch-wide by 50-foot-long rolls. "Silencer Strips" are approximately the same thickness as "Q-Pads" but are a softer, sticky, tar-like substance, with a heavier permanent plastic backing material. Their self-adhesion properties are greater than "Q-Pads," and their flexibility makes them ideal for wrapping around



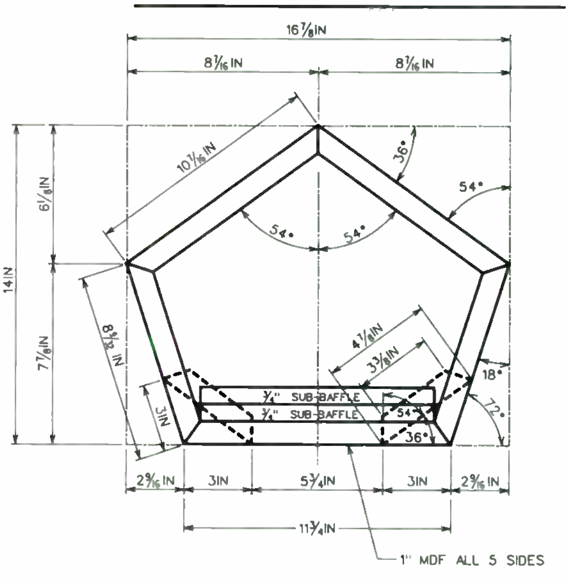


FIGURE 16: Front and top view drawings of Prism V enclosure.

the Accuton rear enclosures. Both of these damping materials provide an audible reduction in the sound of particleboard enclosure walls.

I used Polydax "Norsorex" gaskets on the Focal bass drivers. Made from an inert rubber which seals very well, they also provide a unique damping quality between the driver frame and enclosure. (Part #GMTX 2025 is specified for the Polydax MTX 20.25 TDSN driver.) My only modification was to square off the round gasket to match the shape of the Focal chassis.

Problems caused by backwave reflection through the driver cone, internal standing waves, and system resonance damping are addressed differently. Because the tweeter and midranges have their own self-contained rear enclosures, Accuton has offered solutions to these problems. The bass drivers require their own solutions, including nonparallel enclosure walls (particularly front-to-back but also side-to-side), acoustic foam lining the walls, and bonded Dacron® "AC Stuff" filling the remaining space.

To determine the final "AC Stuff" density, I experimentally varied both it and the number of acoustic foam layers until the enclosure resonance became 63Hz. The effective enclosure volume can be increased a surprising amount by packing more sound-absorptive material into the enclosure. The final stuffing arrangement was a single layer of 2-inch-thick AC foam on all interior surfaces, with approximately 2′ of "AC Stuff" rolled in a cylinder and stuffed into each bass cavity. I also added layers of foam and "Stuff" to the subenclosure, where the midranges and tweeter are mounted, to dampen any airborne vibration reaching their enclosures.

THE KINDEST CUTS. *Figure 16* is the Prism V enclosure, top and front view, including all driver cutout dimensions. I recommend custom routing the depth of driver rebates based on the chassis thickness and gasket material. Accuton driver chassis are 5 mm thick; the Focal chassis is 4 mm thick. Because I covered the entire enclosure (including the front baffle) with oak veneer, it was necessary to compensate for both the veneer's thickness and the hot-melt adhesive used to attach it. I also compensated for the thickness

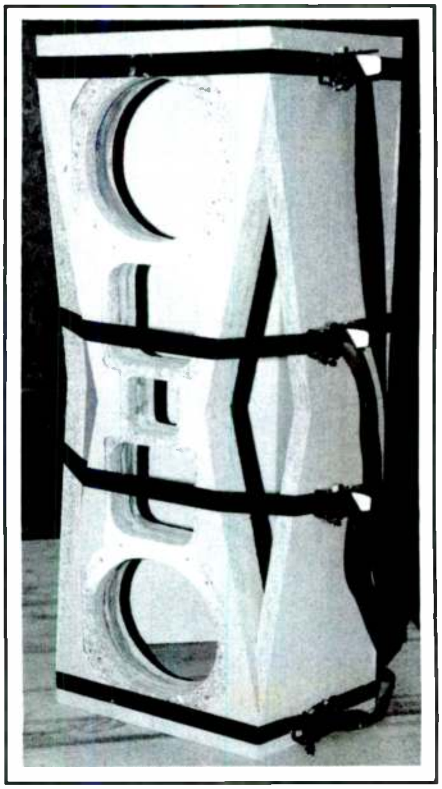


PHOTO 4: Strap clamps used during gluing of enclosure.

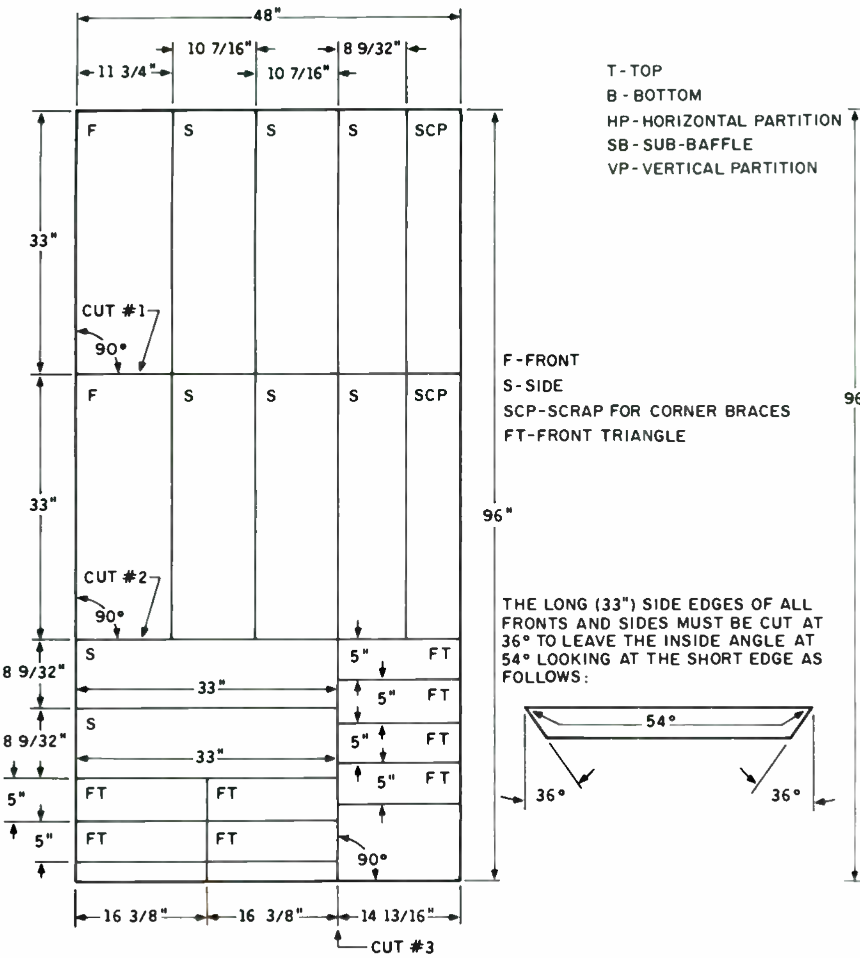


FIGURE 17: 4 × 8 × 1″ MDF particleboard cutting diagram for Prism V.

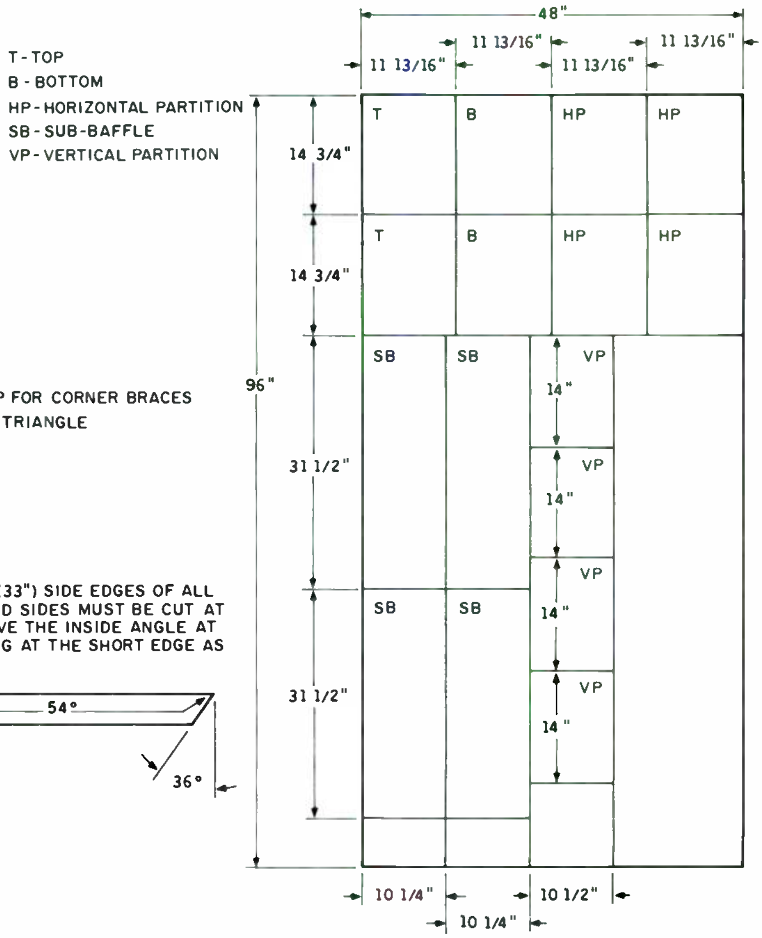


FIGURE 18: 4 × 8 × ¾″ MDF particleboard cutting diagram for Prism V.

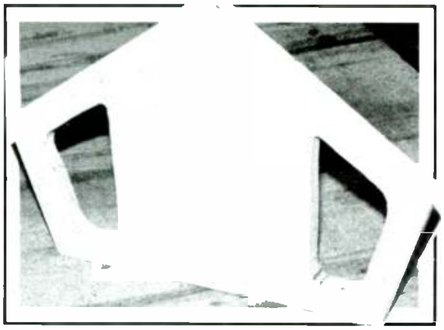


PHOTO 5: An internal horizontal partition.

PHOTO 6: Internal view of vertical partitions.

of the "Norsorex" gaskets because they compress an insignificant amount. The Accuton drivers have their own foam gaskets permanently attached, which compress flat and therefore require no accommodation for depth.

The drawings do not show the enclosure tops, bottoms, and internal horizontal braces/partitions. When laying out the cutting diagram for these pieces, I found that tracing the inside of the enclosure was faster and more accurate. I also found it simpler to cut each vertical partition (also not shown) based on actual depth and height measurements of the available space.

Construction begins with cutting the particleboard (*Figs. 17* and *18*). I used both 1″ and ¾″ MDF depending on the application. Tops and bottoms are ¾″ MDF: the solid oak decorative cap glued to the top, also ¾″, produces a double thickness; the bottom doesn't require extra thickness because it rests on the subwoofer. I also used ¾″ MDF for all interior pieces due to their smaller size, and for the extra baffle layers because the glue lamination provides extra rigidity. I used 1″ MDF for the sides. Pay special attention to cutting the angles in *Fig. 17*: the enclosure's integrity is based upon their accuracy. While the saw is set to these angles, you can also cut the scrap wood into 1½-inch-wide strips, which you can later cut to length for corner braces.

After making the basic cuts, construct the front baffle from a 1″ front piece and two ¾″ subbaffle boards. The latter are cut 1½″ shorter and narrower than the front baffle board to provide a ¾″ space on each end of the 1″ board into which the tops and bottoms will fit. The narrower cut allows the subbaffle boards to fit between the enclosure sides. I used Titebond aliphatic resin glue to bond the three boards together, and also screwed and clamped the assembly while it dried.

I first drew the location of all drivers, cutouts, and the indented baffle shape on the 1″ board. This ensured the screw locations would not interfere with any cutting or driver mounting areas. After the glue dried, I cut out each driver opening and routed the rebates. I next cut the indented shape as close as possible to the apex with a circular saw, finishing the cut with an extra-long saber saw blade. I used the same technique to cut the indentation from the two side pieces which fit next to the front baffle.

When the baffles were finished, I drilled holes for the T-nuts used to mount the bass drivers. The front baffle is 2½″ thick, so I used a drill press to ensure the holes were perpendicular. Since I had secured the midranges and tweeters with drywall screws, I used a sharp awl to create a shallow starting point for the screws rather than drill pilot holes. The drywall screw heads were too large in diameter to fit within the recess in the Accuton driver chassis. With my bench grinder, I turned down their diameter until they fit.

JOIN TOGETHER. The sides were now ready to be simultaneously joined. Latex Liquid Nails creates a very strong bond and is thick enough not to run when pieces are placed vertically. Lay the four sides and the front baffle on the floor, and place a heavy bead of adhesive on each edge. Then raise them to a vertical position and use four strap clamps to hold them in place, as shown in *Photo 4*.

The strap clamps are ideal for pulling all the edges into perfect alignment. The harder I tightened the ratchet on the straps, the more uniform the shape became. If you have accurately cut the angles, the pentagonal shape will naturally find itself. To ensure any internal corner braces will fit tightly, wipe off the excess adhesive while it's still wet.

I allowed the adhesive to harden for 24 hours before removing the strap clamps. Although I had "glued" them to the edges of the enclosure, they pulled free with no damage to the corners. For the second enclosure, I placed wax paper

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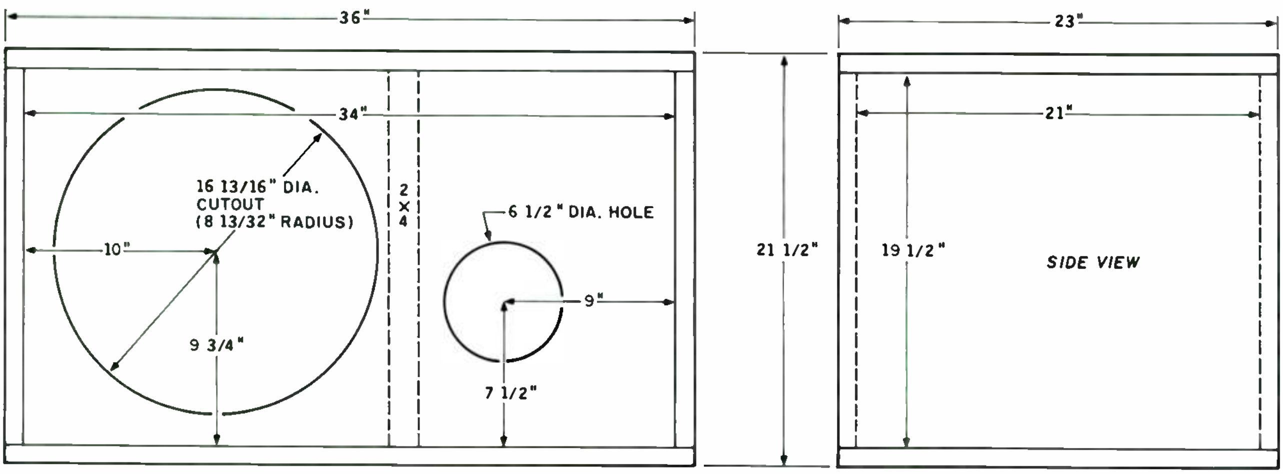
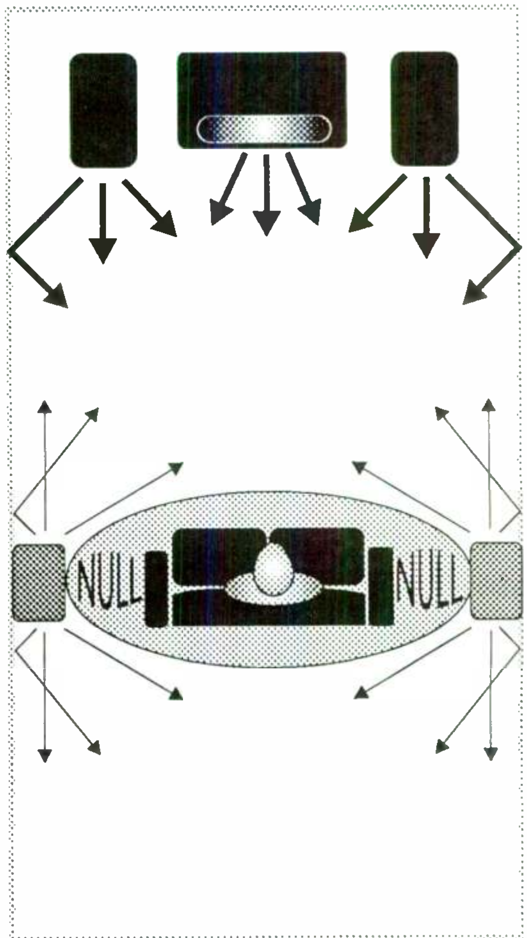


FIGURE 19: Front and side view drawings of subwoofer enclosure.

DIPOLE FOR SURROUND SOUND?

It is a popular notion that to get proper surround sound in a home theater setup one must place the speakers behind the listener, pointing towards the center of the room. In fact, most "surround" speakers come with swivel brackets to allow the user to "aim" the drivers right into the room. The result is an increased localization of the rear channel and a loss of realism. What causes this problem? Aiming the surround speaker towards the listener. The ear receives an improper balance of direct verses reflected sound from the surround speakers. How can a dipole speaker help? A dipole loudspeaker has drivers situated on both the front and rear walls of the cabinet, and are driven out of phase. By taking this design, and placing the cabinet on the sides of the room, in the same plane as the listener, a null zone is created. The majority of the sound that reaches the listener will then be reflected off of the walls in the room, creating a natural, diffuse sound field, making the speakers difficult to locate and increasing the sense of spatial ambiance . Little direct sound will reach the listener, complying to the original specifications laid out by many surround sound protocols.



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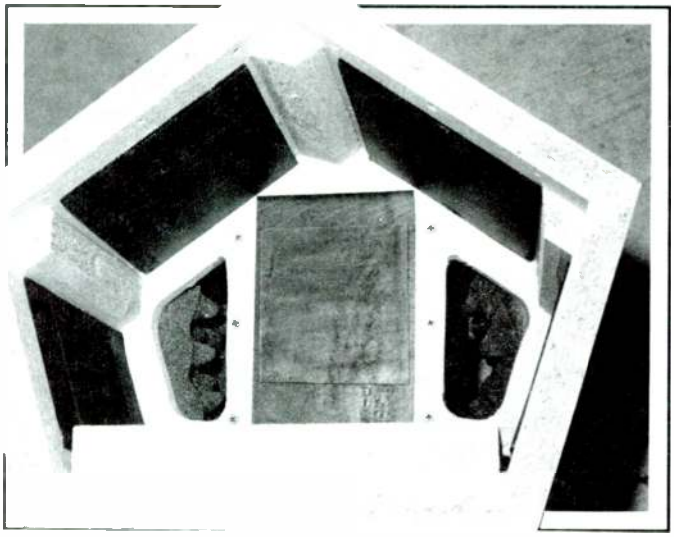

PHOTO 7: Completed installation of vertical and horizontal partitions.

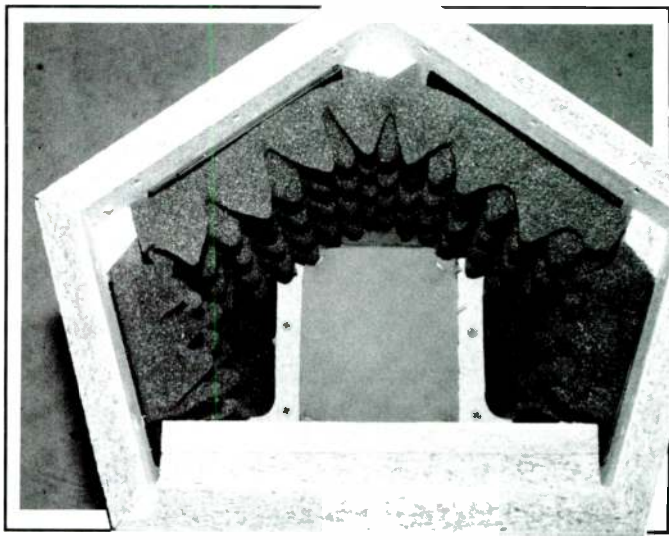

PHOTO 8: Installation of AC foam.

Continued from page 34

under them. At this stage, it's important to have the enclosure edges meet at a point, but later you will round them to minimize diffraction and allow the oak veneer to bend around the radius without splitting. At no point did I use screws to join the five sides.

The next step is to cut the triangular pieces which fill the indentation between the front baffle and sides. This is the most difficult part of the construction process, because while accurate cutting is critical, they are difficult to cut safely. Each triangle is custom-cut based on actual measurements. *Figure 16* shows the general dimensions and angles.

For the two triangles to join properly at their bases, these must be cut at an angle as well. I cut compound angles on each edge with a radial arm saw. The pieces are quite small, so clamping is required, especially when shaving off small "adjustments." Be extremely cautious when cutting these pieces—safety first! After you have cut the triangles to fit, load all the edges with a heavy bead of Liquid Nails and press them into place. I used the strap clamps once again to secure the triangles into perfect alignment with the baffle and sides.

The horizontal partitions, which form the top and bottom of the midrange/tweeter subenclosure, brace the enclosure circumferentially. They fit between the midrange and bass drivers, and you initially cut them identical in size to the enclosure's top and bottom pieces. To accommodate the front baffle's extra thickness, you then cut back by 1½" the edge which butts against it. The horizontal partitions have cutouts as well, which allow the bass drivers to share the same enclosure volume.

Multi-driver loudspeaker systems using similar drivers will track each other better when installed in a common enclosure.[1] *Photo 5* shows how the horizontal partitions initially look, with cutouts on each side to create tunnels up the enclosure sides; however, I later found that only one tunnel cutout is necessary. I was unable to sufficiently reduce the total enclosure volume to raise f_C to the desired frequency until I blocked off one tunnel. This required fabricating pieces of wood to fill in the small gap between the front of the horizontal partitions and the front and side of the enclosure, and sealing it well with Liquid Nails. Obviously, when installing the top and bottom horizontal partitions, you must be certain the tunnel cutouts are located on the same side.

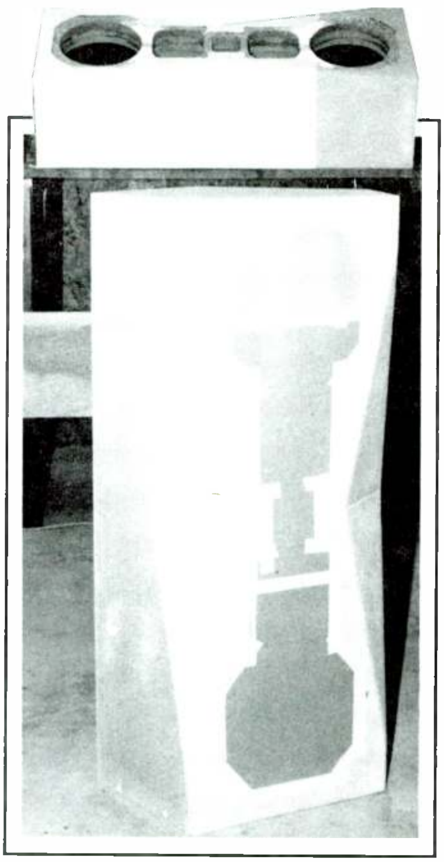

PHOTO 9: Enclosure covered with sheet hot-melt adhesive.

The bottom horizontal partition in each enclosure is installed between the lower midrange and bass driver cutout. The partition must be positioned as close as possible to the midrange cutout to prevent its interference with the placement of T-nuts for the bass drivers.

Begin by measuring the distance from the midpoint to the bottom of the enclosure; draw a line around the enclosure circumference that maintains this distance all the way around. Drill two countersunk pilot holes 4" apart through each of the four sides. Run a large bead of Liquid Nails around the inside of the enclosure where the partition will be mounted, and slide it into position. The pilot holes help ensure the partition is properly positioned and square to the enclosure walls. After the partition is in place, use #8 1¾" flat-head wood screws to secure it to the sides. Drill two countersunk pilot holes through the front baffle and install 3½" flat-head wood screws.

Next, cut the vertical partitions which form the sides of the midrange/tweeter subenclosure and brace the front baffle to the two rear sides. They should fit snugly. The height will permit the top horizontal partition to line up with the edge of the top midrange driver cutout. Position the vertical partitions as close as possible to the edges of the midrange driver cutouts so no air gap will form be-

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tween the partition and the front baffle at its narrowest point near the tweeter.

Photo 6 shows the enclosure with the bottom horizontal and two vertical partitions, including auto body damping material and 2″ AC foam in the tunnels. Before installing the top horizontal partition, be certain to line the inside of the vertical panels with the damping material and secure the rear corner brace with Liquid Nails. I did not use screws to attach the vertical partitions to the front baffle or rear sides, although that is a possibility. A heavy bead of Liquid Nails on the front, bottom, and rear of the vertical partitions secures them until the top horizontal partition is installed.

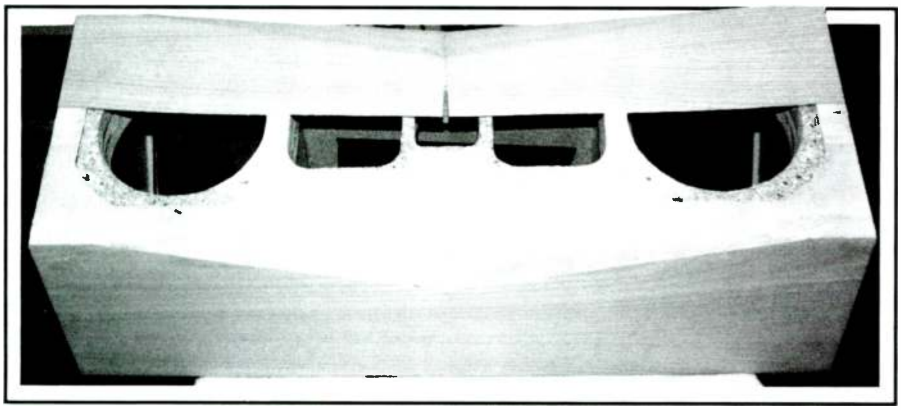

PHOTO 10: Veneer partially attached.

Mark and drill the pilot holes and lay a bead of Liquid Nails on the top edges of the vertical partitions and around the enclosure circumference. To install, secure each horizontal partition to the vertical partitions using wood screws around the circumference and six 2″ drywall screws. *Photo 7* shows the completed installation with the location of the drywall screws; *Photo 8* is the same view with AC foam on the enclosure walls. Cut the corner brace lengths so the enclosure tops and bottoms will rest on them and on the subbaffle, and will lay flush with the enclosure's top/bottom edge.

After drilling circumference pilot holes and laying a heavy bead of Liquid Nails around the circumference and on top of the corner braces and subbaffle, install the tops and bottoms. Ensure they sit flush with the enclosure edges before securing the screws.

ADHESION ADVICE. I finished lining the remaining interior surfaces with acoustic foam, but waited to fill the cavities with AC Stuff. I also waited until after I had finished the outside of the enclosure to drill the holes for the binding posts and Neutrik connectors. Instead, I rounded all the vertical exterior edges so the veneer would bend around the radius without cracking, using a router with a ½″ radius bit and pilot bearing. The depth was set to allow me to run the router up and down each side of the edge for a symmetrical radius.

I covered the enclosure with an oak paper-backed veneer which is available from many lumberyards in 4′ × 8′ and 4′ × 4′ sheets. This type of veneer is warpfree, flexible enough to allow wrapping around properly radiused edges, thin enough to cut with heavy shears or a utility knife, and glueable with sheet hot-melt adhesive.

Often sold as "glue lines," hot-melt adhesive is available in 2′ × 8′ rolls with paper backing on one side. I used four rolls to veneer the satellites and subwoofers. One 4′ × 8′ sheet of veneer covered both satellite enclosures, with enough material left over for the subwoofers. To complete the subwoofers, I purchased an additional 4′ × 4′ piece.

Photo 9 shows one satellite completely covered with the hot melt. In the background is an enclosure with a 2′ width ironed on and the paper backing still in place. The hot melt is applied with a clothes iron set slightly below the "cotton" temperature setting. You simply heat it sufficiently to ensure most of the surface has bonded to the particleboard, allowing the paper backing to be peeled off. This also provides practice for cutting and laying the veneer. I wrapped the 2′ width around the circumference and covered the remainder with a second piece. It can be easily cut to size with scissors and trimmed with a utility knife, much like wallpapering.

I then stood the enclosure on a 2½-inch-thick bass driver baffle cutout to raise it off the work table, and cut the veneer so it would hang past the top and bottom by ½″. I placed the center of the veneer against the enclosure's rear corner and ironed toward the front from both directions. When you iron the veneer, the temperature should be set on "cotton," but keep the iron moving to avoid scorching the wood.

At this point, the advantages of using hot melt rather than contact adhesives become immediately apparent: the iron's heat smooths any waves in the veneer; the first veneer placement need not be the last; with care, you will have no air bubbles or bumps. Be certain to ensure the edges are glued down well. After removing the iron, continue pressing the veneer in place for a few minutes with a roller or your hand wrapped in a small towel (the wood will be hot for several minutes). You can hear where the veneer hasn't been solidly glued to the particleboard. Simply iron over that area again and continue to press until it has cooled a bit. When you reach the indentation cutouts on the side panels, you can stop ironing.

Now lay the enclosure on its side so it will be easier to cut the veneer, three pieces of which cover the enclosure. The four sides are covered by the single piece which you have just attached. Cut a piece off each side, following the rear indentation line, to cover the indentation and half of the front baffle (*Photo 10*). The veneer's 4′ width will cover all but about 1½″ of the top and bottom of the front baffle. Splicing a piece of scrap veneer to fill the gap is very easy and the wood grain completely disguises the splice.

To allow the veneer to conform to the indented surface, I trimmed a narrow "V" from the center of the piece shown in *Photo 10*. I later filled these Vs with small scraps of veneer. With hot-melt adhesive, you can cut as many trial-and-error pieces as you wish and not glue the veneer until everything is lined up perfectly. At this point, I cut all the veneer with a metal straightedge and a very sharp utility knife. You must use a blade which is stiff enough to ensure making straight cuts.

Take your time with this step, and do not attempt to cut completely through the wood in the first pass. For a perfectly smooth, splinterless edge, make several firm passes in the same line until the cut is all the way through. It took a full evening to cut and place each indentation/baffle piece to my satisfaction. If you can't line up the edges perfectly, some kind of wood filler might help disguise the gap. I cut the veneer flush with the enclosure edges using the top and bottom

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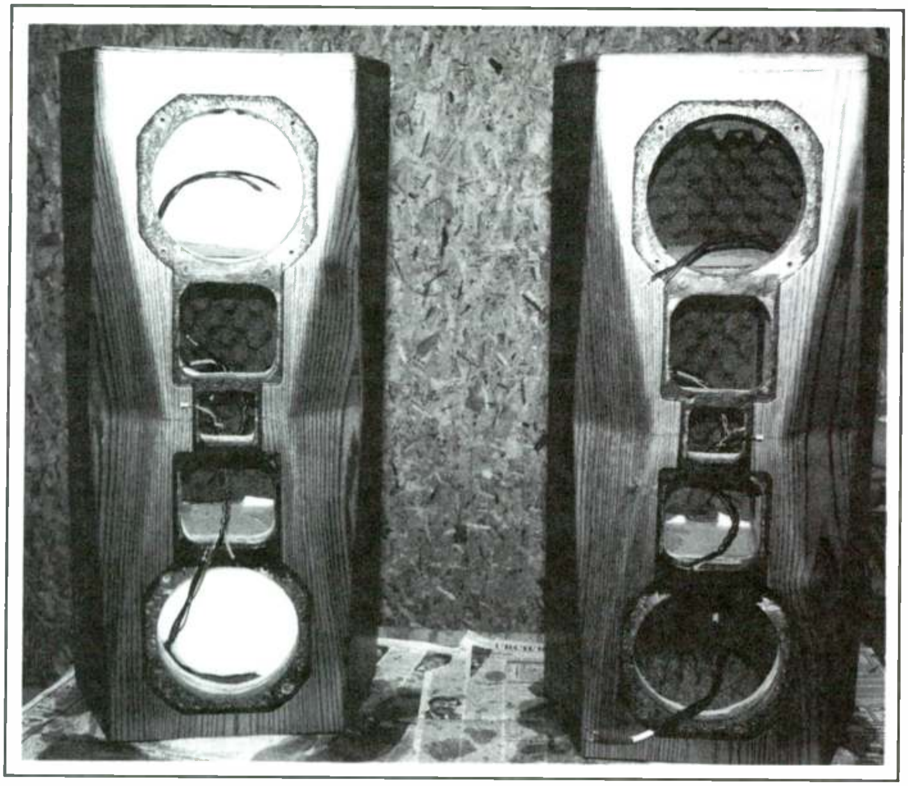

PHOTO 11: Completed veneer finishing.

Continued from page 38

as edge guides. I also used a fresh blade for each piece. The last step of veneer trimming is cutting the driver openings. A large supply of sharp utility knife blades and a lot of patience will help achieve a professional appearance.

SAND, SEAL, DELIVER. A local millwork company made ¾-inch-thick oak boards large enough to cover the tops of the enclosures. I traced the external enclosure shape onto the boards and cut them to size, then used a router with a pilot bearing to make a ½" radius on the top edge. The oak caps are secured with Liquid Nails; a heavy tool box placed on top ensures good adhesion and no gaps.

I lightly sanded the enclosures with an orbital sander, using 220-grit sandpaper. Be extremely careful on the corners, especially with power sanders, because the veneer is very thin. I stained the enclosures with two coats of Minwax "Golden Oak," and lightly sanded between coats with 400-grit sandpaper. Then I applied three coats of Minwax satin polyurethane varnish and sanded as before to ensure a smooth surface.

Photo 11 shows the finished enclosures with black paint bordering the driver cutouts and the internal wiring installed. Wiring to the bass and midrange drivers is with dual runs from the input terminals to each driver, instead of a jumper between each driver pair. This low-inductance wiring method was recommended by G.R. Koonce ("Crossovers For the Novice," *SB* 5/90, p. 38). I used Audioquest "Type 12" OFHC wire to the bass drivers, and Kimber Cable Type 4VS to the midranges and tweeter.

As noted in the crossover section, I connected the midrange and tweeter wires to the female Neutrik chassis mount connector. A simple 1-inch-diameter hole drilled in the rear of the enclosure provided mounting access. The brass Focal binding posts, to which I connected the bass driver wires, are the long version which extend through 1-inch-thick enclosure walls. I simply drilled two holes, spaced ¾" apart, large enough in diameter so the posts would thread snugly through the wall. After tightening the locking nuts, I soldered the internal wires. This installation was the simplest and cleanest I'd ever made using binding posts. I decided which speaker would be the left and which the right, and mounted the posts on the side which would face the rear wall when the speakers were angled inward toward the listener.

Photo 12 shows the enclosure tuning process, during which I removed the bass drivers several times to add or remove stuffing material. T-nuts were mandatory, and the sturdy Norsorex gaskets were unaffected by the frequent removal. Once the tuning was finalized, I used "blue" Locktite to seal the bolt threads and prevent loosening. I can push on one driver, and the other will move forward and remain in that position until I release the first driver. *Photo 13* is the completed Prism V.

The last cosmetic detail was the front grille. It was the first grille I had ever used which did not affect the measured frequency response, even under the scrutiny of the Techron Analyzer. I used ¼-inch-thick, open-pore foam commonly sold in 24" lengths for window air conditioner filtering. Because the enclosure was taller than 24", I spliced two pieces together by butting the edges and laying a very thin bead of clear glue-gun adhesive on the back side. From the front, it is invisible, and I positioned the seam so it lines up in the space between the bass and midrange driver frames.

I used a single-edge razor blade to cut the foam, and a saucer as a template to cut the rounded corners. The plastic-loop half of a Velcro® strip held the grille at the top and bottom of the enclosure, while a double thickness of ⅜-inch-wide, high-density foam gasket behind the Velcro spaced the grille away from the front baffle. This spacing is necessary to provide clearance for the bass drivers' rubber suspensions. A bead of clear glue-gun adhesive added to the foam gasket's

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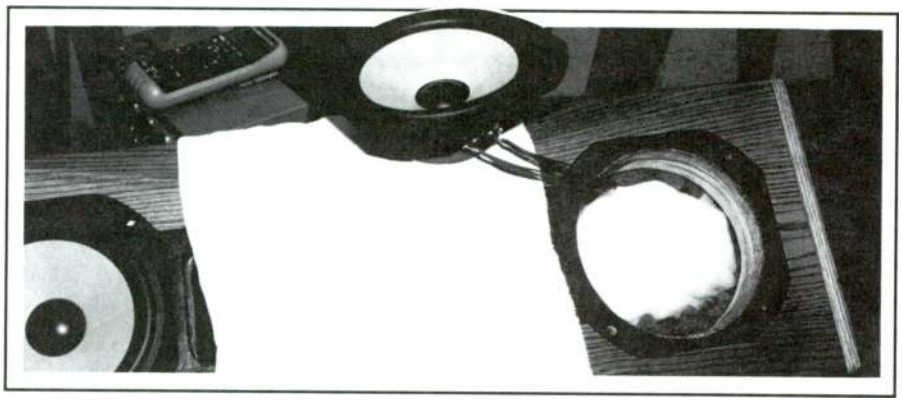

PHOTO 12: Bass enclosure tuning by varying density of stuffing.

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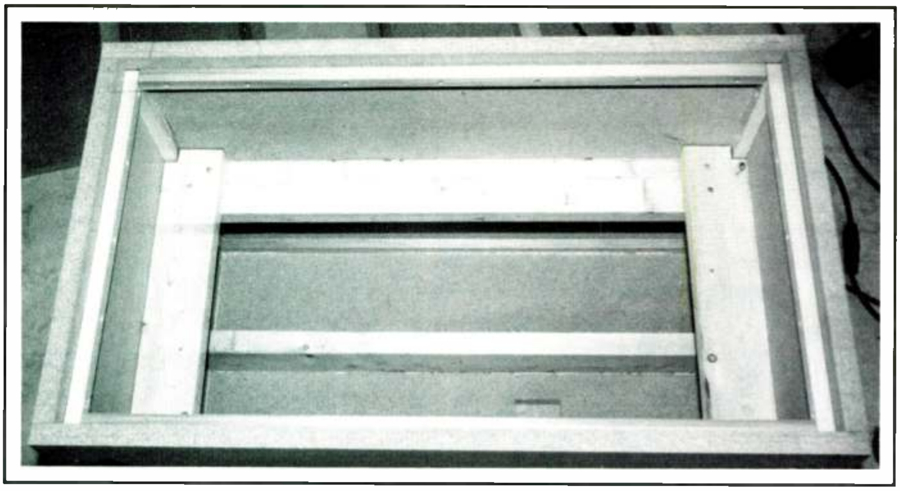

PHOTO 14: Subwoofer 2 × 4 internal bracing.

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sure shape, using an 18″ stamped-metal woofer grille with rubber edge and wrapped in black lycra fabric. When stretched around the grille frame, this material becomes open. I attached it with hot-melt glue to the rubber edge and sewed it to the back side of the metal grille. The grille is the same diameter as the JBL driver and attaches directly to the front of the mounting flange with strips of Velcro. I used a glue gun to strengthen the Velcro's attachment to the driver and grille frames. A pair of brass "L" brackets mounted at the bottom of each JBL driver support the weight of the metal grille, while the Velcro retains proper placement.

A grille placed over the port of a vented system can degrade performance by obstructing air flow. I avoided the need for a cosmetic covering by painting the port a matching black. Black enamel paint will stick to the plastic port if you first wash and scrub it with a "Brillo" pad. *Photo 15* is the completed Prism V/JBL Subwoofer system, with grilles, in my listening room.

SET-UP. I placed the Prism Vs on the subwoofers directly on top of the JBL drivers, angled toward the listening position. The bass driver centers are approximately 3″ behind the front of the subwoofer cabinet. Each Prism V has three ½-inch-diameter felt pads attached to the bottom of the enclosure: two on either side of the front baffle and one at the rear corner.

In discussions over coupling satellites to their stand or subwoofer to minimize enclosure motion, felt pads are not considered as effective as spiking. Having only three points of contact increases the pressure between the satellite and subwoofer enclosures, however, while felt allows the satellite to be repositioned without damaging the top of the subwoofer. These are coupled to the floor through casters, which are also considered inadequate compared to spiking. Since I require the ability to move the speakers away from the rear wall for optimum placement during critical listening, and since the Prism Vs weigh approximately 100 lbs. each (and provide substantial mass loading to the top of the heavier subwoofer enclosures), little if anything is to be gained by attempting to further couple such massive enclosures.

The JBL driver's red terminal is connected to the positive output of a noninverting amplifier. Although a positive voltage applied to the driver terminal produces a backward motion of the cone, I determined that this connection was correct by measuring at the listening position with a "Mitey Mike" microphone and 63Hz warble tone. The positive terminal of the bass drivers and positive input to the midrange-tweeter passive crossover are connected to the positive output of noninverting amplifiers.

Using the "Mitey Mike" and warble tones again, I based the output level setting of the bass and midrange-tweeter amplifiers on measurements made at one meter on the tweeter axis. The level of the subwoofer amplifier was also based on measurements taken at the listening position with this measuring system.

My listening room is 13½′ wide, 8½′ high, and the long dimension extends acoustically the full 47′ width of the house. I placed the speakers against the long wall near one of the short walls, spaced 8′ apart. Their midpoint is 10′ from the listening position. The subwoofers are mirror-imaged with the drivers on the inside and the ports on the outside. The front of the satellites are toed-in toward the listening area.

Photo 15 shows the complete system in the listening room. The speakers are in their "normal" position with the enclosures pushed against the back wall. For critical listening, I pull out the subwoofers so their fronts are 32″ from the rear wall. This position also brings the speakers out in front of the entertainment center. In determining the optimum spacing from the rear and side walls, I was greatly influenced by the "Listening Room" computer program

PHOTO 15: Completed Prism V Satellite/JBL Subwoofer with grilles attached, in listening room.

from Sitting Duck Software. *(Note: "The Listening Room" is available from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458-0243, (603) 924-6371, FAX (603) 924-9467.—Ed.)*

LISTENING IMPRESSIONS. While objectively describing the sound of your own speakers is difficult, anyone considering building them needs to have some idea of their sound. The integration of drivers, crossover, and cabinet design has produced a measurably fine system which is musically very satisfying. One-third octave pink noise, warble tones, and swept sine waves confirm that the octave-to-octave spectral balance is very smooth over the full 20Hz–20kHz range. Coloration is very low due to the absence of significant peaks and dips in the response. Subwoofer-to-satellite blending is truly flawless, with a proper bass-to-treble balance. High-frequency smoothness and extension are as good as I have ever heard, and low-frequency detail and articulation are exceptional.

The only concession to a "no-compromise" design is in low-frequency extension. Ideally, a larger enclosure (12 ft.^{3}) or compound loading of the subwoofer drivers would produce a 3dB down point closer to 20Hz or below. With 99.9% of the music I listen to, however, there is nothing to be gained by making such a change. Smaller woofer systems may go as deep or deeper, but they lack the dynamic capability necessary for realism at moderate-to-high volume levels, and they will also produce dynamic compression and higher distortion levels.

The Prism V Satellite's spatial rendition is very natural, with precise image placement within a properly sized soundstage. The sound is open and spacious, while maintaining accurate placement of images laterally and with good depth. The (5,3) geometry also produces very stable imaging of the proper height and size. The speaker system does not impart its signature on recordings, but allows the music to sound as the recording engineer intended. Furthermore, freedom from vertical lobing problems permits flexible listener seating placement without shifting frequency response or tonal balance.

Definition and clarity are very good without excessive forwardness or an exaggerated upper midrange. This system excels at recreating delicate low level, individual, and small group recordings, but has the power handling to produce the powerful dynamics of the full orchestra without sacrificing clarity or sounding strained. Inner voices are clear and distinguishable, while full-blown rock recordings are great fun because you can recreate the live concert experience. The investment in time and money has produced a wonderfully natural and thoroughly enjoyable loudspeaker system which I heartily recommend.

(Several corrections to Fig. 13, *which appeared in Part I [SB 4/93, p. 26], should be noted: op amp U5A is mislabeled as a TL072—it should be an OP275GP; also, capacitor C9 should be 100N.—Ed.)*

SOURCES

Audio Concepts, Inc.
AC Components
901 S. 4th St.
LaCrosse, WI 54601
(608) 784-4570
(AC foam and "AC Stuff")

Madisound Speaker Components
PO Box 44283
Madison, WI 53744-4283
(608) 831-3433
(passive crossover components)

REFERENCE

Greiner, R.A. and Mark Allie, *Acoustical and Electrical Interaction in Multi-Driver Arrays*, presented at the 70th Convention of the AES, New York, October 30–November 2, 1981, preprint #1818 (B-6).

Software Report

Blaubox 1.2

Reviewed by G.R. Koonce
Contributing Editor

BLAUBOX 1.2, Blaupunkt Division of Bosch Corp., 2800 S. 25th Ave., Broadview, IL 60153. My kit included one 3.5″ 720K format disk and a 75-page manual. Suggested price is $199. The manual indicates Blaubox is also available on 5.25″ 1.2M floppy disk.

Blaubox is a software package which runs on IBM-compatible computers for the design of woofer enclosures and crossovers, and is intended for use by dealers in aiding customers with enclosure design. The manual mentions subwoofers and car applications, and the software has an internal database of Blaupunkt drivers. This database can be expanded up to 1,000 entries with additional drivers of your choosing.

The program provides for Closed-Box (CB), Vented-Box (VB), and single- or dual-vented bandpass (BP) enclosure designs. It will also support the Isobarik driver configuration with all its box types, but does not support the BP configuration with a port between the two chambers. Plotting of small-signal frequency response is provided for any system designed, and enclosure designs culminate in drawings showing how to cut material for three different box shapes. Blaubox works simultaneously with up to two box/driver combinations so you can work with and compare a pair of drivers.

The software also provides for the design of low-pass (LP) and high-pass (HP) passive crossover sections of first through third order (slopes of 6–18 dB/octave). Blaubox is limited to the design of two-way passive crossovers, as bandpass crossover sections for midrange application are not supported.

In addition to full on-line help, Blaubox also offers on-line technical information covering basic acoustics and electronics, as well as information on woofer selection and enclosure design. This is a very nice feature for both the dealer and the novice builder.

I have reviewed the software from the standpoint of the home speaker builder. What Blaubox provides will thus be compared to what I believe the home speaker builder expects from his/her enclosure design software.

Computer Requirements

The program will run on any IBM-compatible machine, from PC/XT (8086) through 80486. Although it will run from a floppy disk, it is best run from a hard disk. The minimum memory requirement is 512K of installed RAM. The program requires DOS 3.3 or later and EGA or VGA (monochrome or color) graphics. VGA is highly recommended, as some graphic screens may be truncated on the bottom with EGA-graphic machines. Optional full mouse support is available if your computer has a Microsoft-compatible mouse. The program supports Epson 9-pin and 24-pin dot matrix printers and compatibles, as well as Hewlett-Packard LaserJet II or compatible printers (in 75, 150 or 300 DPI resolutions). I believe a floating point coprocessor is supported, although I have found no statement to that effect.

For this review, I used a 50MHz 486DX IBM clone with SVGA capabilities, operating from DOS 5.0. The system has a Panasonic KX-P2123 printer which emulates the Epson LQ-860. It worked well with Blaubox when I selected the Epson LQ-1500 option.

Manual

The first 22 pages of Blaubox's excellent manual are dedicated to computer considerations and program operation. Pages 23 through 71 provide a series of appendices covering such basics as acoustics, electronics, and box design and fabrication, and ending in an Audio Glossary of Terms (an unusual feature for a speaker-design software package). A good deal of this information is available in summary form in both the on-line help and technical discussion screens.

Page 43 of the manual describes how to test drivers for the T/S parameters, although the equations provided for establishing Q_{TS} are not the standard. They do not provide Q_{ES} and Q_{MS}, only Q_{TS} directly. I tried them on two drivers against the more standard test approach and they worked properly, as shown in *Table 1*. The equation for computing driver V_{AS} from test data (p. 44 of the manual) is not the more accurate version, so I would recommend using measurement techniques and equations from *SB* articles or any of the standard references.

Program Setup

The Blaubox disk contains an Install.Exe program that will install the program on your hard disk. Simply follow the instructions in the manual. To run the program, log on to the floppy drive or to the hard disk subdirectory containing the program and type: BLAUBOX <Enter>.

Blaubox will determine your video capability and start in a compatible mode. You can immediately move to Screen #5 to change the video between monochrome and color, or to set up the proper printer option. All my reviewing was done with the SCREEN COLOR set to Default, which yielded a color display. Since Blaubox must be able to write to the disk it is running from, do not write protect it if using a floppy disk. The program writes

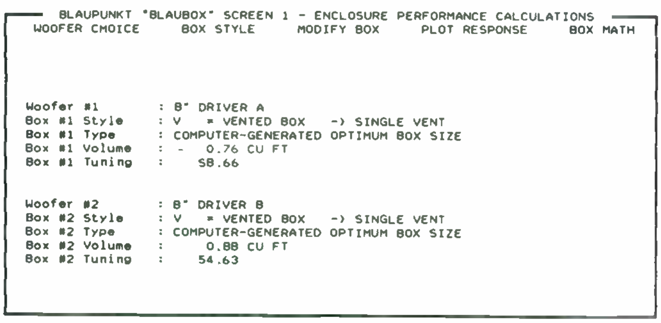

FIGURE 1: Screen #1 showing computer-generated VB designs.

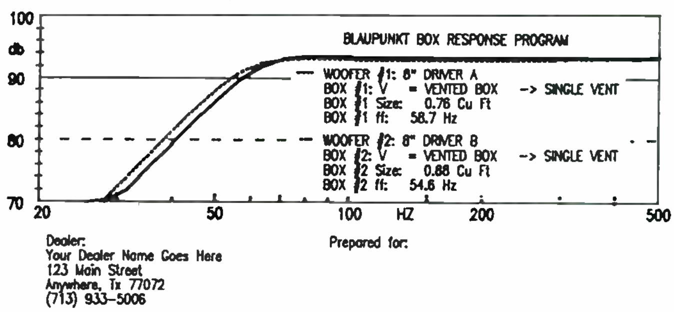

FIGURE 2: Printed PLOT RESPONSE output for the two VB designs.

TABLE 1

COMPARISON OF RESULTS USING EQUATIONS IN THE MANUAL WITH STANDARD EQUATIONS

	8″ DRIVER A			8″ DRIVER B		
	Q_{ES}	Q_{MS}	Q_{TS}	Q_{ES}	Q_{MS}	Q_{TS}
Via Manual Equations	/	/	0.294	/	/	0.320
Via Standard Equations	0.335	2.903	0.301	0.357	2.877	0.317

TABLE 2

TEN BOX STYLES SUPPORTED BY BLAUBOX

(Shows Name Used By Blaubox)

NAME	DESCRIPTION
S	Sealed box (closed box)
SI	Sealed box with Isobarik drivers
V	Vented box
VI	Vented box with Isobarik drivers
BP4	Bandpass box with single vent
BP4I	Bandpass box with single vent and Isobarik drivers
BP5	Bandpass box with single vent and added inductor
BP5I	Bandpass box with single vent, added inductor and Isobarik drivers
BP6	Bandpass box with both sides vented
BP6I	Bandpass box with both sides vented and Isobarik drivers

Note: Isobarik uses two identical drivers of type selected.

TABLE 3

BOX MATH DATA ENTRY LIMITS AND DISPLAY FORMATS

CONVERSIONS	INPUT LIMITS	OUTPUT DISPLAY
Cubic Inches	0.01–999999.99	Up to 7 digits, decimal, 2 digits
Cubic Feet	0.01–999.99 (to Cu In) 0.0001–999.9999 (to Liters)	Up to 3 digits, decimal, 4 digits
Liters	0.01–999999.99	Up to 5 digits, decimal, 2 digits

Volume Computation:
H, W and D inputs all in inches, range 0.01–999.99.
Volume in cubic feet displayed with up to 4 digits before decimal and 3 digits after.
Volume in liters displayed with up to 8 digits before decimal and 4 digits after.

to disk any driver data you enter to the database and also certain default data pertaining to the program startup.

Program Description

Blaubox operates from a main menu offering seven screens for various functions and the ability to Reset all data, as well as the ability to Quit and return to DOS. Listed below are the seven screens and the menu items offered by each. When I refer to these screen menu items, I will show them in uppercase.

• **SCREEN #1—Enclosure Performance Calculations**: Once your drivers are installed in the database, system design is handled in Screen #1. WOOFER CHOICE allows you to select the driver for each box (or system) from those in the database. It also offers the option of canceling box #2 if you are working with only one design.

Use BOX STYLE next to select the type of box you are designing from the ten offered (*Table 2*). When working with two systems, for example, you can have a different box style for each. Once you have selected a box style, the program displays the computer-generated design for that box style on the screen. *Figure 1* shows Screen #1 for VB designs with my two defined 8″ drivers. Blaubox works primarily with a text mode display so you can print the screens and windows displayed by using <Shift> + <Print Screen>. This nice feature allows you to easily document your design. For clean printouts, move the mouse cursor to the bottom of the screen before printing, as you will get a glitch (missing character) in whichever line it appears.

You can use MODIFY BOX to define new box volumes, new tunings, and a new inductor value if appropriate. Note that Blaubox does not do any nonoptimum designs. Once you change a box volume, you must also provide the other information for the new design.

You can view the design response via PLOT RESPONSE, and can always return to the computer-designed boxes via the MODIFY BOX options. *Figure 2* shows the PLOT RESPONSE output to the printer for the computer-optimum VB designs shown in *Fig. 1* (the PLOT RESPONSE-to-screen presentation contains the top two portions shown in the figure), including identification of the two curves as well as the driver, box type, and parameters for each system. In fact, *Fig. 2* represents most of the information you would like documented about your design.

The box at the bottom of *Fig. 2* displays the dealer and customer information which you can enter via Screen #5. This box is also intended to provide space for additional handwritten notes. The program does not offer any way to change either the frequency or dB SPL ranges used in PLOT RESPONSE. The shape of the response plots for CB and VB computer designs presented by Blaubox agree with plots produced by other software for the same system parameters, within the accuracy with which you can read the plots. As shown in *Fig. 2*, Blaubox established a passband response level of about 94dB for the two 8″ drivers. I calculated their reference efficiencies at 93.4dB (Driver A) and 93.1dB (Driver B).

Ten box styles are offered, so if you get confused on Screen #1, press F2 to see a drawing of the possibilities (reproduced on manual page 45, and can also be called up while working on Screen #2). When working with BP designs, Blaubox produces both chamber volumes and one or two tunings as appropriate. I was told that Blaubox always designs BP systems with a system damping factor (S) of 0.6. For the BP5 or BP5I design, Blaubox provides the value of the inductor used. When you change to a user-specified design, remember that you are responsible for all values: volumes, tunings, and the inductor if used. You can PLOT RESPONSE any design to see what you are getting.

When you change from one box style to its Isobarik equivalent, all chamber volumes halve and any tunings remain the same, which is the correct result. When changing from the BP5 to the BP5I, the choke value remained the same—incorrect! I discuss this problem later.

The final menu item in Screen #1 is BOX MATH, which allows you to compute rectangular box volumes and make conversions between cubic feet, cubic inches, and liters. Data cannot be transferred into or out of BOX MATH, as it is a free-standing function. BOX MATH apparently uses the conversion factor of 1 ft.^{3} = 28.3153 liters. Data entry limits and display formats are shown in *Table 3*.

When I tried to design all ten box styles for the drivers I had defined with all low- and all high-limit data, the resulting designs were weird. Problems (discussed later) developed when I tried to use PLOT RESPONSE with these designs.

• **SCREEN #2—Final Box Fabrication**: Once you have established your system designs, use Screen #2 for the actual enclosure design.

BOX SHAPE allows you to make either

TABLE 4

MODIFY BOX DATA ENTRY LIMITS

Rectangular Box	Height, Width* and Depth	0.01–999.99″
Tubular Box	Length* and Diameter	0.01–999.99″
Wedge Box	Height, Width*, Top Depth and Bottom Depth	0.01–999.99″
Material Thickness	(all shapes)	0–999.99″

* For BP designs, enter two of these, both with the limits shown.

system a Rectangular (a normal six-flat-sided box), Tubular (a round tube with flat circular ends), or Wedge (a six-sided box with one face tipped at an angle).

Once a shape is defined, use MODIFY DESIGN to define the enclosure dimensions. Remember, in this window you are working with the enclosure's outside dimensions. The window allows you to change the material thickness from the default value, and the program also allows material thickness to be set to zero for those who think better in internal dimensions. Later, you can go back and add material thickness to correct the dimensions.

The program does not design the enclosure: you must adjust the dimensions until you get the volume you are looking for; for comparison, the volume of the enclosure you have defined is displayed in the MODIFY DESIGN window. *Table 4* shows the data entry limits for MODIFY BOX with the three different box shapes. The wedge-shape box, which wants the top depth smaller than the bottom depth, will accept a smaller bottom depth and interchange them if necessary. The program would not allow me to set the top and bottom depths equal to yield a rectangular box.

Screen #2 also allows design of the port or ports via the PORT menu item. If the system has no port when this item is selected, you will receive an error message. Enter a port diameter in the allowable range of 0.001–999.999″, and the program will provide the port length based on the enclosure volume and tuning. Blaubox appears to be designing ports which stand free at one end and are flanged at the outside end. If you highlight the port-length data field, the program will not allow data entry, as it only designs length based on diameter. Some problems I encountered with port design will be discussed later.

The DRAW BOX menu item will produce drawings of the enclosure design to the screen or the printer. You must be careful here, as only system #1 will produce a drawing; you cannot draw system #2. A single-screen drawing is provided for the rectangular and tubular shapes, but the wedge shape produces three pages of screen drawing, including information on the angle the tipped face makes to horizontal (90° for a rectangular shape) and the cut angles used to produce this box. *Figure 3* shows the printed design for a rectangular-shaped box for box #1 of *Fig. 1*, the 8″ Driver A in a program-designed VB.

• **SCREEN #3—Speaker Parameter Database**: This screen allows you to add, modify, delete, and review driver entries in the database.

SCROLL DATABASE allows you to examine all driver entries in the database.

MODIFY WOOFER allows you to modify data for a driver in the database. You cannot modify either the Woofer Name data or data for the Blaupunkt drivers which are in the database when you receive the program.

DELETE WOOFER allows you to delete a driver from the database. You cannot delete the Blaupunkt drivers in the database when you receive the program.

ADD WOOFER allows you to add a driver to the database (*Fig. 4*). You provide the required data items for the driver along with its name.

• **SCREEN #4—Crossover Design**: This screen is used for crossover-section design: low-pass (LP) for use with woofers, and high-pass (HP) with tweeters.

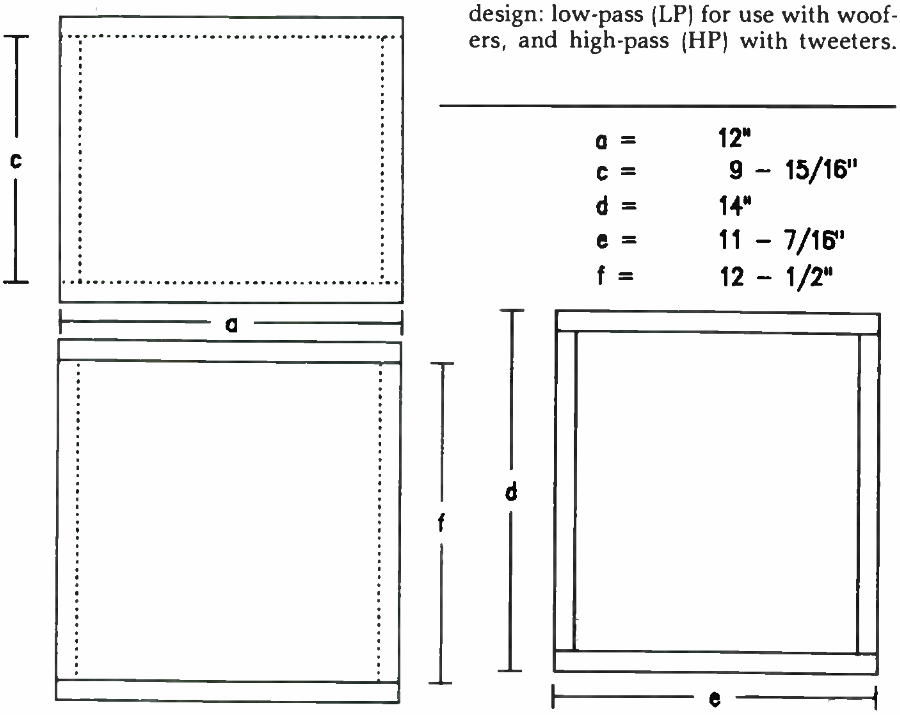

FIGURE 3: DRAW BOX to printer for Box #1 of the VB designs.

TABLE 5

ACCEPTABLE DATA RANGES FOR DRIVER DATA ENTRY

Q_{ES} or Q_{TS}	= 0.01–2.000
Q_{MS}	= 0.01–20.000
f_S	= 1.00–100.00*
V_{AS}	= 0.01–99.99 ft.³ or 0.01 to 999.99 liters
Z_E	= 0.01–19.99Ω**
Power	= 1–9,999W
X_{MAX}	= 0.001–99.999 in inches or in millimeters
Cone Dia. & Category Dia.	= 3.00–29.99″

*Not good if you work with small woofers
**Important only for BP5 or BP51 designs

Three-way crossover design is not provided. Select the desired slope (6, 12, or 18dB/octave) in LP or HP from the menu, then enter the load resistance (R_{LOAD}) and crossover frequency (f_{CO}). The program initially defaults to values of 4Ω and 200Hz. The allowable data range for load resistance is 0.01–999.99Ω; for crossover frequency, it is 100–20kHz with no decimal digits allowed.

Blaubox then presents you with the appropriate schematic and component values. I verified the values for a Butterworth crossover section. Load resistance and crossover frequency values are automatically entered as the new defaults so you can review many options easily, and you can print all these text screens to document your crossover design. Although no information about the relative electrical polarities of the drivers is given on the crossover schematics, manual page 54 does address this issue.

• **SCREEN #5—Printer, Color, User, and Materials Configuration**: Used for configuring the printer, screen, and certain default parameters. SCREEN COLOR allows you to force monochrome or color. The latter is definitely recommended with Blaubox.

Menu item DEALER INFO allows you to enter information which will appear as the dealer information on the PLOT RESPONSE printed output (*Fig. 2*). This information is written to disk and will be restored when you restart Blaubox, and is not cleared when you select Reset Blaubox.

Menu item CUSTOMER INFO allows entry of the customer information which appears as "Prepared for:" in the PLOT RESPONSE printed output. The information is lost when you exit or reset Blaubox.

This screen also contains the MATERIAL menu item which allows setting the default material thickness to be used when Blaubox is started.

Menu item PRINTER allows you to select various printer options, including Oki PlugNPlay, HP LaserJet II 75, 150 and 300 DPI, User Defined, Epson MX100 and MX100 HD, and Epson LQ1500. Since the

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```
BLAUPUNKT "BLAUBOX" SCREEN 3 - SPEAKER PARAMETER DATABASE
SCROLL DATABASE      MODIFY WOOFER      DELETE WOOFER      ADD WOOFER

                        Woofer Parameters

        Woofer Name     : 8" DRIVER A
     ------------------------------------------------------------
        Choose Q Type          :   Separate Qes and Qms     **
        Elec. Q         (QES):             0.335
        Mech. Q         (QMS):             2.903
        Total Q         (Qts):             0.300
        Resonant Freq   (fs):              46.00     HERTZ
        Equiv. Volume (Vas):               1.74      CU FT    **
        Impedance (Ze)         :           8.00      OHMS
        Max Contin. Power      :           50        WATTS RMS
        Excursion      (Xmax):             0.120     INCHES   **
        Cone Diameter          :           6.70      INCHES
        Category Diameter      :           8.00      INCHES

        ** Use SPACE bar to select Q type and Units

             Ctrl-ENTER: Accept    ESC: Ignore Changes
```

FIGURE 4: ADD WOOFER data window showing driver parameters entered.

```
BLAUPUNKT "BLAUBOX" SCREEN 1 - ENCLOSURE PERFORMANCE CALCULATIONS
WOOFER CHOICE    BOX STYLE    MODIFY BOX    PLOT RESPONSE    BOX MATH
Woofer #1        : 8" DRIVER A
Box #1 Style     : V   = VENTED BOX    -> SINGLE VENT
Box #1 Type      : COMPUTER-GENERATED OPTIMUM BOX SIZE
Box #1 Volume    :    10.00 CU FT
Box #1 Tuning    :    58.66


Woofer #2        : 8" DRIVER B
Box #2 Style     : V   = VENTED BOX    -> SINGLE VENT
Box #2 Type      : COMPUTER-GENERATED OPTIMUM BOX SIZE
Box #2 Volume    :    10.00 CU FT
Box #2 Tuning    :    54.63
```

FIGURE 5: Screen #1 showing incorrect box volumes after trying to escape MODIFY BOX.

```
BLAUPUNKT "BLAUBOX" SCREEN 2 - FINAL BOX FABRICATION
BOX SHAPE    MODIFY DIMENSIONS    PORT    BOX MATH    DRAW BOX
CURRENT BOX: #1
Box #1 Style     : V   = VENTED BOX    -> SINGLE VENT
Box #1 Shape     : RECTANGULAR
User-Set Volume  :      1.50 CU FT

Original Box Tuning :    23.00 HZ
Current Box Tuning  :    23.00 HZ
Port Length:    5.10 IN    Port Diameter:    3.00 IN


Material Thickness:  0.750  (INCHES)

F5: Select Box #2
```

FIGURE 6: Screen #2 showing incorrect retained Port data; correct length should be 21.78".

```
BLAUPUNKT "BLAUBOX" SCREEN 3 - SPEAKER PARAMETER DATABASE
SCROLL DATABASE      MODIFY WOOFER      DELETE WOOFER      ADD WOOFER

                        Woofer Parameters

        Woofer Name     : TEST OF QTS UPDATE
     ------------------------------------------------------------
        Choose Q Type          :   Separate Qes and Qms     **
        Elec. Q         (QES):             0.335
        Mech. Q         (QMS):             2.903
        Total Q         (Qts):             1.234
        Resonant Freq. (fs):               46.00     HERTZ
        Equiv. Volume (Vas):               1.74      CU FT    **
        Impedance (Ze)         :           8.00      OHMS
        Max. Contin. Power     :           50        WATTS RMS
        Excursion      (Xmax):             0.120     INCHES   **
        Cone Diameter          :           6.70      INCHES
        Category Diameter      :           8.00      INCHES

        ** Use SPACE bar to select Q type and Units

             Ctrl-ENTER: Accept    ESC: Ignore Changes
```

FIGURE 7: ADD WOOFER window showing how incorrect Q_{TS} value is retained.

Continued from page 48
Epson LQ1500 option worked fine, I stayed with it. If none of the options will support your printer, you will probably be unable to print PLOT RESPONSE and DRAW BOX. Almost everything else is on text screens and compatible with any printer your computer supports.

- **SCREEN #6—Using Blaubox**: Basic information on how a dealer can use the program to guide a customer down the right purchase path. The topics include customer guidance, woofer choice, box style, and fabrication.
- **SCREEN #7—Tech Talk on Woofer Box Design**: On-line technical help for subjects including acoustics, electronics, woofer design, and box design.
- **Nonscreen Items**: The main menu also offers "Reset Blaubox," which clears all the data and selections you have entered, except for items already identified as written to disk. Essentially, it tries to return Blaubox to its state when you started the program. When selected and accepted, you are presented with a confirmation box which allows resetting or returning to the program without changes. Main menu item "Quit Blaubox to DOS" exits the program. Once selected and accepted, you are gone with no confirmation box.

Blaubox has a built-in screen-saver feature. After three minutes of inactivity, the program returns to the opening screen; pressing any key will bring you back. The program offers full mouse support with the left button equivalent to <Enter> and the right to <Esc>.

Program Operation

This program has a lot of capability which I tried to exercise as much as possible. Working from a position of having a pair of drivers and attempting to design an enclosure for them, the following describes using Blaubox to accomplish this.

Blaubox will not work with drivers not included in the database, so I first installed my two drivers. I also installed some drivers with strange data. *Figure 4* shows the ADD WOOFER window under Screen #3.

When you try to select woofers for each system, the Woofer Name data item will be displayed, so enter something you will recognize. You cannot modify this name once you have entered the driver into the database; to change it requires reentering the driver. Blaubox will warn you if you have picked a Woofer Name which already exists in the database and offers you the option to return to the ADD WOOFER window to rename the driver. You are offered two options for driver Q: "total Q_T" and "separate Q_{ES} and Q_{MS}." If you have both Q_{ES} and Q_{MS}, you should select this option and the program will compute and display Q_{TS}.

This window requires you to enter all the indicated information, although I do not believe it is all used. Certainly the Q_S, f_S and V_{AS} are used. Impedance (Z_E) is also used if you design a BP5 or BP5I system to figure the inductor value. I believe the last four items are not used and you can make up values for these if necessary, but I can't be sure this is true. The data ranges acceptable to each item are shown in *Table 5*. You have the option of entering V_{AS} either in cubic feet or liters, and X_{MAX} either in inches or millimeters. I created drivers having all the data set to the low limit (or all set to the high limit) to see if the program could handle them. Such drivers would never appear in real life.

Data entry in Blaubox is fairly consistent. If you type the full number of characters the program allows, it will automatically advance to the next item. Otherwise, press enter or click the left mouse button. Once you reach the entry of f_S, you will be unable to go back and edit an entry until you have entered all the data. You can then move about the window via the mouse, arrow, or tab keys.

Each method has a slightly different effect. The mouse will select the full data item. The <Tab> key will advance down the window, but treats numbers with decimal points as two separate items (to the left and right of the decimal point). Shift + <Tab> works in reverse order, moving up the window. The arrow keys move from item to item; on numeric items, they move character by character. You insert or overwrite data via the <Insert> key. When a data box is selected, you can clear the existing data by pressing the spacebar.

Once you have completed the data in the ADD DRIVER window, you are given the option of either escaping without adding the driver (press <Esc> or click the right mouse button) or of accepting the data (<Ctrl> + <Enter>); however, I found no way to accept data windows with the mouse. Clicking the left mouse button, supposedly the equivalent of <Enter>, would not work even if I held the <Ctrl> key.

Screen #3 allows you to review all the drivers in the database via SCROLL DATABASE. You are prompted for the first letter of the name you wish to begin with, but you can move forward or backward through the database using function keys. With the MODIFY WOOFER menu items, you can change any data on the drivers you enter to the database, except the Woofer Name. (Remember, you cannot modify or delete the default Blaupunkt drivers that come with Blaubox.) The DELETE WOOFER item allows you to remove drivers after answering "yes" to a confirmation box.

In general, I found that Screen #3 provides all the needed capability to enter data for the drivers I wished to use. Again, remember that you must enter the driver to the database before you can design with it. In my opinion, the manual should contain a section clarifying how each item you enter is used.

TABLE 6

TESTS OF REPORTED INDUCTOR SIZE VERSUS DRIVER IMPEDANCE

VALUE IN DATABASE	INDUCTOR VALUE REPORTED BY BLAUBOX	
Driver Impedance (Z_E)	BP5-Style Inductor	BP5I-Style Inductor
2Ω	0.52mH	0.52mH
4Ω	1.03mH	1.03mH
8Ω	2.07mH	2.07mH
16Ω	4.13mH	4.13mH

Problem Areas

In these areas the program generated or displayed incorrect or invalid information or halted execution. I consider the first six items major problems, because they could cause you to document wrong results for normal design activity. The remaining items will probably occur only when you enter weird data or ask for an unreasonable design—this doesn't mean they shouldn't be fixed.

1. Inability to escape from MODIFY BOX. This was a major problem. The program starts in Screen #1 with a computer optimum design by default, and then allows you to modify it. Once you have typed the revisions into the MODIFY BOX window, you are offered the options of either accepting them or escaping. Once entered, a value stays in the program even if you select ignore via <Esc> or the right mouse button. If you select PLOT RESPONSE, the plots are developed with the parameters you changed. When you return to Screen #1, the box type is still shown as computer generated, but the parameters have changed. See *Fig. 5*, which should have box volumes identical to *Fig. 1*.

You must always reestablish the computer-generated designs after trying to escape from the MODIFY BOX window. To do this, select MODIFY BOX and then computer-generated for the design(s) in question.

2. Improper display of box type. If you are working with a given box style and have modified it, Screen #1 will show box type as "USER-SPECIFIED BOX SIZE." If you now use BOX STYLE to change from a CB to a VB, when you return to Screen #1 Blaubox will show results for a default computer-generated box of the new style, but the box type is still shown as "USER-SPECIFIED BOX SIZE." You must reestablish the computer-generated design as described above.

3. Displaying wrong duct length. After PORT design for a vented enclosure on Screen #2, the port diameter and length are displayed. If you return to Screen #1 and change something associated with the design, on return to Screen #2 you will see the new design presented, but the old port diameter and length are still displayed. *Figure 6* shows the results of this. Always select PORT and reestablish a valid port design before assuming you have a final design.

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PRACTICA MUSICA: SOF-MUS1M3G
YOUR PERSONAL MUSIC TUTOR Software $114.95

PRACTICA MUSICA is training for your ear, as well as the most fun way yet devised to learn music. Noted for its outstanding sound quality, PM offers a wide variety of musical games or activities (*practica*) designed to help you develop specific musical skills. Featured are pitch reading; scales; interval ear training; interval playing and spelling; chord ear training; chord playing and spelling; and melody ear training for pitch, for rhythm, and for both. PM also identifies chords as you play them, generates example melodies, and displays staff notation. By Jeffrey Evans. Usable with any Macintosh. Includes operating manual plus 190-page textbook *Windows on Music* (not a reference to Microsoft's product). 1987-1993, Macintosh only.

PLAY IT BY EAR Software SOF-PLY1BXG $99.00

Award-winning PLAY IT BY EAR is an interactive program that will help you scale new heights, if you'll pardon the expression. It provides a variety of self-paced exercises in a realistic learning environment, featuring an on-screen keyboard or guitar fretboard. You'll find that it develops your listening sense and enjoyment, by honing your ability to recognize single tones, intervals, and chords by ear--and by their location on the keyboard or fretboard. 1991 finalist in Software Publishers Association "Best Home Learning" category; 1992 finalist for "Best Music Program," *Multimedia World Magazine*. By Renga Development Group/Ibis Software. Requires 640K; DOS 2.0+; one floppy drive; IBM, Logitech, or Microsoft-compatible mouse; CGA, EGA, VGA, or Hercules; computer speaker (no extra hardware needed). MIDI or sound card recommended but not necessary. 64-page manual. 1990, IBM only (please specify disk size).

NOTEPLAY Software

Designed primarily for people who want to learn to play music, or to improve their current playing abilities, this package can be used to teach you how to read notes on a staff and play them from a keyboard. Using either the computer keyboard (which has been mapped to replicate an electronic keyboard) or an actual MIDI keyboard, you select and play back the notes displayed on a staff. In this game format, points are awarded for speed and accuracy. Thirty-six levels are available, with new drills introduced at each. By Renga Development Group/Ibis Software. Standard version usable with internal speaker only, but also supports sound card, sound card with MIDI, or MIDI card; Windows version requires Windows-compatible sound or MIDI card. 28-page manual. 1992, IBM only. Purchasing options available:

SOF-NPL1BXG	NOTEPLAY standard version, requires 640K, please specify disk size	$49.95
SOF-NPL2B3GW	NOTEPLAY FOR WINDOWS, requires 2Mb, 3½" disk supplied	49.95

Build Your Own Home Theater BKS47 $16.95

For the do-it-yourselfer who is looking for bargains but is still interested in quality, here's how to create your own dream system for a fraction of the cost of having it done for you. Includes information on home theater found nowhere else, as well as how-to instructions. By Robert Wolenik. 1993, 200pp., 7 3/8 x 9 1/8, softbound.

Modern Acoustical Imaging BKIE2 $79.95

This book reviews recent developments in acoustical imaging, describing how sound can produce object images which cannot be obtained using light, x-rays, or other types of radiation. The thirty-five IEEE (Institute of Electrical and Electronics Engineers) reprint papers are broken into eight parts: Pulse-Echo Techniques; Holography; Tomography; Microscopy; Imaging Systems in General; Seismic Exploration; Signal Analysis and Processing; and Image Understanding. Edited by Hua Lee and Glen Wade. 1986, 433pp., 8⅞ x 11, hardbound.

TERM Loudspeaker Development Software

NEW THIS ISSUE

These well-known packages have high-resolution graphics, on-line help, and a menu-driven format that makes them extremely easy to use. Features common to TERM-1 and TERM-PRO include a 10,000-driver-capacity database with multiple library support; enclosure design capabilities for sealed, ported, and isobarik sealed and ported; predicted enclosure response and SPL plots; port and enclosure layout design functions, including wedge, rectangular, or bandpass designs; passive crossover design for first, second, and third order high pass, bandpass, low pass, notch filters; Linkwitz-Riley, Bessell, BEC, Butterworth, Chebychev design; and acoustic curve overlays with crossover enabling toggle. TERM-PRO (only) also includes single reflex bandpass (4th); isobarik SRBP (4th); SRBP with coil (5th); isobarik SRBP with coil (5th); dual reflex bandpass (6th); isobarik DRBP (6th); DRBP with coil (7th); and isobarik DRBP with coil (7th). By Wayne Harris. 1989-1992, IBM only. XT/AT/compatible; one disk drive (hard recommended); 640K RAM; MS-DOS 3.0+; CGA, EGA, or VGA; Epson dot matrix and HP LaserJet II compatible; mouse optional. Purchasing options available:

SOF-TRM1BXG	TERM-1 Loudspeaker Development Software, 221pp. manual, please specify disk size	**$199.00**
SOF-TRM2BXG	TERM-PRO Loudspeaker Development Software, 403pp. manual, please specify disk size; English, German, Spanish, and Swedish software versions are included with each package	**399.00**

Supercon Heavy-Duty Electrical Connectors

These high-quality plugs and receptacles by Superior incorporate many advanced engineering features designed to provide safe, rapid, and positive connections. Socket-type plugs have a functionally designed grip for handling ease. Connection can be soldered or solderless, and cable-fastening screws accommodate a wide range of cable sizes. Panel-mount pin-type receptacles (jacks) feature connection to a threaded stud by wire wrap-around, by lug or bus bar connection. Maximum panel thickness: .25". 100A types rated 125-250V AC or DC current interrupting; 600V unenergized connect or disconnect use only; CSA certified. 250A types rated 600V unenergized connect or disconnect use only. Available in black or red. PLEASE SPECIFY COLOR. Purchasing options available:

SCSCON-100P	100A Plug, 3.81"L x 1.50"DI	**$24.95**
SCSCON-100J	100A Jack, 2.50"L x 1.50"DI	**24.95**
SCSCON-250P	250A Plug, 5.00"L x 1.50"DI	**37.95**
SCSCON-250J	250A Jack, 3.56"L x 2.00"DI	**37.95**

AudioSource Utility CD CDLLC-3 $34.95

This new three-in-one CD from California features test tones and music tracks, a special section for Dolby Pro Logic surround sound setups, and a digitally encoded cleaning system for all types of CD players. Test tracks include channel ID, polarity, localization, sweep tones, dynamic impact/transient response check, and digital silence. Produced by Grammy winner Jeffrey Weber, the five music tracks are "Do the Shrimp" by Luis Conte; "Poncho" by Chris Smith; "Never Give Up" by Tim Weisberg; "Fanfare" by Bill Meyers; and "Up" by Nelson Kole. The Dolby test portion includes channel ID to verify L/R connections and speaker placement and localization to verify imaging and sound placement. The ingenious cleaning process quickly and easily eliminates distortion, mistracking, slower access times, and unnecessary error correction due to damage from foreign elements such as dust, dirt, smoke, and moisture.

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$100.00–199.99	5.00	20.00	15.00	20.00	30.00	40.00
> $200.00	6.00	30.00	25.00	30.00	40.00	50.00

NEW THIS ISSUE

The Amazing HyperClock Kit — KS-11 — $99.00

This great timepiece for wall or table has to be seen to be believed. It claims to be (and is) like no other clock ever and proclaims itself a kit whose time has come (get it?). Based on a custom-programmed Intel 8749 microcontroller, HyperClock features six numeric LEDs to display eight unique time display modes; regular or before-the-hour time display (8:45 or 15:9--"fifteen before nine"); fade-out/fade-in or instantaneous digit changes; exclusive fade-in/fade-out LED chaser that simulates a second hand using a ring of sixty LEDs; chime or mute option; graphic ebb tide and flood tide display showing approximate tide changes based on 12:25:05 high-to-high cycle; wake-up alarm (chime) along with alarm-enabled LED; day/month display with automatic month transition; and 12-hour notation with PM LED. By SkiTronix. Full instructions included, as well as plans for a wooden case. Kit includes PCB, all components and displays, and 120VAC wall-mount transformer. 9V backup battery not included. Usable as bare electronics; with clockface (cover) sold below; or with other case or clockface of suggested or your own design. Not available assembled. A fantastic gift for a constructor--if you can stand to part with it! Purchasing options also available:

KS-11CF	HyperClock Ruby Red Plexiglas Clockface Cover, octagonal, 7" in diameter	**$ 19.95**
KS-11/S	Complete Unassembled HyperClock Kit, including Clockface Cover KS-11CF, at a savings of $4!	**114.95**

Fowler Mass Couplers

The idea of mass coupling is simple: by rigidly connecting a loudspeaker of relatively low mass to a highly massive structure (the floor), the effective mass of the enclosure is significantly enhanced. This treatment results in tighter bass response, cleaner transients, and an overall improvement in imaging capability. Fowler couplers feature ease and neatness of installation and level adjustment; long threading to allow significant speaker tilt; sharp points to easily penetrate carpet; hardened steel construction; and reversible (unscrewable) design. Four units recommended per speaker. Each unit consists of toe or spike, threaded insert, and jam nut. From Fowler Audio. Sold in sets of four only; individual units not sold separately. Purchasing options available:

HDFT/4	Set of four Fowler Toe units. Require $\frac{3}{8}$" holes and 6mm Allen wrench. Toe height is $\frac{1}{2}$".	**$ 9.95**
HDFS/4	Set of four Fowler Spike units. Require 1/2" holes and 10mm Allen wrench. Toe height is $\frac{3}{4}$".	**14.95**

Famous ProGold Contact Conditioner

ProGold is a one-step treatment that conditions gold connectors, contacts, and other metal surfaces, enhancing the conductivity characteristics to efficiently transmit electrical signals. Coating the entire contact surface and connection, it provides superior protection from abrasion (insertion resistance), arcing, RFI, wear, and atmospheric contamination. Nonflammable, nontoxic, environmentally safe. By Caig Laboratories, Inc. Purchasing options available:

KM-6PGL7	ProGold Liquid: 7.4ml vial with brush	$19.95
KM-6PGL25	ProGold Liquid: 25ml precision dispenser	39.95
KM-6PG	ProGold Kit: 5.5-oz. spray, 50 PG wipes, PG pen (stick) applicator, lint-free cloths, papers, swabs, cleaning brushes	49.95

Ultra-Low-Leakage Pico-Amp Diodes — SDPAD1 — 10/$1.95

These Siliconix FN5015 (PAD1 Series) diodes feature leakage currents which are practically immeasurable (5pA max. typical), providing a superior alternative to conventional diode technology when reverse current (leakage) must be minimized. They are ideal for protecting the inputs of expensive preamps, and have numerous other audiophile applications as well, since their extremely low leakage current means that they generate very, very little noise. TO-18 (modified) package (cathode, anode only). Sold only in packages of ten.

THIELE/SMALL MEASUREMENT Software — SOF-TSM1B5 — $29.95

This handy program puts measuring Thiele/Small parameters within the reach of many an ordinary hobbyist, taking about two minutes per driver and requiring basically an oscillator, frequency counter, amplifier, two DVMs, oscilloscope, and some miscellaneous other parts and equipment, such as a ruler. Using a simple hookup configuration explained on the disk, this method quickly and accurately calculates Q_{ES}, Q_{MS}, Q_{TS}, V_{AS}, F_S, B*L, M_{MD}, and C_{MS}. The complete procedure is carefully outlined in the program's README file and is easy to implement. It does not use the -3dB methodology, which is highly prone to inaccuracy, but instead determines Q from the frequencies where Z equals the geometric mean of R_{DC} and Z at f_S. This program also calculates the frequency dependent parameters used in LEAP 4.1, and is the officially pre-registered version of the similar Shareware program available on the Madisound BBS or the Audiophile Net. By Michael Thompson. Requires DOS 2.0+. IBM $5\frac{1}{4}$" DS/HD only.

Equipment Preservation Jack-Its — SCJKI/10 — 10/$3.95

Jack-Its are spare connector protectors made from soft, conforming vinyl. Resembling nipples, they fit snugly over any RCA jack to provide a weathertight fit, usually after you initially protect the connector surfaces with Cramolin/Deoxit/ProGold. Black only. Sold only in packages of ten.

North Creek Tapped Coils

High-quality #14 AWG tapped coils from North Creek Music Systems feature air core, oxygenfree copper, and military grade enamel. Four inductors for the price of one! Purchasing options available:

LNCTC-S14	Small (.2, .3, .4, .5mH) Tapped Coil	**$14.95**
LNCTC-M14	Medium (.6, .7, .85, 1mH) Tapped Coil	**16.95**
LNCTC-L14	Large (1.2, 1.35, 1.5, 1.7mH) Tapped Coil	**21.95**
LNCTC-X14	Extra Large (2.0, 2.5, 3.0, 3.5mH) Tapped Coil	**24.95**

WOODSIZE Software

This astounding package determines lumber sizes for speaker cabinets--and what a job it does! Although it is great for just about any use, WOODSIZE was designed with auto sound in mind and thus "visualizes" the cabinet as sitting under the rear deck of a typical sedan. Cabinet types available are sealed; vented; single or double reflex coupled cavity; and single or double reflex coupled cavity isobarik. Input parameters are wood thickness; driver diameter and depth; air displaced by driver; first and second enclosure volume(s); and first and second vent diameter(s) and length(s). Output data are the exterior dimensions of the cabinet; exact quantity and size of each wood piece required, including braces; exact square footage of wood required (no waste); internal depth, height, and width; and exact air displacement (cu. in.) by driver, vent(s), and bracing. 13-page instruction manual includes assembly diagrams for cabinet options. By Allen D. Schultz. IBM only. Purchasing options available:

SOF-WSZ1B3	WOODSIZE Software, $3\frac{1}{2}$" DS/DD IBM disk	**$34.95**
SOF-WSZ1B5	WOODSIZE Software, $5\frac{1}{4}$" DS/DD IBM disk	**34.95**

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$50.00–99.99	4.00	15.00	7.50	15.00	20.00	30.00
$100.00–199.99	5.00	20.00	15.00	20.00	30.00	40.00
> $200.00	6.00	30.00	25.00	30.00	40.00	50.00

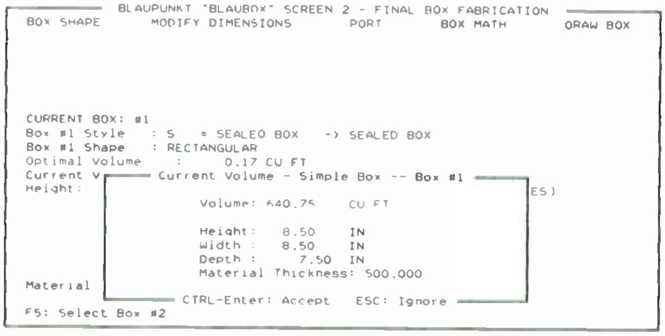

FIGURE 8: MODIFY DIMENSIONS window showing data overflow problem in volume; true volume = –564640.75 ft.^{3}; typed thickness as 500, should be .500.

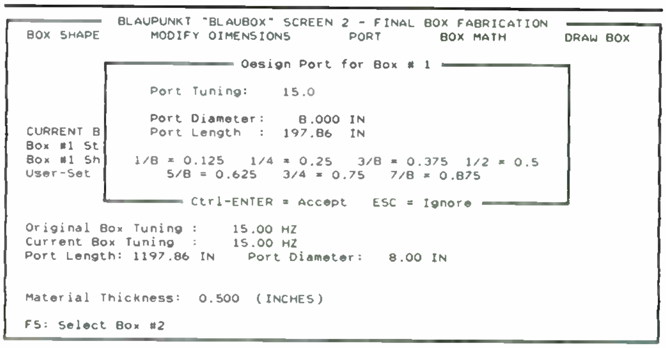

FIGURE 9: PORT window showing data overflow problem in Port Length; true value = 1197.86″.

Continued from page 51

4. Isobarik inductor size. When going from a BP5 to a BP5I design, the inductor value is not changed. As *Table 6* shows, the reported inductor value is a function of driver impedance. If you use the Isobarik drivers in parallel, the driver impedance will halve and the inductor size should also halve. If the Isobarik drivers are in series, the inductor value should double. Consequently, when using the BP5I box style, remember to halve the inductor value shown for woofers in parallel and double it for woofers in series. The manual recommends using the drivers in parallel, and so do I. Clearly, if you are using a BP5 or BP5I box style, you want the true driver impedance in the database to obtain a valid inductor value.

5. Attempts to DRAW BOX with invalid systems. Enclosure designs can conceivably be created with volumes of zero or negative cubic feet; this may occur in only one of the two systems with which you are working. If you request PLOT RESPONSE to the screen with such a design, you are presented with an error message saying "Box Volume vf too small. Press any key to continue."

Pressing a key, one of two things may happen: if one design is valid, you get a plot for that design; if neither design is valid, you get a blank screen with a flashing cursor. Pressing any key again will return you to Screen #1. So far, the problem is minor. If you request PLOT RESPONSE to the printer, however, it becomes major. You are greeted with the same error message and no choice but to press a key. The program then halts execution with the message "BGI Error: Graphics not initiated (Use InitGraph)."

Any time the error message appears, pressing any key should return you to Screen #1. You should not be allowed to continue plotting until you have removed or corrected the offending system. Do not call PLOT RESPONSE if either system is invalid and *always* plot to screen before you output to the printer.

6. Improper rounding in DRAW BOX. The program incorrectly "rounds" the data for the top depth, and possibly other dimensions. DRAW BOX always displays dimensions in inches and fractions, not decimal inches. A top depth input of 5.95″ is correctly displayed as 5$^{15}/_{16}$″; however, an input of 5.99″ is incorrectly rounded to 5″ rather than 6″.

7. Failure to update Q_{TS} in ADD WOOFER. When adding a woofer to the database, you can end up with a missing or wrong display of Q_{TS}, although this does not cause problems in program operation, as it appears to ignore Q_{TS} if Q_{ES} and Q_{MS} are entered. The problem arises if you wish to print the ADD WOOFER window to document your system. The Q_{TS} value can be incorrect if you began by entering only Q_{TS}, then changed your mind and entered Q_{ES} and Q_{MS} instead, or if you changed Q_{ES} or Q_{MS} while Q_{TS} was displayed, as the Q_{TS} value is not corrected (*Fig. 7*). Move up to the line "Choose Q Type" via <Tab>, arrows or mouse, then move off the line. This forces Q_{TS} to be recalculated and displayed. The program should be modified so that any time Q_{TS} does not display the correct value it is cleared.

TABLE 7

COMPARISON OF VENTED-BOX DESIGN TECHNIQUES

DRIVER	Q_{TS}	0.2	0.3	0.4	0.5	0.6	0.7	0.8
QB_3	V_B	0.257	0.699	1.795	6.525			
	f_B	58.2	39.4	30.3	25.1			
C_4	V_B		0.713	1.794	4.309	7.275	10.277	13.652
	f_B		33.1	30.3	24.1	20.4	18.3	17.0
BB_4	V_B		0.786	1.440	2.320	3.445		
	f_B		30.0	30.0	30.0	30.0		
S/M	V_B	0.197	0.753	1.945	4.061	7.412	12.328	19.15
	f_B	59.1	40.0	30.4	24.5	20.6	17.8	15.6
BLAUB	V_B	0.39	0.87	1.54	2.41	3.47	4.72	6.17
	f_B	57.5	38.3	28.7	23.0	19.2	16.4	14.4
Smallest Box		S/M	QB_3	BB_4	BB_4	BB_4	BLAUB	BLAUB

Notes: Driver f_S = 30 and V_{AS} = 2 ft.^{3}; VB is box volume in cubic feet. f_B is box tuned frequency in Hz. QB_3 means SQB_3 or QB_3 alignment, etc. S/M is design by Small/Margolis equations. BLAUB = BLAUBOX design. All cases for total box Q = 7.

TABLE 8

ABSOLUTE PASSBAND SPL DISPLAYED BY BLAUBOX

CASE	DRIVER		INPUT DATA			PASSBAND PLOT
#	SIZE	SPL	Q_{ES}	Q_{MS}	Q_{TS}	SPL IN dB
1	12″	96.5	0.299	1.530	/	97.5
2	12″	96.5	/	/	0.250	98.0
3	8″	93.4	0.335	2.903	/	94.1
4	8″	93.4	/	/	0.300	94.1
5	8″	/	0.305	20.000	/	94.1
6	8″	/	2.000	0.353	/	86.1
7	4″	87.2	0.605	1.995	/	88.0
8	4″	87.2	/	/	0.464	88.9
9	6.5″	82.9	0.540	7.993	/	83.7
10	6.5″	82.9	/	/	0.506	83.5

8. Execution halted in dual-vented BP design. If both chamber volumes and tunings are the same, the two port outputs should be equal and out of phase, producing a null output. While this is not a good BP design, the program should tolerate it. For example, if you set the volumes to 1.0 $ft.^3$ and the tunings to 40Hz, asking for PLOT REPONSE will cause execution to halt with the message: Runtime Error 207. You probably will not encounter this problem if you use valid dual-vented BP designs.

9. Volume data overflow in MODIFY DIMENSIONS. The input data ranges are so large in this window that it is possible to generate designs with negative volumes. The window truncates the volume display so you may not know it is negative until you accept it and return to Screen #2 (*Fig. 8*).

10. Port length data overflow in PORT. You can enter a port diameter that causes the displayed port length to overflow in the PORT window (*Fig. 9*). We again have the problem of the program displaying incorrect information, but in an area you probably will not encounter.

11. Loss of mouse capability. On several occasions, I lost the ability to use the mouse in small data-entry windows. I could open the window, but then the mouse cursor disappeared and the buttons were inoperative. This may be a computer-sensitive problem.

Nitpicks

These are simply suggestions for things I would like to see changed.

1. Lack of resolution on volume data. In most cases, volumes in cubic feet are only displayed to two decimal places, which is insufficient when working with smaller woofers.

2. No date on plots. The current computer date should be output on the PLOT RESPONSE to the printer.

3. Bypassing opening screens. A command line parameter option could bypass the two opening screens and go directly to the main menu.

4. Parameter f_3 not computed/displayed. With the scale shown on the PLOT RESPONSE curves and absolute SPL used rather than relative, identifying the −3dB point is almost impossible. The program should provide a means of identifying f_3.

5. Data entry overflow. The data fields are designed for a certain number of decimal places. If you type in data with more decimal places, it places this data in the next field. The program should simply ignore the extra entries.

6. Does not design actual enclosures. Presently, you must enter all dimensions and play to reach the desired volume. I would like to see the program calculate the final dimension to yield the desired volume when requested to do so.

7. DRAW BOX should include the following items: output explicitly the material thickness being used; the computer current date; port-design information; driver identification. Additionally, it should allow use of either Box #1 or Box #2.

8. Port and box-design data. Should be displayed simultaneously on one screen.

9. Crossover inductor value resolution. The crossover design screens display only two decimal digits on the inductance; three places are needed to prevent a result of 0mH being shown.

10. Drivers that won't fit in the box. The program requires you to enter the "Category Diameter" for the driver and should alert you if that diameter will not fit on any flat surface of the enclosure.

11. Default materials thickness entered via Screen #5 does not take effect until you exit and restart Blaubox; it should take effect immediately.

12. No R_G. Blaubox should support entry of a value for resistance in series with the driver.

13. No exit confirmation box on Quit.

14. Forced entry of driver data. You should only be required to enter data that the program will actually use.

Home Builder Differences

In some areas, Blaubox does things differently from what the home builder may expect:

1. The computer-generated CB always

appears with total system Q_{TC} equal to about 1.0. For a different value, you must play with the box volume manually and Q_{TC} is not displayed. You must design the CB externally and feed Blaubox the proper box volume.

2. I have been unable to verify that Blaubox always designs VB systems with a total box Q (Q_B or Q_L) of 7. *Table 7* compares the results of various design approaches for VB designs with drivers having Q_{TS} from 02. to 0.8. Blaubox apparently is not designing with the normal alignment charts or the Small/Margolis equations. While the manual claims that computer designs are the "smallest box with reasonable flat frequency response," *Table 7* indicates that this may not be true. The question also arises over the flat frequency response claim. *Figure 10* shows the frequency responses for the Blaubox designs at Q_{TS} = 0.7 and 0.8.

3. Blaubox does not actually do any nonoptimum VB designs. If you provide the designs, then Blaubox will plot the response, design the port, and allow design of the actual enclosure in the three shapes it supports.

4. The SPL and frequency span ranges of the response plots are frozen. This, combined with plotting the response in absolute SPL, makes identification of the system's −3dB cut-off frequency difficult. Normally, reference efficiency is calculated from Q_{ES} and then converted to SPL. In the cases where you do not provide Q_{ES}, the program must somehow establish SPL based only on Q_{TS} (*Table 8*). If Q_{ES} is entered, Blaubox uses it to set SPL; if only Q_{TS} is entered, the program applies some algorithm to establish SPL from Q_{TS}.

Summary

Blaubox is a program basically designed for dealers, and thus has a very friendly user interface, but it does freeze some design parameters. It might appeal to the novice, but in some instances frustrate the experienced builder. Blaubox supports the design of closed-box, vented-box, and three types of bandpass-box systems, allowing a single driver or dual-Isobarik drivers with all system types. The program carries the design through to display or print enclosure construction drawings for three specific box shapes. In addition, it supports the design of first-, second- and third-order high-pass and low-pass Butterworth crossover sections.

Blaubox's nicest features are the full mouse support, on-line help, and the unusual inclusion of on-line technical information. The package also includes an extremely complete operating manual. Most screens and windows are in text mode, thus allowing quick printouts to document your designs.

The program has some coding bugs you must watch for. Many of these problems result from unusually wide allowable data input ranges, and should cause little problem with normal usage.

Thomas D. Breithaupt of Blaupunkt:

We at Blaupunkt appreciate your review of the Blaubox computer program. I must say that Mr. Koonce's thoroughness is unparalleled and his comments are usually fair, often humorous, but sometimes debatable.

It's important to understand the history of the need for Blaubox to understand the program. We have felt that the car audio aftermarket is clearly stratified into three levels of competency. "Level 1" encompasses the retailer who you feel comfortable with doing just about any kind of work on your car without fear of jeopardizing its electrical or mechanical integrity. They are remarkably aware of loudspeaker technology and have the skills to accurately build things such as subwoofer boxes. Unfortunately, we speculate that only about 10% of the retailers fit this level.

"Level 3" is a depressingly large category, we fear around 40%, who work out of converted gas stations. They don't have the time, skills, or desire to build moderate-level performance systems. Off-the-shelf boom-boxes are the de rigueur *for this group.*

Sandwiched in between these two groups is what we refer to as the "Level 2" dealer. They can do very nice work, and have the desires and tools to improve upon their work, but are limited in the skills and/or time to develop skills for things like custom designed subwoofer boxes. The Blaubox program was designed for the midrange retailer who is really looking to step up.

Also, I should point out the typical user. Because of the ease of use, we have numerous retailers around the country who are buying PCs to place in their showrooms, so the person walking in off the street wanting a 15" woofer in a shoebox can be quickly pointed away from such an installation.

We make no claims toward being able to replace software such as LEAP or SPEAK, but we do pride ourselves on Blaubox's simple user interface, features such as the customized blueprint-style wood printouts, and on-line math calculator and "Tech Talk" to help the casual user. Both floor salespeople and technicians can use Blaubox.

Regarding program "bugs," I must address this definition. If the program "creates" values that are impossible (e.g., negative measurement values), then I agree that this is a program bug. If the program totally crashes at any point, I really call this a bug. But, if you input an insanely stupid value (e.g., wood thicknesses of several feet), then shame on you. We had over 40 preliminary Beta users and eventually narrowed down to ten serious software "pounders" who we felt exercised the program well. I could not replicate several of the minor issues Mr. Koonce discovered. With this I am baffled. He did

Continued on page 81

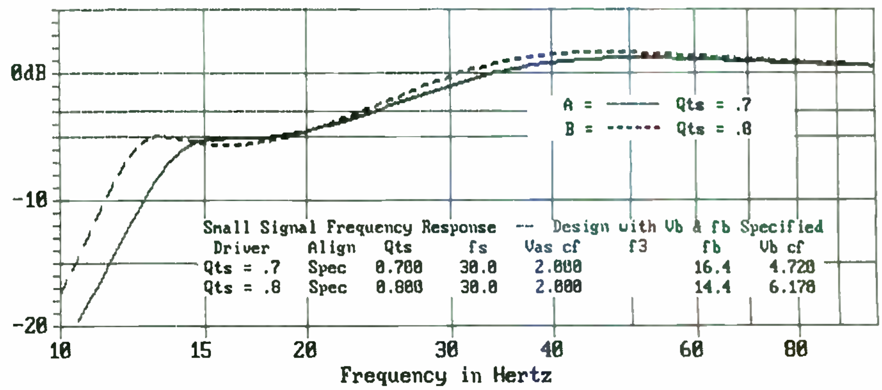

FIGURE 10: Response shapes for Blaubox VB designs at Q_{TS} = 0.7 and 0.8.

A TALE OF THREE SPEAKER PROJECTS

BY SCOTT HENION

It was the worst of times—apartment rearranging time. Having endured countless furniture adjustments, a ray of light fell upon the scene. If its appearance were improved (i.e., made unobtrusive), the stereo could take up residence in the living room.

This was a tall order. How do you make speakers with 15 drivers per side unobtrusive? The answer: high ceilings, camouflage, some equalization, and 19 drivers per side. Basically, you make a tall, shallow enclosure with a grille cloth which helps hide it.

Color is also crucial. While black is normally considered a reducing color, it contrasts starkly with white walls and is therefore not conducive to harmonious blending. White blends in very well, and this becomes a requirement when your speakers are 7′ tall and 2′ wide.

BACK TO BASSIS. The previous speaker incarnation had insufficient bass, which led me to use eight 10″ woofers. I calculated a displacement-limited SPL of 144dB/1M at 20Hz based on the nomographs in Siegfried Linkwitz's article "Excursion-Limited SPL Nomographs" (*SB* 4/84, p. 24). Getting to 20Hz requires equalization, so I purchased and assembled a Marchand Electronics "Bassis" parametric equalizer (EQ).

The EQ has controls for frequency and amount of boost as well as damping (Q_B and Q_S). It allows up to two octaves of bass extension so the system's natural bass response can fall off higher than would normally be acceptable. Woofers with f_S above 20Hz can be used, and, in fact, most decent woofers will suffice.

I decided to use Precision/Peerless TD-255Fs. Although these woofers are better suited to reflex designs, their price was right. Calculations made from manufacturers' specs indicated the cabinet was about 1½ ft.^{3}, for an f_3 of 65Hz and F8 of 40Hz. Eight 10″ drivers provide a large area and can move a large volume of air, making extension to 20Hz possible with the EQ. The only other requirement is enough electrical power to implement the 24dB of boost.

I prepared four of the woofers by playing a 30Hz sine wave through each at a few watts for about six hours, which was sufficient to break in the speakers. Following the measurement techniques outlined in Vance Dickason's *Loudspeaker Design Cookbook*, I obtained the following values: R_E = 6.3Ω, f_S = 28.9Hz, V_{AS} = 4.98 ft.^{3}, and Q_{TS} = 0.276.[1]

A poor seal between the woofer and test box prevented me from getting consistent results, so I made several measurements. Finally, I made a seal from foam rubber cut to size, and used screws through all the woofer mounting holes. With the woofer properly mounted, I was able to get consistent results from both of Dickason's methods, and from the method outlined by David Weems.[2]

I chose a Q_{TC} of 0.577, because it of-

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Scott Henion is married and has a two-year-old son. He is employed at MIT Lincoln Laboratory where he designs, builds, experiments with, and rebuilds lasers and laser-based systems. He has a master of science degree in physics and enjoys the taste of sawdust.

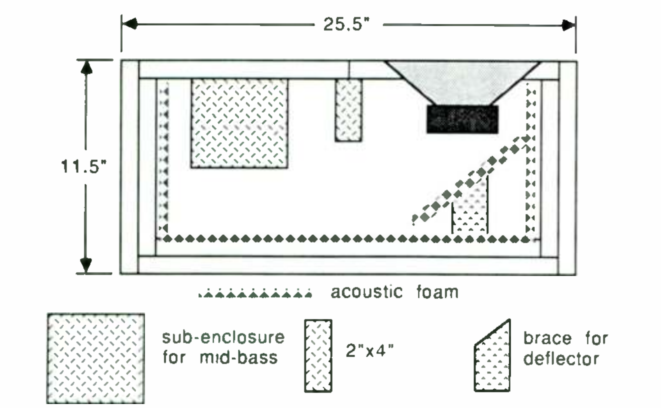

FIGURE 1: Enclosure top view. The reflector behind the woofers, sides, and back of the enclosure are lined with acoustic foam.

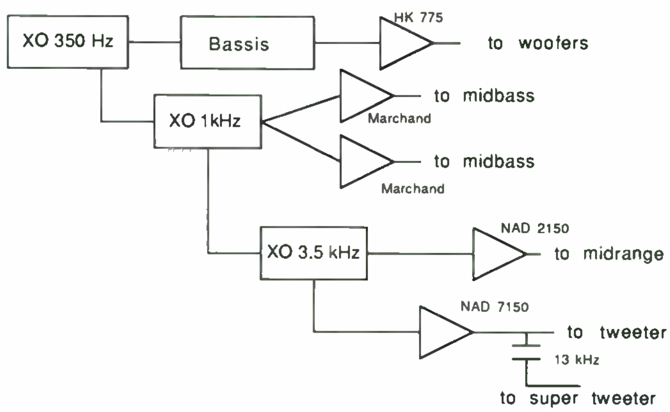

FIGURE 2: Crossover/amplifier setup. The four-way design used five amplifiers and a Bassis EQ on the lowest frequencies.

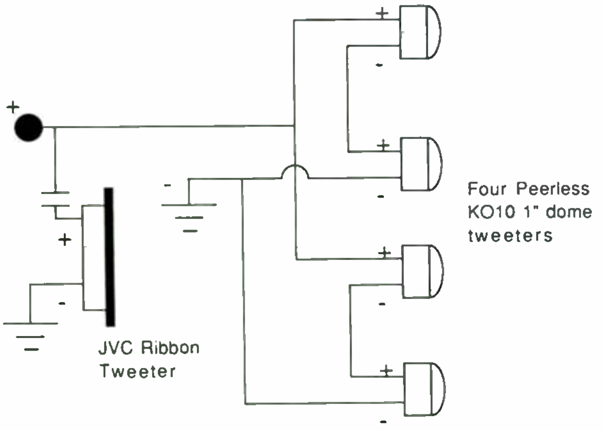

FIGURE 3: Crossover and electrical connection of tweeter array. I set the crossover frequency at 13kHz with a 1.5μF Mylar capacitor.

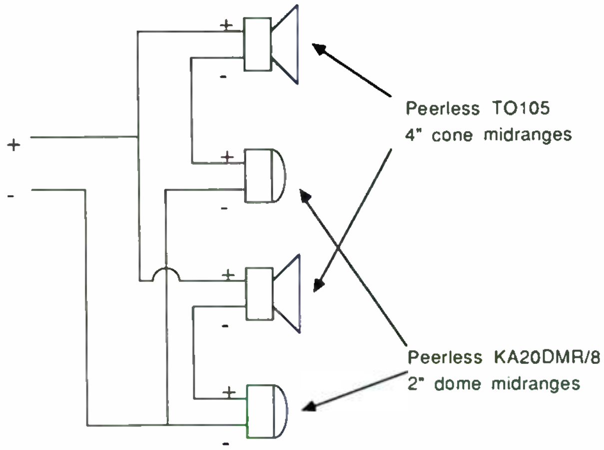

FIGURE 4: Electrical connection of midrange drivers.

fers the flattest delay and a controlled rolloff which I could extend. From that value, I calculated the box volume of 1.46 ft.³/woofer. I planned to extend the f_3 of 76Hz two octaves with the Bassis.

PLAIN PINE BOX. The straightforward construction began with a 7′ × 2′ × 1′ box made from 1″ × 12″ pine. I used butt joints, since few people can see the top of a 7′ speaker (*Fig. 1*). The only visible surfaces are the two sides and the front, which is covered by a grille cloth.

To construct each cabinet, simply cut two 1″ × 12″ boards to 7′ lengths. Cut a 10-inch-wide, ¾-inch-thick piece of particleboard to a length of 6′10½″. Space this ¾″ from all edges, then glue and screw it to the inside. Repeat for the other side. The top and bottom are ¾-inch-thick pieces of any wood you choose. Cut two pieces to 24″ × 11½″, two other pieces to 22½″ × 10″, and join them in the same manner as the sides. I used particleboard for the back, although you can also use plywood. The back panel should be 6′10½″ tall, 24″ wide, and ¾″ thick.

Instead of using braces, I cut a piece of wood 6′9″ × 22½″, and glued and screwed it ¾″ from all edges. For the front baffle, I cut two ¾-inch-thick pieces of plywood to 12″ wide and 6′10½″ long. I routed the eight woofer holes in one piece, and the other driver holes in the other. To stiffen the front, I put a 2″ × 4″ × 6′9″ piece vertically where the two front pieces join. It should be thin face out for maximum strength and an easier fit with the drivers.

To assemble the cabinet, I laid all the pieces on the floor and put the top, bottom, and sides together. I applied wood glue, clamped them with pipe and strap clamps, and screwed from the top and bottom into the sides. The 2″ × 4″ board screws in from the top and bottom. Each front panel screws onto the ledges formed by the inner pieces; the back screws onto the backs of the same ledges. For access to the inside, I put weather stripping on the ledges, then screwed on the back. I sealed the front and all the seams with silicone caulk.

I added a diagonal piece behind the woofers so the sound would not bounce off the back of the cabinet. The mid-bass drivers also require small enclosures, which I attached to the back of the baffle. The total volume measured 15% under-sized—10 instead of 11.7 ft.³ That places the alignment between a Q_{TC} of 0.577 and 0.707 for a lower f_3 of 73Hz, with flat response. So I stuffed the enclosure with about five pounds of Acousta-Stuf and lined the back and sides with acoustic foam. This adjustment should increase the apparent volume to the original alignment.

I planned to arrange the other drivers in a curve so they would be equidistant from the listening position. The basic idea came from Scott Ellis' article "The Curvilinear Vertical Array" (*SB* 2/85, p. 7). I mounted the drivers parallel to the front, but spaced out to approximate the curve, with each driver's acoustic center on the curve. Using wooden rings which I cut with a router, I spaced the midrange and tweeter drivers from the

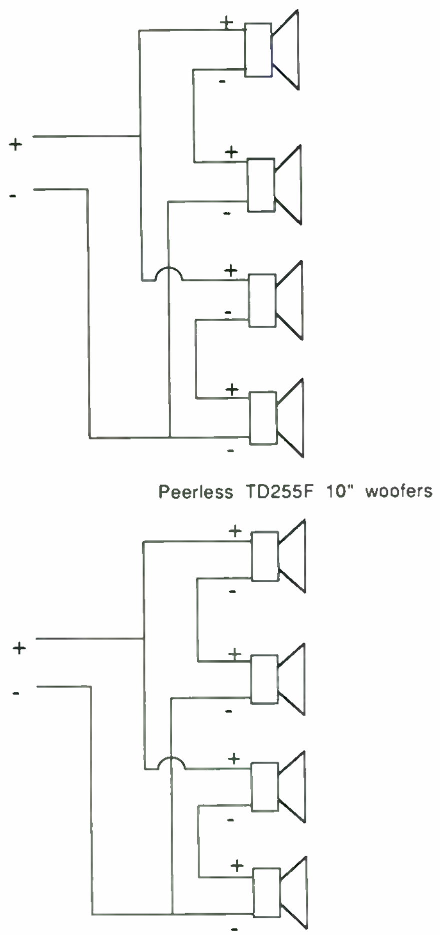

FIGURE 5: Electrical connection of woofers. The two series-parallel arrays are connected at the amplifier.

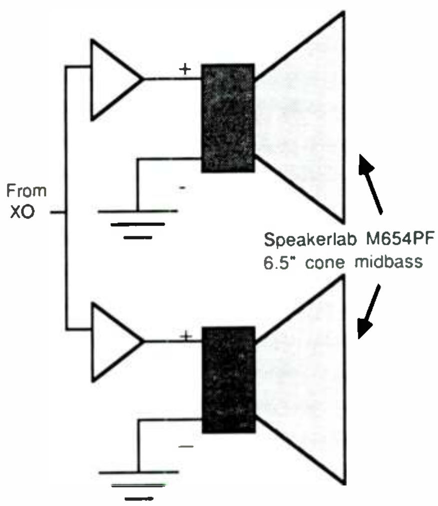

FIGURE 6: Electrical hook-up for mid-bass drivers. Each driver has a dedicated 50W amplifier driven by the electronic crossover.

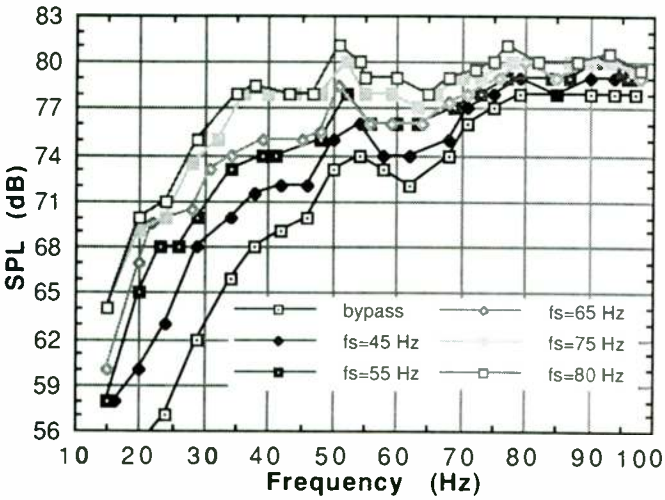

FIGURE 7: SPL curves for various Bassis EQ settings. The curves are for a single woofer with the microphone very close to it. The output is definitely in the small-signal regime. $Q_B = Q_S = 0.7$ for all curves. Note the improved performance with greater f_S (frequency where boost is applied).

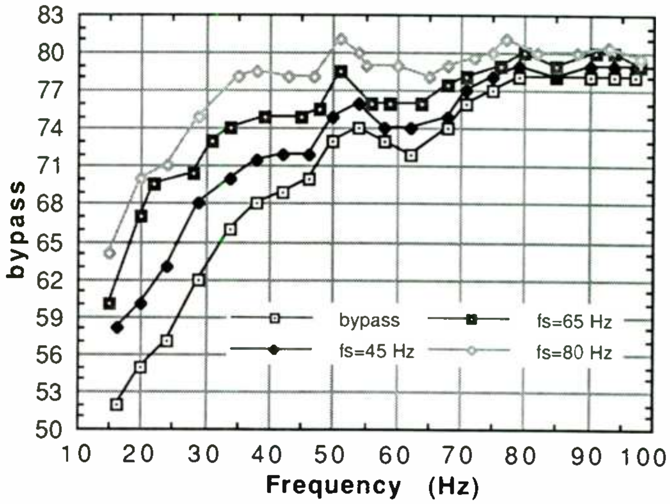

FIGURE 8: SPL curve of the unequalized bypass. Least satisfactory f_S = 45Hz, and most satisfactory f_S = 85Hz.

front baffle. The drivers are mounted in pairs above and below, from the center out, in the following order: super tweeter, dome tweeter, dome midrange, dome tweeter, cone midrange, mid-bass.

FLUSHED WITH PRIDE. I mounted the super tweeter and first dome midranges flush with the front; the dome midranges are 1¹⁄₁₆″ out, the second dome tweeters ¾″ out, and the cone midranges 2″ out from the front. This leaves a small baffle area which helps decrease diffraction effects. I made pads about ½-inch thick from layers of ⅛-inch-thick felt, glued sparingly with hot melt glue, and applied them around the drivers.

The drivers' asymmetrical (left/right) placement on the front of the enclosure prevents the same diffraction pattern from occurring in both directions and decreases the effects of cabinet-edge diffraction. The upper bass drivers are flush with the baffle and 3½″ from the center plane of the super tweeter. To help decrease diffraction and reflections vertically, I placed rolls of felt between the drivers and any protruding baffles. I built the upper bass drivers' subenclosures into the main enclosure.

I used a passive 6dB/octave high-pass filter between the tweeters and the super tweeter. For all others (*Fig. 2*), I used 24dB/octave active crossovers from Marchand Electronics. I connected the Peerless KO10 tweeters in series-parallel configuration (*Fig. 3*), each cone mid-range in series with a dome midrange, and then these pairs in parallel (*Fig. 4*). I also connected the woofers in series-parallel for a 4Ω impedance (*Fig. 5*).

Using the multi-way active crossover meant that I needed four amplifiers, three of which I had from the previous incarnation. For the fourth, I purchased some kits from Marchand. These were 50W each into 8Ω, and I assembled two per channel for the mid-bass drivers, one amp per driver (*Fig. 6*). This helped match sensitivity and power requirements. The bass is driven by a Harman Kardon HK-775, 130W/channel into 8Ω, dual-mono amp. The midrange and tweeters have NAD 2150/7150 50W/channel amps, for a total amplifier output power of several hundred watts into the various impedances. All the amps are capable of at least 3dB headroom.

The crossover frequencies are 350Hz to the Speaker Lab M654PF 6.5″ upper-bass drivers. The next crossover is at

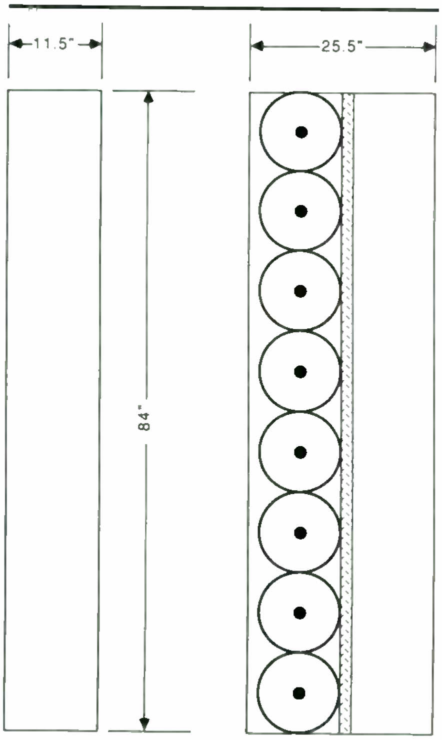

FIGURE 9: Bass enclosure as used in second incarnation, with ribbon driver. I replaced the baffle containing the other drivers with a braced piece of particleboard.

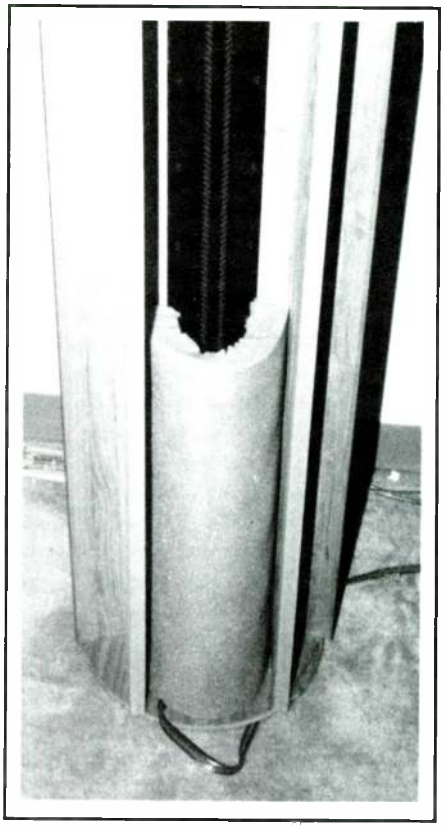

PHOTO 1: The rear of the ribbon enclosures, showing one piece of Sonex. For monopole operation, three pieces are used to absorb the radiation from the back of the speaker.

1kHz to the midranges: two Peerless TO105 4" cone midranges and two Peerless KA20DMR/8 2" domes per channel. The final active crossover is at 3.5kHz to the KO10s. The passive crossover to the super tweeter, a JVC Dynaflat, is at 13kHz. I used some crude SPL measurements with a sine wave generator, an amplifier, and a Radio Shack SPL meter to adjust the Bassis (*Figs. 7* and *8*).

The speakers now sounded quite good and were unobtrusive, although positioning them for good imaging was difficult without blocking one of the windows. Compromise was in order, and I began implementing some improvements.

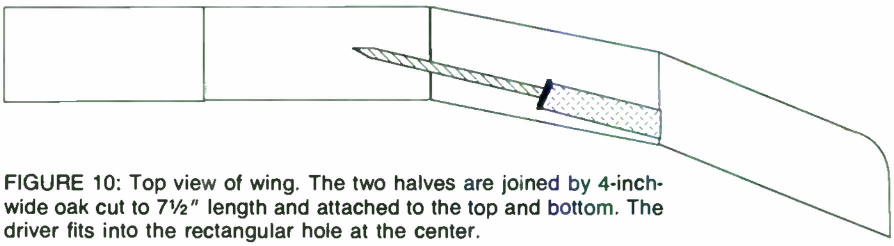

FIGURE 10: Top view of wing. The two halves are joined by 4-inch-wide oak cut to 7½" length and attached to the top and bottom. The driver fits into the rectangular hole at the center.

THE BIG LEAGUES. In the meantime, I had built two smaller projects, a two-way transmission line and a three-way second-order, for which I used Vifa D25AG-35-06 aluminum-dome tweeters. I liked their sound very much, and the imaging was far superior to the larger system's. I decided to take drastic action on the big speakers: leave the bass units unchanged and upgrade the treble (*Fig. 9*). Swapping tweeters would be the simplest measure. I was confident the sound would be better, and I would move the drivers into a separate enclosure which could be positioned for improved imaging.

Speaker Lab had just introduced a wide-range ribbon driver with a large radiating surface which promised decent SPLs and a low crossover point. Based on previous experience using LMP, I was convinced implementing few crossover points was easier than many. This would make the system a two-way, and I decided to build a cabinet which would allow me to experiment with both dipole and monopole configurations.

To get to 150Hz, the speakers need a 12-inch-wide baffle. I made a slightly curved baffle of ¾-inch-thick oak by ripping 1" × 2" × 6′ boards with a 10° angle on one edge. I first glued them together, then to an uncut 1" × 3" × 6′ oak board, to form one side or wing (*Fig. 10*). I rounded the outside edges using a router with a quarter-round bit. The ribbon's magnet structure is 4" wide, so I ripped a piece of oak to that width. I then cut four pieces (two for each speaker) to make up the difference in height of the magnet structure and the 6-foot-tall wings, and glued them together. I clamped the curves together, and also drilled and counter sunk screws through the edges of the wings. Sanding the front removed sharp corners and rounded the surface at the joints.

The wings are 14½" wide (*Fig. 11*), although the effective width is probably less because of the curve. In any event, it's close enough to satisfy the driver requirements. For added stability, I used a piece of oak plywood 14" in diameter as the base. Two 1" × 5" × 6′ oak pieces, glued and angle-bracketed to the back of the wings on either side of the magnet structure with extra clearance side to side, make up the rest of the cabinet. The sides form a "U" with the front, into which I inserted an opposing "U" bent from 1′ × 2′ pieces of Sonex, as shown in *Photo 1*. This allowed monopole operation (dipole without Sonex).

One of the active crossovers is the Marchand 24dB/octave at 150Hz (*Fig. 12*). I also tried a Heathkit electronic

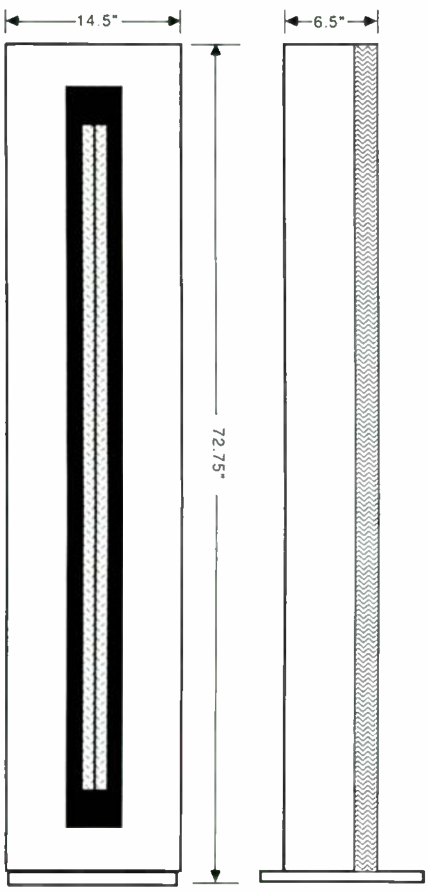

FIGURE 11: Front, side, and top views of the winged enclosures.

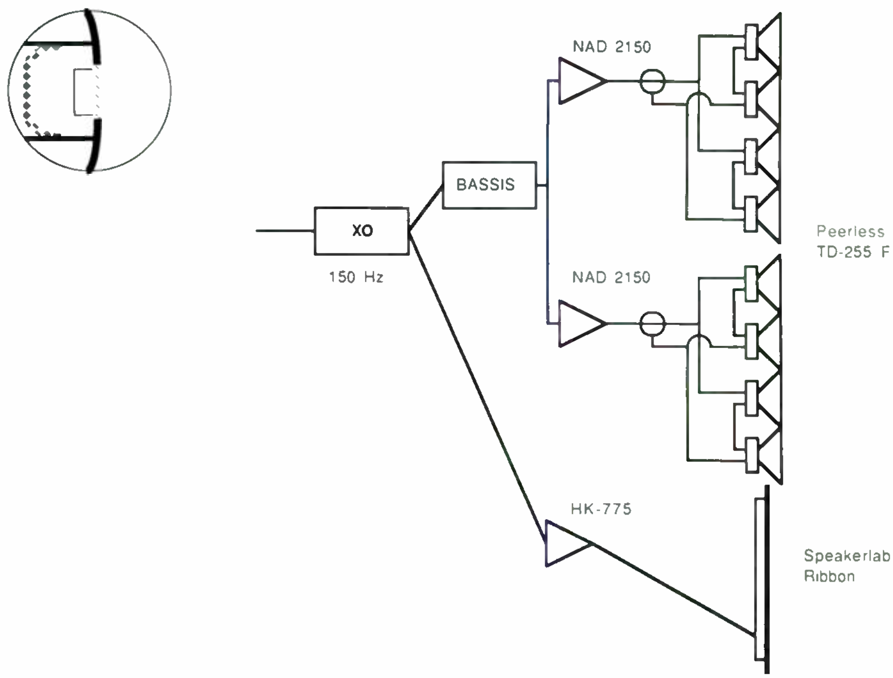

FIGURE 12: System electrical connections. Each woofer array has an 8Ω impedance and is driven by an amplifier.

crossover, the AD-1702, which provides 6 or 18dB/octave slopes for high- and low-pass, as well as independent frequency selection at 40, 60, 80, 100, 125, or 150Hz and bass level control. I used LMP to model the responses, which showed small differences at 150Hz (*Figs. 13* and *14*). The actual sound was indistinguishable during listening tests. I chose the 24dB/octave on the basis of less frequency overlap and better power handling/lower distortion due to the steeper slope.

The Harman Kardon amps now drive the ribbons, and each NAD drives one bass channel. Each channel of the nominally stereo amp is driven with one channel of the Bassis, and a series-parallel quartet of woofers with each channel (*Fig. 12*). The resulting higher-effective sensitivity matches the woofer section to the ribbons. The HKs are fairly high gain (28dB compared to the NADs' 20dB). More amps can be added to the woofer section as the Bassis is capable of driving fairly low input impedance. Since its specification is at 100Ω minimum, several combinations are possible.

The winged treble units enable flexible positioning, while the bass units can remain against the walls. The imaging is greatly improved, and the ribbons' sound is excellent. Subtle details are now revealed, there is definitely more clarity, and dynamics are good. The ribbons have a notch filter which removes a response peak caused by resonance from the air gap between the magnet rows.

All in all, the exercise was well worth the effort. The only disappointment was that the darker stained pine of the bass enclosures didn't really match the oak (*Photos 2* and *3*).

BEDSIDE FABLES. It was time to update my two-way speakers, which had 6.5″ woofers (Peerless TP165Rs) and 1″ tweeters (Peerless KO10s). I decided to replace the tweeters with Vifa D25AG-35-06, an aluminum-dome tweeter with low resonance (850Hz), good power handling (100W), and superb sound. I used a 24dB/octave passive crossover with the original cabinets (a second-order Q_{TC} = 0.7). Encouraged by the results, I built new transmission-line enclosures.

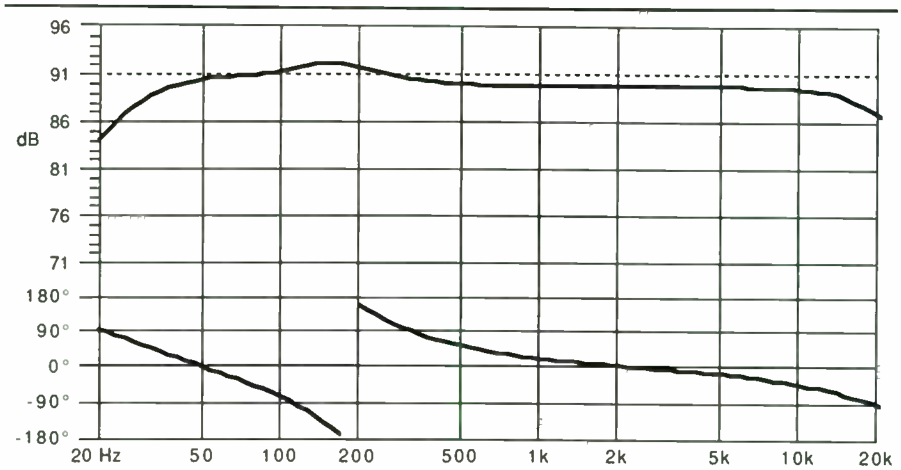

FIGURE 13: LMP model using the Heathkit 18dB/octave crossover.

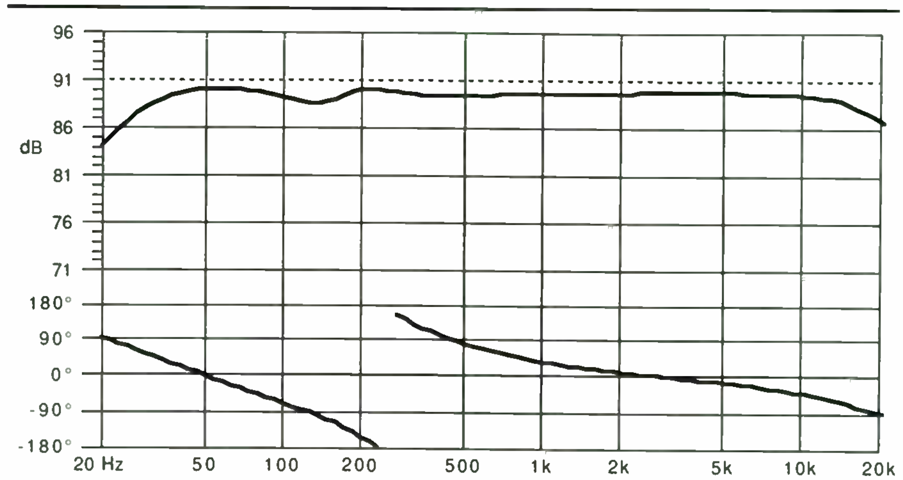

FIGURE 14: LMP model using Marchand 24dB/octave crossover.

Since I had never built a TL, I decided to start with a small, standard line. I believe that shortening the length to less than a quarter wave, after correction in the stuffed line, results in a modified

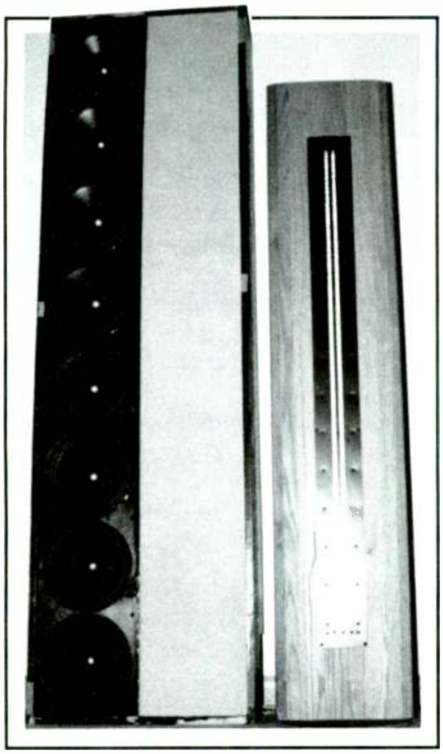

PHOTO 2: The speakers showing the bass unit and separate ribbon driver enclosure. The 8–10″ woofers were used in both incarnations of the speakers.

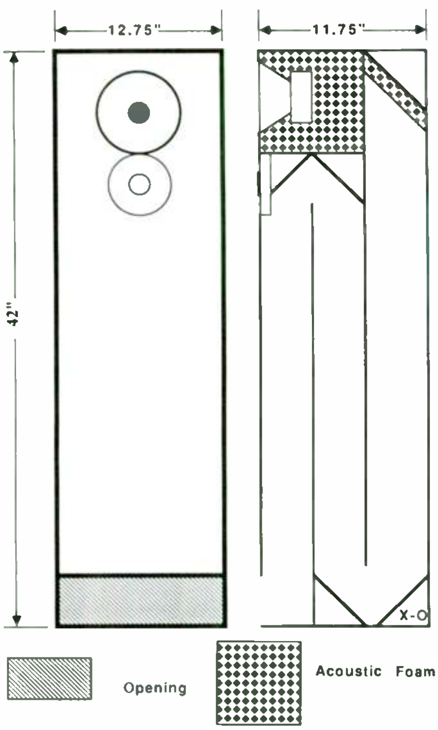

FIGURE 15: Front and side views of the TL enclosure. The entire bass chamber is lined with acoustic foam. The crossover is below the reflector in the bottom of the enclosure.

vented or perhaps second-order in a very leaky box. With a full quarter-wave TL, the resonant frequency is theoretically all that matters, so I made one at 35Hz. As these speakers were intended for the bedroom, they should be fairly tall so the tweeters will be at ear level for listening in bed.

I made them from solid mahogany shelving, 1″ × 12″ × 8′, with no knots or blemishes. The assembly is straightforward: a box with slots routed in the sides for the dividers to make the line, and a lid fitting into the top and secured with silicone glue (*Fig. 15*).

I cut the sides to 42″ lengths, then routed ⅜-inch-wide, ½-inch-deep grooves to accept the ⅜-inch-thick flake board dividers for the line. Using a router guide, I started the grooves at the bottom and stopped about 8″ from the top. From the front edge, the slots are 3⅝″ and 6¾″. This leaves cross-sectional areas of 2¾″ × 11″, 2⅞″ × 11″, and 3¼″ × 11″ for the line. I cut the dividers 11⅝″ wide and 30″ long. The reflectors are ¾″ scrap pine, with 45° bevels on each end about 3″ across the face and 11″ long, which I glued and screwed to the dividers at the appropriate ends. A larger reflector, about 7″ across the face, also needs to be cut for the back of the woofer chamber.

I cut the side slots to be snug in width, and deep enough so the dividers would slide in fairly easily but would not rattle. The back is ¾-inch-thick plywood, 11¾″ wide and 41¼″ long. It fits into a ⅝-inch-wide, ¾-inch-deep rabbet routed in the back inside edge of both sides. Stopping ¾″ from the top will prevent the groove from showing. Behind the woofer, a piece of ¾-inch-thick plywood cut to fit snugly seals the bottom from the line's second and third sections. I glued the front, back, and sides together, positioned the divider, then screwed and glued the reflector onto the line area's front, top, and inside corners. Sliding in the dividers and reflectors, I applied silicone caulk along the joint at the slots, then screwed the remaining reflector to the back of the first line section at the bottom.

I routed out the woofer and tweeter holes and rabbeted the woofer hole so it was flush. The tweeter is actually set

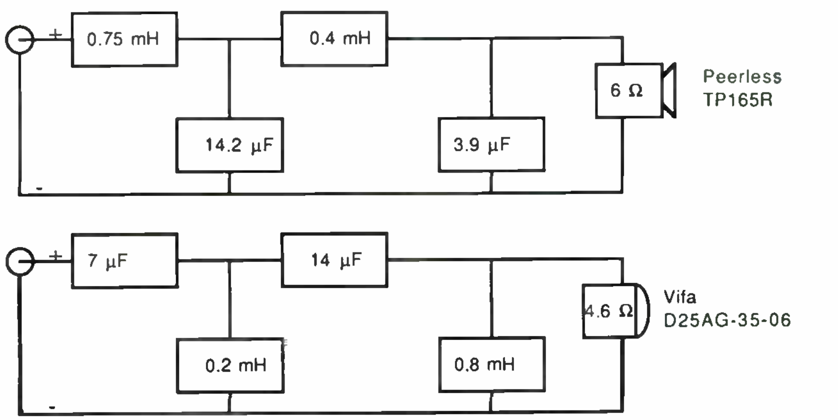

FIGURE 16: 24dB/octave crossover. Not shown are the zobels used on the woofer and the attenuator for the tweeter.

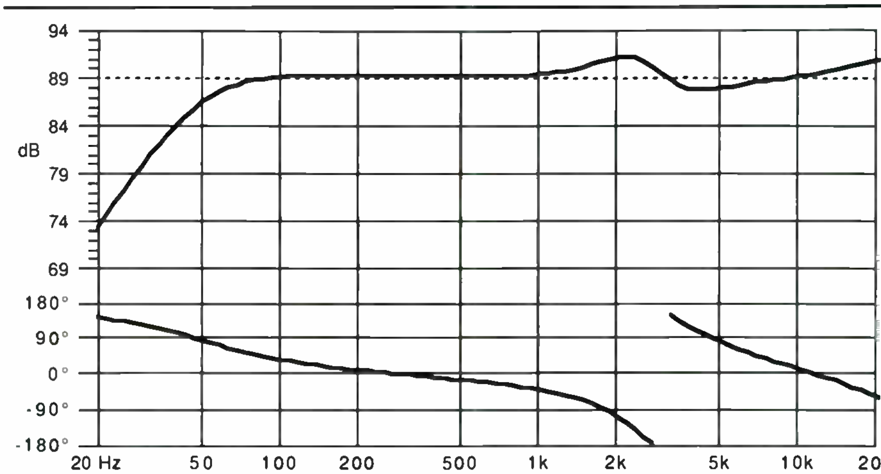

FIGURE 17: LMP model of speaker system.

slightly into the last reflector, so this also needed to be routed. I rounded the cabinet edges with a ½" quarter-round bit. The top is mahogany cut to fit flush with the front and sides, and to cover the back. I lined the top chamber with acoustic foam, and started the stuffing (Dacron ½lb./ft.³) in the line itself with a little overhang into the chamber.

To allow for the slight differences in area between the line lengths, I tapered the stuffing density from slightly lower to higher. The line area is always at least 30 in.³, which is quite a bit larger than usual. The tweeter is located below the woofer, so the chamber behind the woofer will be small and the line as long as possible.

The crossover is under one of the reflectors at the bottom of the cabinet. I chose a 24dB/octave passive crossover at approximately 3kHz (*Fig. 16*) because I like the sound, and because there is minimum overlap in frequency coverage of the two drivers, since overlap can cause response irregularities.

Using LMP for final parts value selection (*Fig. 17*), I opted for commercial air-core inductors, Mylar® capacitors, and noninductive 20W and 50W power resistors. I did not use a zobel on the tweeter, because it has no resonance

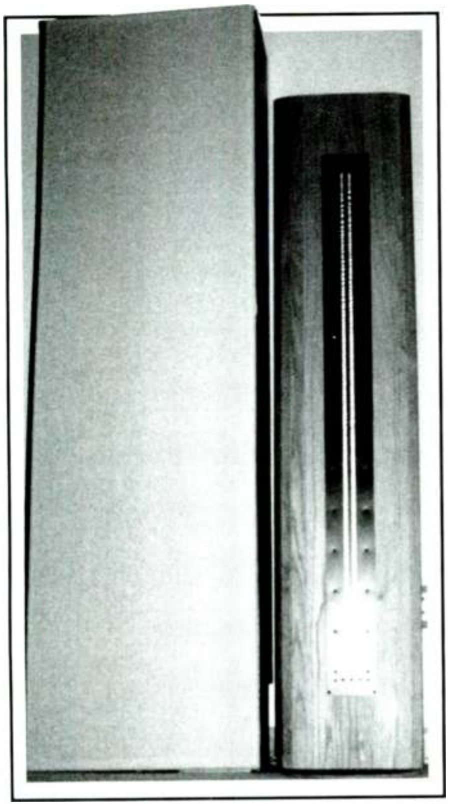

PHOTO 3: The speakers with grille cloth on. The grilles are made of fabric I found at a local fabric store, and stretched over a frame made of quarter-round molding which is secured to the speaker with Velcro.

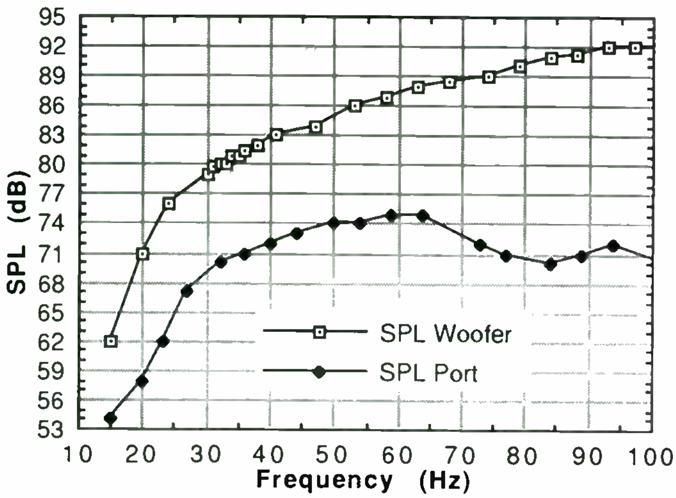

FIGURE 18: Speaker output at low frequencies. The woofer and port output was measured with the microphone very close to the cone and in the port.

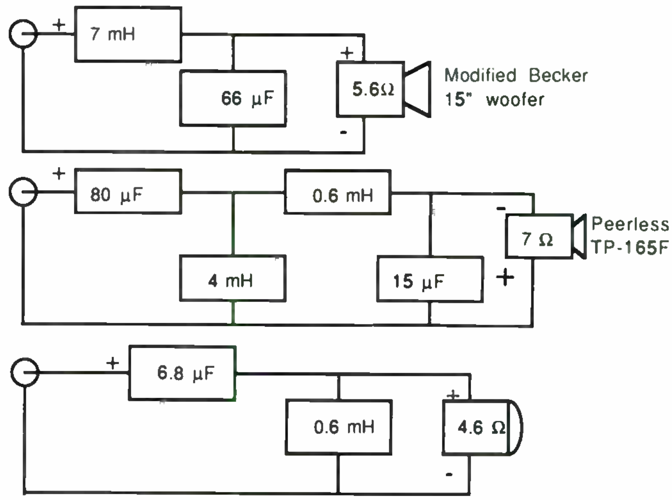

FIGURE 19: Crossover for the "Big and Loud" system. The phase of the midrange is reversed.

near the crossover frequency and its impedance is fairly flat. The design formulas are from *The Loudspeaker Design Cookbook* and Robert Bullock's series of articles on "Passive Crossover Networks" (*SB* 1/85, p. 13; 2/85, p. 26; and 3/85, p. 14). The tweeter needed approximately 5dB of attenuation to match the woofer. All internal wiring is 12-gauge stranded wire.

I finished the speakers with stain and polyurethane, and rounded the edges with a router and ½" quarter-round bit. This detail was the most pleasing and the most subtle. It also helps reduce diffraction. I have yet to build grilles (*Photo 4*).

The sound is good and the bass not overly powerful, although the system seems to lack the authority of some others I've built (*Fig. 18*), which is not surprising given a 6½" woofer. The high end is very good, the top octave or two is more detailed and yet less abrasive than before. The tweeters are an unqualified success: the imaging is excellent as is the sound stage, the location stable and precise.

BIG AND LOUD. When I offered to build speakers for a friend, she gave me a list of requirements which included big, loud, and not too expensive. Big is no problem, but loud with good sound can be expensive. I already had drivers: decent Becker 15" paper and Peerless TP-165F 6½" poly woofers, both with foam surrounds. I decided to use the Vifa D25AG-35-06 tweeters again.

Measurements and calculations showed that a 7–8 ft.³ box would do nicely. The f_3 would be about 30Hz with a fairly flat response; Q_{TC} would be about 0.7. I measured the following parameters: f_S = 19Hz, V_{AS} = 10 ft.³, Q_T = 0.47, and applied the formulas and tables from *The Loudspeaker Design Cookbook*. To improve the woofers, I applied several coats of Elmer's carpenter glue thinned with water, which made the cones much stiffer but added little mass (which would have reduced the efficiency). The midrange could be married at a low enough frequency to minimize any serious sonic shortcomings. I envisioned a satellite/subwoofer in one cabinet, which used to be called a three-way.

The design included putting the 6½" driver in a subenclosure near the tweeter at the top of the cabinet. I chose the crossover point low enough so the driver would cover most of the voice fundamentals, thus avoiding any tubbiness from the woofer. As a compromise to save on inductor costs while remaining at a low frequency, I chose 300Hz. The 2.5kHz crossover to the tweeter kept the driver dispersion from being a problem, with the other crossovers at 12dB/octave (*Fig. 19*). The midrange required some attenuation, so I raised the impedance to

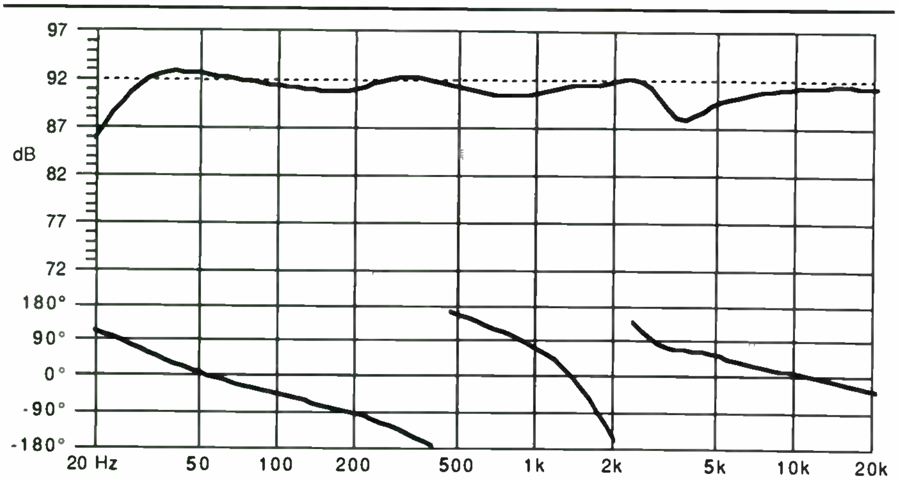

FIGURE 20: LMP model of the system.

REFERENCES

1. Dickason, Vance, *The Loudspeaker Design Cookbook*, 4th ed., Audio Amateur Press, 1991.
2. Weems, David, *Designing, Building and Testing Your Own Speaker System—With Projects*, [Tab], 1990.

SOURCES

Marchand Electronics
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(716) 265-4930
FAX (716) 265-1614

Old Colony Sound Lab
PO Box 243
Peterborough, NH 03458-0243
(603) 924-6371
FAX (603) 924-9467
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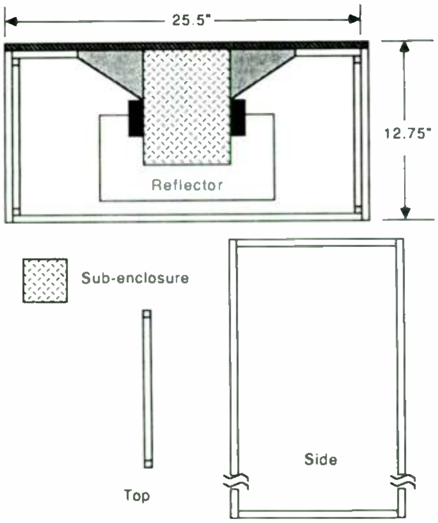

FIGURE 21: Top view of cabinet. I lined all the inside surfaces with acoustic foam, and loosely stuffed the box with Dacron. I reinforced all the internal corners with 1" × 1" pieces of wood. Not shown are front-to-back braces. These were 1" × 2" scraps, glued from the front to back at various points in the cabinet. The brace locations are not critical, but staggered rather than perfectly symmetrical locations are preferred. The reflector, back, top, and sides are lined with foam.

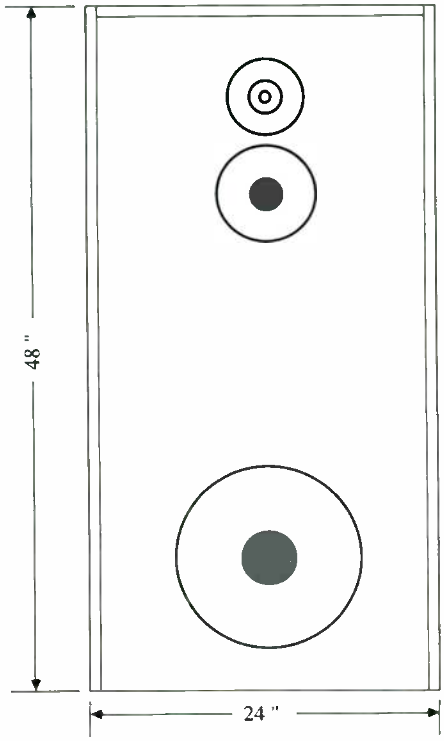

FIGURE 22: Front view of speaker showing 1" × 2" oak trim.

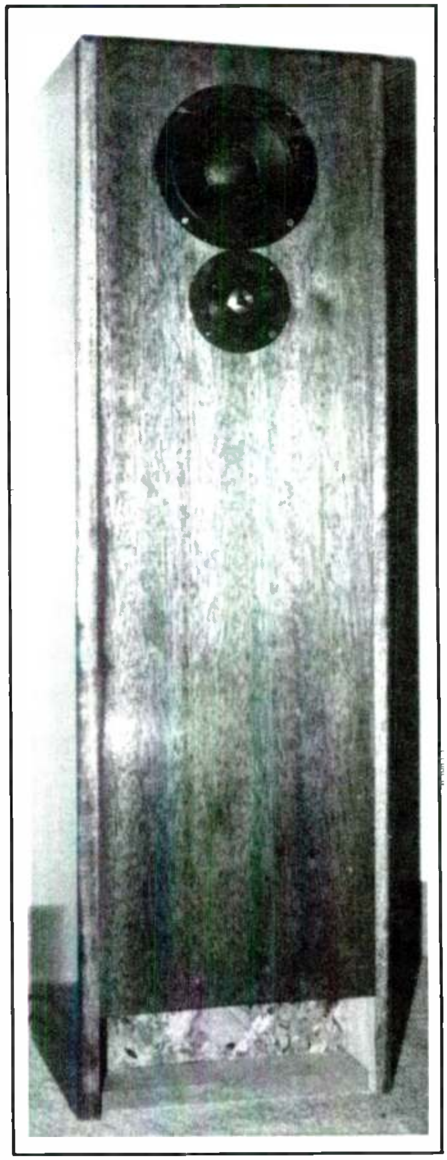

PHOTO 4: The completed transmission-line speakers. The line opening is at the bottom.

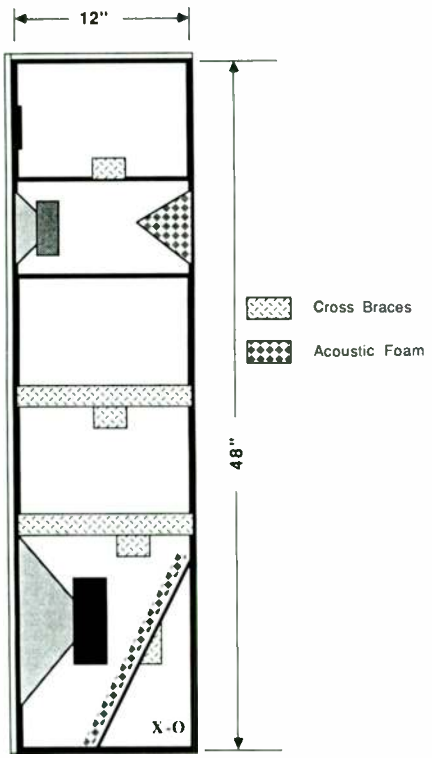

FIGURE 23: Side view of speaker showing cross braces, reflector behind woofer, midrange subenclosure, and crossover location.

7Ω with the zobel/attenuator scheme. I used LMP to adjust the values to some extent (*Fig. 20*).

I built a 2′ × 4′ × 1′ cabinet. Since I planned to make the speakers from oak plywood, which comes in 2′ × 4′ sheets, five sheets could be used with no waste. One 2′ × 2′ piece would be left over for future use. The extra volume could be used for braces and partitions to reduce resonances and standing waves.

I ripped two sheets of 2′ × 4′ oak-veneered plywood in half lengthwise for the sides. From another sheet, I cut two 2′ × 1′ pieces for the tops. For the back, I used ¾-inch-thick plywood, 2′ × 4′. I glued and screwed pieces of 1" × 1" pine flush with all front and back edges. This made assembly easier and the finished project stronger. I glued the sides on, screwing from the inside, through the 1" × 1" pieces on the front and back (*Figs. 21* and *22*).

I used butt joints to assemble the cabinet, with the front and back flush with the sides. I then covered the plywood edges with 1" × 2" oak pieces, framing the front and top, which I glued and nailed sparingly with #8 finishing nails.

I cut the grille from a piece of ¾" plywood. It is held on by two dowels, glued to the front, and inserted into holes in the frame. I lined the circumference of the cutouts with thick felt to reduce diffraction. The midrange cutout is a little oversize so several layers of felt would not interfere with the cone. To attach the cloth, I used hot melt glue, starting on one of the straight sides and working around. Any problems can be corrected by heating the area and pulling the cloth tighter. The cloth/glue bead makes a good shock absorber and prevents the frame from rattling.

The inside of the cabinet includes front-to-back braces. A reflector behind the woofer deflects the rear wave so it bounces up through the box, and reduces standing waves. I attached the bottom last to allow access for installing the braces, deflector, and crossover, which I placed behind the reflector (*Fig. 23*).

I padded down the tweeter about 3dB with fixed resistors. The bass is solid but not boomy, and voices are very natural. I would have liked a crossover at or below 200Hz, but the sound was so good that the extra expense was not warranted. The imaging is quite good, with a solid soundstage and some depth. Our friend was quite happy with the speakers—until she moved.

Special Report

A&S Audiophile Sound-Off 1992

By Bruce C. Edgar
Contributing Editor

Once a year, grown men are confined in a dark room and subjected to strange sounds which emanate from unearthly contraptions—is this some weird initiation rite? No, it's the annual A&S Speakers Audiophile Sound-Off, where repeated listening to innumerable speakers over the course of two days becomes a real torture test for the judges.

The 1992 event, held on November 13–14, featured a total of 30 entries, up from the previous year's 19. The speakers were divided into small and large categories: the former included all systems with 8″ or smaller woofers, the latter all systems with woofers larger than 8″. For reference standards in judging the entries, PSB of Canada supplied their Stratus Mini and Stratus Gold models in the small and large categories, respectively.

The speakers were set up behind a black (acoustically transparent) screen so their appearance would not be a factor in the judging. The electronics included a Muse-supplied preamp and amp, and an MSB Gold CD player supplied by Mark Brassfield.

The Judging

The judges included Ken Kantor of Now Hear This, Inc., Corey Greenberg of *Stereophile* magazine, and Don Keele of *Audio* magazine replacing Keith Johnson. Judging of the small speaker group began with a screening process whereby each entry was compared to the PSB Stratus Minis. The midband pink noise levels were first equalized with level controls on Ken's A/B switching box and an A-weighted sound level meter. Once the levels were matched, the judges compared the candidate to the reference speaker with pink noise from track #15 of the *Stereophile* test CD 2.

The pink noise test is very demanding of speakers and serves as a good screening test. So, after listening to the candidate's pink noise characteristics, the judges had a pretty good idea of its strengths and weaknesses (i.e., good spectral balance or obvious imbalances between drivers). Prominences, response peaks and holes, and other spectral anomalies were also detected.

The next phase involved playing selected tracks from CDs supplied by the judges. Track #2 of the "Fairfield Four" (Warner Bros. 9 26945-2) features Afro-American gospel singers from Mississippi, and it became the standard for judging midrange quality since the all-male voices covered the entire midrange. Other selections included Rickie Lee Jones, the Red Hot Chili Peppers, the B&K Pro Audio Test CD, and the Dorian organ version of "Pictures at an Exhibition."

At last year's contest, white noise was used to diagnose lobing problems, but it was eliminated this year in an effort to save time. The criterion became: "How does it sound where I'm sitting?" Imaging was not a primary consideration in the initial round, but, as judging approached the final selection, a solid center image was certainly an advantage.

After sorting through the entries and comparing them to the PSB Stratus Minis, the judges arrived at a first cut of the small speaker category. Twelve entries were eliminated on obvious faults, such as overly bright tweeters, midrange prominences or peaks, or other tonal imbalances in the response. The seven remaining candidates were evaluated, using an elimination tree to produce a quick winner. They were then grouped into three pairs, with the seventh drawing a bye in the first round.

In each pairing, the entries were level-matched with pink noise and the A/B box. The "Fairfield Four" CD was played to identify any midrange anomalies, while other selections pinpointed suspected differences. The judges then voted on the best speaker of the pairing.

The four candidates for the second round were grouped into two pairs. Testing began with the same pink noise level matching procedure, followed by the "Fairfield Four." (To allay any suspicions, the speaker with the first round bye did not survive the second round.)

The final round involved the top two small speakers, identified only as #10 and #14, with the former eventually victorious. The determining factor proved to be which speaker exhibited the least amount of response problems. Speaker #10 sounded very smooth, especially on vocals, but had an upper midrange peak; #14 exhibited a very smooth but forward character, with some blunting of transients.

The large category judging began on Saturday with one-on-one comparisons with the PSB Stratus Gold floor-standing speakers. The same pink noise matching and "Fairfield Four" midrange procedures were used for the comparison tests. The bass responses were tested with the Dorian organ and B&K CDs (track #1), along with the "Tropic Affair" CD (track #8) from Reference Recordings.

The primary weaknesses in the large speakers were found in the midrange with tonal imbalances, peaks, prominences, and the like. Only three out of eleven entries made it to the elimination round. The finalists (#1, #2, and #11) were paired off with each other, matched in levels, and compared for strengths and weaknesses. It became obvious to everyone that #1 and #2 had some imaging and radiation pattern problems, respectively; #11 was fairly well-balanced, with a mid-bass hole the only prominent fault.

The Outcome

The judges always seem surprised by the physical appearance of the speakers which they have been judging sight unseen, and this year's winners certainly had unusual configurations (*Photo 1*). The winner of the small speaker category, designed by Joseph Jong, used a Seas P17RC woofer on a sloping front with a front-firing Focal T90ti tweeter. The crossover used a first-order network on the woofer with some additional contouring, and a second-order network on the tweeter. (The cabinet drawings were published in an A&S Speakers ad in *SB* 2/93.)

The large category winner, designed by Tyler Hammond, also had an unusual configuration with a four-way modular design. It used a quasi-sixth-order bandpass subwoofer (Peerless 260WR/8 driver) with an Eton 7-380-32 low-midrange driver, an Audax MDA-100 upper-midrange filler driver, and a Morel MDT-33 tweeter. The enclosures were commercially made boxes with additional damping. The crossover consisted of second-order networks with contouring and zobels. Details are available from A&S.

The problems of midrange coloration highlighted by the "Fairfield Four" CD dwarfed all other concerns. One of the typical departures from accuracy was a prominence in the midrange, which might be solved by testing speakers in different rooms to ascertain how their tonal balance changes.

A more subtle problem is midrange timbre, which cannot be cured by simply adjusting the level. Trying different drivers which cover the midrange is one way to explore any possible timbre problems.

Judges' Recommendations

I asked the judges for their advice to present and future entrants. Here are some selected comments.

Ken: "It is very hard to get anywhere without instrumentation . . . tools like an oscillator, a resistor, and a voltmeter that you can measure T/S parameters and impedance. . . .Instead of remembering what a commercial product sounded like, drag one down to your listening room . . . and really face what you are doing right and not doing right. . . . Keep it simple."

Corey: "It seemed to me from what designs sounded better at this stage of amateur speaker building, less is more. I also definitely recommend that people try their speakers in other people's basements."

PHOTO 1: The judges (left to right): Ken Kantor, Corey Greenberg, and Don Keele, with the large and small category winners.

Don: "There are some excellent test CDs available now, and on a CD the test signals are almost as good as the original test generators. And with a Radio Shack sound level meter, there is much you can do with the test CDs. You can also buy an octave equalizer from Radio Shack with an analyzer built in which is a cheap but effective tool . . . If the 1kHz band is 6dB above the 500Hz band, there is something wrong. Also pay attention to the spatial coverage of the system. Do the sit down/stand up [listening] test. From a technical side, I would recommend purchasing the AES anthologies on loudspeakers because that gives sage advice from people who came before you."

The Future

I talked with Arthur Rosenblum at length about rule changes. Everyone wants the Sound-Off to remain a contest for the amateur speaker builder, and to encourage the beginner to enter and learn from the experience.

Consequently, Arthur says that future Sound-Offs "will not be accepting entries from anyone who advertises their speakers for sale, sells their speakers to dealers for resale, publishes in the literature of the field, is employed by a speaker manufacturer, or who has won the Sound-Off in the previous two years." Other rule changes will be announced before the 1993 contest.

Speaker Builder

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Tools, Tips & Techniques

FOAM SURROUND REPAIR

My neighbor recently gave me a load of old stereo equipment and in it was a pair of decrepit AR-3a speakers. The AR-3a was one of the most popular almost-high-end speakers of their day (late 1960s). They were most noted for the prodigious quantity and quality of bass produced from their 12″ acoustic suspension woofer and reasonably sized cabinets. (AR's founder, Edgar Villchur, had invented the acoustic suspension technique some 15 years before.) By today's standards, their mids and highs are nothing to get excited about (the old paper dome drivers can't compare to modern fabric dome and metal dome drivers), but their bass performance remains somewhat exceptional.

I decided to use the AR-3a to assume the low-bass production duties from my modified Dynaco A-255 ("Modifying Dynaco's A-25," *SB* 6/90, p. 53). The Dynacos give up the ghost at around 45Hz. The AR-3a was reputed to be adequate to the low 30s. However, I couldn't check this directly. My AR-3a had a serious problem: the foam surrounds on the woofers had rotted out. This is a common problem in many older AR and Advent speaker systems.

I could have set things right in several ways. I could have, as AR recommends, replaced the entire driver. At close to $100 each, that just didn't make sense for this low-budget adventure. I could have sent the drivers out for reconing. Reconing replaces the entire cone assembly, including the cone itself, the voice coil, spider, and foam surround. The problem with this approach is that AR does not offer factory parts to independent reconers. The old AR-3a woofer design is unique and it's unlikely the reconed driver would sound anything like the original. Finally, I could repair the foam surround.

Many speaker repair services (see the classified ads in *TAA* and *SB*) are glad to do the work. They usually charge from $50–90/pair plus shipping and handling. One shop, Ken's Hi-fi Clinic (Box 1088, Flat Rock, NC 28731, (704) 693-3459), sells a foam surround repair kit for $27.95/pair, including shipping. In the spirit of low-budget, high-end sound, and since I'm reasonably handy, I decided to try it. I called and placed an order.

Ken's kit consists of two new foam surrounds, two small syringes of white contact cement, and a sheet of instructions. The only thing that's missing is a generous supply of swabs with which to spread the glue.

The surrounds are made of what appears to be sturdy, good quality foam. Unlike the original AR surrounds, Ken's have a seam. The seam is roughly a 1-inch-wide overlap in which the surround is two foam layers thick. The surround's roll (the semi-tubular part between the flats that attach the cone to the basket) can be installed either up or down. The old AR-3a surrounds had the roll side up.

The first step was to remove the old surround. Most of it simply fell apart when I touched it. It was black, gooey, sticky stuff. I just put my finger through the roll and went around the cone gathering it up in one grimy gob. That was easy.

The outer edge of the old surround was glued to a masonite spacer that sets on the outer edge of the basket. Getting that part off the spacer proved to be a trial. Ken's instructions suggested that denatured alcohol could help speed the job, but I found the glue AR used to be impervious. I ended up just rubbing the old glue and foam off the spacer (along with a layer or two of skin) with my thumbs. This was tedious and took about an hour per driver but the final result was quite clean.

The inner edge of the old surround was glued to the edge of the cone. There's simply no way to get the old foam and glue off the cone without damaging it. The best I could do was to trim the old surround down to the outer edge of the cone. The foam/glue/cone boundary was reasonably flat, so I didn't expect that any problems would arise from this.

Once the old surround was removed, it was time to install the new surround. Following the instructions, I spread a thin layer of contact cement on the top of the cone's outer edge and the bottom of the inner edge of the surround (over the old foam and glue). I had to carefully apply a thin layer of glue. (Contact cement dries fastest when it's applied in a thin layer.) Each of the supplied syringes came filled with just enough glue to do one surround, with very little to spare.

I waited until the sheen of the glue dulled (around ten minutes or so) and carefully positioned the surround. The glue has a relatively low tack for a contact cement, so I could position and reposition to my heart's content. Once I had it in place, I pressed it down firmly and it was there for good. Make sure to let the glue dry; if it's not, the surround will pull away. In addition, pay special attention to the seam/overlap area. At this point, the instructions advised assuring that the cone is properly centered so its voice coil doesn't rub as it is driven in and out. Per the instructions, I pressed the cone down and allowed it to return by itself.

I then set about gluing the outer edge of the surround in much the same manner as the inner edge. After gluing the inner edge, the outer edge sticks up over the masonite spacer, leaving barely enough room to insert a glue-dipped swab. Taking care to get good glue coverage, I again centered the cone just before I pressed the outer edge down and after allowing enough time for the glue to dry. Next, I firmly pressed the surround into place.

After letting the driver dry overnight and wiping the cone lightly with a damp sponge, the result was a speaker that looked like new. When I pressed the cone down, there was no rubbing and it restored smoothly to its neutral position.

Finally, I installed the driver back into its cabinet. I hooked the AR-3a to one channel of my AdCom GFA-535 amplifier, replacing one of the modified Dynacos. It clearly bettered the remaining Dynaco in low bass extension. With the *Stereophile* test CD, I could hear warble tones down to 31.5Hz; the Dynacos gave up as usual at around 45. Since I have yet to properly seal the cabinet (the garage where the ARs were stored was quite damp and the sow bugs made a meal of the bottom panel of the cabinet), I have hope that the AR's sound will further improve.

Len Moskowitz
Teaneck, NJ 07666

Wayland's Wood World

SIMPLY GREAT FINISHES

By Bob Wayland

When you build an enclosure, finishing may be the last step but it's the first thing people notice. For most of us, it represents a constant struggle with streaks and cloudiness. Dust and particles are seemingly drawn to the new, sticky surface like iron filings to a magnet.

We all wish for a finishing technique which eliminates these problems, and at the same time produces a surface that shines like silver or has the warm patina of an hand-rubbed antique. Let's also wish for a surface which can be quickly and easily repaired, and is water and alcohol resistant. When we combine old-fashioned techniques with modern coatings, our wishes are likely to be granted.

I will describe techniques which penetrate the wood's surface as opposed to the more difficult, and often unsatisfactory, surface coatings such as lacquers and varnishes. Our goal is to protect the surface from water damage, natural aging, abrasion, and dirt, while enhancing its natural beauty. These finishes are designed to be applied clear or over stains. If you have design considerations which require painted or textured finishes, the following suggestions are not for you, as they require an entirely different technique. Such coverings are specialized and detailed application instructions are usually provided by the manufacturer.

Penchant for Penetrants

Penetrating finishes are easy to apply and produce good results, making them the choice of both amateurs and professionals. Relatively resistant to heat, water and alcohol, they are easy to maintain and repair. In addition, they tend to improve with age.

Commercial penetrating finishes include Danish, linseed, and tung oils. They penetrate the surface pores and harden to provide a sealed upper layer which forms a protective barrier. Because this layer is part of the wood structure, it will not chip or flake. You can easily repair it by applying water or steam, and then retreating with the penetrating finish. With brisk buffing, many of these finishes polymerize to increase their protection.

Since the wood's top layer becomes the finished surface, its preparation is very important. Be certain you remove any traces of glue, oil, or dirt. I normally use a finer grade of sandpaper than for applying a surface coating which, for hardwoods, means 400 grit. You can remove the fine residual hairs (which tend to clog the surface pores) with a scraper, and the finish will appear deeper. The final surface will be smooth and professional looking, and you won't have the worries of brush marks, runs, lap overs, and dust accumulation.

Prepared oil finishes are the easiest to use but also the most expensive. The best known is Watco Danish Oil, which is available in either clear or a variety of mixed-in stains. The finish becomes part of the wood, so you don't have the mess associated with stained coatings.

If your enclosure is made from an open-pored wood such as oak, you should first apply a coat of paste filler. I then apply a very thick coat of Watco and allow it to set overnight. This leaves a thick, gummy base on the surface, to which I apply a second coat. Within a few minutes, I wet rub it with the same grit of wet-or-dry sandpaper as I used to prepare the surface. I briskly sand with the grain, wiping off any excess with a piece of scrap wool cloth, and let it dry completely. I then repeat this procedure using 4/0 steel wool.

If you wish a more durable surface, you may apply a fourth or even a fifth coat. For a higher gloss, brush on a layer of 2- or 3-lb. cut shellac as the last coat. Let this dry until it becomes sticky, then immediately rub it out with 3/0 steel wool. It is important to remove all the shellac from the surface, otherwise you'll have a real mess.

Grain of Truth

Linseed oil, made from flaxseed, is an old favorite. To ensure it will harden, you must mix it with turpentine, usually in a one-to-one ratio. Allow the first coat to dry overnight, then apply the second coat with wet-or-dry 600-grit sandpaper, taking care to go *with* the grain. After this has thoroughly dried, apply the last coat. When it becomes tacky, rub it *against* the grain with a piece of coarse cloth. Wipe off any excess with a clean cloth. For a shinier surface, you can sprinkle on a bit of rottenstone and, with a felt pad, polish it *with* the grain.

Another favorite finish is tung oil, also called nut, China nut, or China wood. This natural oil is made from tung tree nuts, and can be polymerized into a hard, durable surface. At about $20/quart it is also very expensive, so it is usually mixed with other less-expensive ingredients. Successive coats of these mixtures will produce a high-gloss finish.

Cooking the tung oil modifies it for a harder, glossier surface. A tung-oil sealer which contains about 20% cooked oil is often used for first coats, and acts as a base for other tung oil mixtures. You can produce almost any desired gloss by changing the amount of tung oil. For a virtually flat, low-gloss finish, use a mixture of about one-fourth cooked tung oil blended into a base of equal parts linseed oil and turpentine. Increasing the amount to 35% or so will result in a medium-luster finish; high-gloss finishes are produced at about 50%.

Be warned that mixtures with high tung oil concentrations are difficult to apply. They must be used while still in the fluid stage, otherwise lap marks and unevenness will show in the finish. The secret is multiple thin coats applied with considerable (normally, longer than 15 minutes) hard rubbing.

Test of Time

A penetrating finish which has worked very well for me over the years has actually been in use since before 1600. To make it, put boiled linseed oil in the top of a double boiler and heat it to the 150°F range. Grate beeswax into the oil, stirring constantly, until it is supersaturated (the mixture should form a thick paste when cool). Apply the finish while it is hot. You can wear dishwashing gloves, but keep the mixture in the double boiler as hot as your hands can tolerate.

Be very careful: you are dealing with

a combustible mixture. Don't use this method in a confined area! Use an appliance such as an electric hot plate which allows you to set the temperature.

For the first coat, apply an over-generous amount and let it set for about five minutes. With a coarse cloth, rub in the direction of the grain. When this has thoroughly dried, apply another coat and immediately rub it out. Drying time will depend upon the weather; with high humidity, it could take several days.

Try to keep the surface as warm as possible via friction. Fifteen minutes of rubbing is the minimum for all surfaces. You can't over-do it. Apply two or three more coats in the same manner. Between coats, sand with worn, very fine sandpaper, say 600 grit. Buff the last coat with a lamb's wool pad. Circular pads that mount in the chuck of an electric hand drill are perfect for polishing.

Another favorite finish was given to me by Sam Maloof, who recommends a mixture of equal parts pure tung oil, boiled linseed oil, and a high-grade polyurethane. Apply it as you would the linseed oil and beeswax mixture, with the gloss determined by your choice of polyurethane. I often apply seven or eight coats before reaching the point of diminishing returns, where additional coats result in no improvement.

With any of the penetrating finishes, I advise applying a new coat every month or two for the first year, and once a year thereafter. If you must polish your enclosure, use only lemon oil, preferably one that doesn't contain a solvent. If you wipe off any excess oil and buff, you shouldn't have a problem with wax buildup.

Penetrating finishes are sensitive to oxidation and require special attention for storage. Some people place marbles or clean stones in the storage cans to decrease the amount of trapped air. I find that collapsible plastic containers offer more control over the amount of air trapped in the jug.

One last word of warning: the used rags will spontaneously combust and are a major fire hazard. Store or dispose of them in an airtight container with a minimum of trapped oxygen. Some people put the used rags in a pail full of water. Just keep in mind that the water is no longer potable!

If you should have a
TECHNICAL QUERY...
about an article appearing in this magazine, write it clearly, leaving space for a reply and referencing the magazine, the article and the page about which you are inquiring. Enclose a self-addressed stamped envelope and send these to *Speaker Builder*, PO Box 494, Peterborough, NH 03458.

SB Mailbox

SOURCES RESCINDED

In the 3/93 issue of *SB*, we published an article on "Speaker Enclosure Screws" by Robert Spear and Alex Thornhill. It has come to our attention that several of the addresses and phone numbers provided for the suppliers in that article are incorrect. The correct information is:

Equality Screw Co.
PO Box 1645
El Cajon, CA 92022
(800) 854-2886
FAX (619) 440-3979

Osmose Wood Preserving Co.
PO Drawer O
Griffin, GA 30224
(800) 241-0240

VSI
Stanton, CA 90680
(714) 891-8400

The address for John Wagner & Assoc. is also incorrect, but that company could not be reached and is believed to be out of business.

We apologize for any inconvenience this has caused.

DEAR *SB* READERS

The time has come for this speaker writer to move on; I am going to be doing some loudspeaker reviewing and other editorial work for *The Audio Critic* (and will continue to appear occasionally in the Boston Audio Society *Speaker*). So this note is just a way to say goodbye officially to all of you, and to repeat what an honor it's been to appear in such distinguished company and before such an accomplished readership.

For the last two years in these pages I've been analyzing basic properties of loudspeaker and room behavior which govern playback sound: boundary augmentation below 500Hz, horizontal radiation above 500Hz. Hearing from some of you on these subjects through letters, in private correspondence, and via the Internet has been stimulating and a real pleasure. I hope I have contributed in useful fashion to the ongoing dialog about loudspeaker performance. I thank you for reading. And for the opportunity to meet you in the first place, many thanks to Ed Dell Jr. and his hardworking staff.

David Moran
Lincoln, MA 01733

ROCKFORD FILES

After reading the Rockford Kit Report by Ray Alden (*SB* 4/93, p. 54), I called the (800) number provided to get additional information. I was promptly informed that these kits had been discontinued some time ago, and that plans and schematics also were not available. The Rockford BMR20 described in the Term-Pro Update section has been discontinued as well.

It might be prudent to verify component availability prior to publication. Sad to say, the entire report should have remained an unpublished manuscript.

James M. Annal
Evergreen Park, IL 60642

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.

REFORMED REFERENCE

Reference #6 in Randy Parker's article, "The Prism V Satellite/JBL Subwoofer" (*SB* 4/93, p. 27), is incorrect. There is no such article as "New Lows in Home-Built Subwoofers" in the August 1985 issue of *Audio*. Could someone please provide the correct reference?

Phil Biehl
Tigard, OR 97223

Randy Parker responds:

I'm sorry for the confusion; the article reference contains a typo—mine, not *SB*'s. It should state the August 1983 issue of *Audio*.

EQUATIONAL QUERY

Referring to *Table 6* in Bruce Hermann's article, "A Sixth-Order T/S Subwoofer Design" (*SB* 3/93, p. 16), what are f_H, f_M and f_L, and how are f_{SB}, Q_{MSB}, Q_{ESB}, Q_{TSB}, h and Q_L derived from them? Thanks for your help.

John Elliott
Pocomoke, MD 21851

Bruce Hermann responds:

The Thiele/Small model for a speaker in a vented box predicts that the woofer impedance, as a function of frequency, will be modified from what it was in free air. Instead of finding a single impedance peak at the free-air resonance, you will find two peaks when the speaker is placed in a vented box. The parameters defined: f_L is the measured frequency of the lower peak; f_H is the frequency of the higher; f_M is the frequency of the impedance minimum between the two peaks; and R_M

is the impedance at the minimum frequency. The value of R_M must be greater than the voice coil's DC resistance R_E, otherwise you will have a problem with Equation 5.

The free-air and vented-box measurements, along with the relationships derived from the T/S model, allow you to compute the entries in the remaining columns of *Table 6*. My notes indicate I used $f_S \approx 19$, $Q_{MS} \approx 14$, $Q_{ES} \approx 0.32$ for the free-air values, and 1.33 for the ratio of R_M to R_E, instead of the average values mentioned in the article (p. 23). For more details, refer to the discussion by Robert M. Bullock in "Fine Points of Vented Speaker Design" (*SB* 2/81, p. 18).

The equations are:

$$f_{SB} = \frac{f_L f_H}{f_M} \quad (1)$$

$$Q_{MSB} = \frac{f_S Q_{MS}}{f_{SB}} \qquad Q_{ESB} = \frac{f_S Q_{ES}}{f_{SB}} \qquad Q_{TSB} = \frac{f_S Q_{TS}}{f_{SB}} \quad (2)$$

$$h = \frac{f_M}{f_{SB}} \quad (3)$$

$$\alpha = \frac{(f_H^2 - f_M^2)(f_M^2 - f_L^2)}{f_H^2 f_L^2} \quad (4)$$

$$Q_L = \frac{h}{\alpha}\left[\frac{1}{Q_{ESB}\left(\frac{R_M}{R_E} - 1\right)} - \frac{1}{Q_{MSB}}\right] \quad (5)$$

If you are interested in a mathematical derivation of these equations, see the articles by Small which appeared in the *JAES* (references 10-18 in my article).

ON IMPULSE

G.R. Koonce raises the issue of impulse testing loudspeakers ("Matters of Import," *SB* 3/93, p. 66). Specifically, he states: "I thought it was accepted that impulse testing does not yield results which agree with other classical approaches."

My experience has been that for audio purposes this is the very strength of impulse testing. When I became interested in audio twenty years ago, one of my first observations was that music on a scope bore no resemblance whatever to the steady-state test signals usually employed.

Equally, the musical realism (for want of a better term) from audio equipment bore similarly scant resemblance to test results. While the real turkeys can be spotted by such measurements, it takes a wide bandwidth, wide dynamic range, and asymmetric waveform to sort out the successes. Music is a very convenient example of such a waveform, but it can be somewhat elusive in trying to identify specific design attributes.

Impulses are convenient measuring signals which provoke the kind of behavior seen with music. The results of impulse testing with exploding wire alerted A.R. Bailey to the benefits of his "Nonresonant Loudspeaker Enclosure Design," popularly known as transmission-line enclosures (*Wireless World*, October 1965). Mr. Koonce also states: "The speaker system (drivers or crossover components) may behave in some nonlinear fashion which is not corrected for."

Speaker systems will behave in a nonlinear fashion, which we should try to identify and rectify as far as possible. For testing purposes, the only bandwidth limitation should be that of the best sources: 4-20kHz digital and 15-30kHz analog. Unfortunately, most speakers still have a long way to go before we can comfortably describe their output as an accurate translation of their electrical input, but it can be very interesting and entertaining getting there.

Mark Wheeler
Littleover, Derby, England

Contributing Editor G.R. Koonce responds:

Let me first apologize for my rather confusing letter published in *SB* 3/93 (p. 66). It was edited from a personal communication with the editor and intended to be constructive to IMP. I had no intention of putting *Stereophile* in the Sonar transducer testing business, and I apologize to them for the letter's reading.

Mr. Wheeler and I are more in agreement than his letter would indicate. Our disagreement lies in the use of the word "impulse," so I will instead use the term "transient testing," with which I have no problem. My objection, and I think that of others, is with "unit impulse" testing (i.e., using a very sharp test pulse that in theory covers infinite bandwidth). I do not think it wise to evaluate a speaker system with a test signal that may cause linearity problems in the crossover or drivers due to the inability to handle frequencies in the megahertz range.

IMP uses a rectangular test pulse for cost reasons. I believe the more expensive transient testers have gone to other test pulse shapes, such as maximum length sequences or gated sinusoids. I totally agree with Mr. Wheeler that music is transient in nature, and any testing which shows a system's inability to handle music signals is valuable.

I totally support Bill Waslo's efforts and can happily say that I am using IMP in my present testing. After 30-plus years of doing something one way, changing to IMP was not an easy decision. Also, while kit building was once a beloved hobby, old eyes and lowered hand coordination now make it a real challenge. I proceeded slowly and IMP worked when completed, so don't let its assembly deter you. My major problem was finding a port board such that my computer would recognize a second parallel port.

My test amplifier does not contain a volume control, so I added one to IMP to allow adjusting the output pulse level. In accordance with Mr. Waslo's recommendation in his response to my letter, I have limited the test pulse bandwidth. *Figure 1* shows the schematic for the output circuit I am using in my IMP. The switch is placed in fast when using the higher-rate test pulse and in slow for the lower rate. The first-order filters limit the test signal bandwidth and also impose a slew rate limit on the pulse, something I feel is vital to ensure proper testing and which has worked out well.

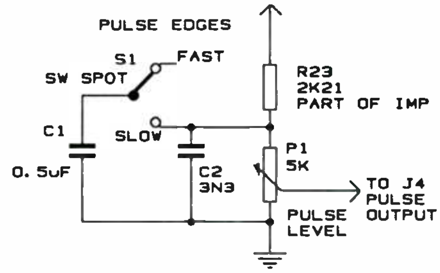

FIGURE 1: IMP output circuit schematic.

Mr. Waslo has stated to me that leaving IMP connected to the printer port while it is not powered up causes no problem. Regarding whether it is safe to plug/unplug the mike while IMP is powered up, as it applies a 2V bias, he again stated that this is not a problem. He warns, however, that plugging in a self-powered mike which could produce an input transient approaching 5V could latch up the CMOS amplifier and is to be avoided.

If anyone believes that producing acceptable test performance with a transient tester such as IMP ensures the speaker system will perform properly with music, I have already demonstrated this is untrue. I used IMP to test a waveguide system and finally produced test results agreeing very well with the system's predicted response. When the waveguide was inserted in a real system and music played, however, the results were terrible. I believe I have located the problem by using "old" test methods (pink noise and RTA) and am working on a cure. Perhaps if I had somewhat more experience with transient test techniques, I would have spotted the problem earlier.

I have also used IMP to tune vented-box systems, develop zobels for drivers, and evaluate finished closed-box systems. IMP is much quicker than my older, steady-state test techniques in all these areas, and the agreement between them has been very good. IMP is indeed a valuable test tool, but, like any other tool, it will not guarantee a successful speaker system. Your ears should be the final test.

In summary, IMP is a spectacular buy for $249. It works as advertised and the software is excellent. (While I have some nitpicks in this area, I have not located anything to date I could classify as a bug.) I recommend bandlimiting the test signal on IMP or any other transient tester. Finally, it is possible for a speaker system to test well on IMP and still not perform acceptably with real music. I believe Mr. Wheeler and I are really in agreement.

Bill Waslo responds:

While I am obviously partial to impulse testing, it has not been my experience that it gives results which disagree markedly with classical approaches (other than the greater amount of information obtainable when time behavior, phase, and magnitude are all determined). When differences show up, the trouble is usually methodology. The theory presents no problem: frequency response *is* the Fourier Transform of impulse response—there's no sleight of hand here.

True, a large impulse could conceivably excite large- rather than small-signal behavior in a quick driver or panel, but so could a sine wave or pink noise signal if applied at too high a level. No tool works well when used improperly. In addition, the continuous signals can lead to confusion and measurement error from echo contamination, a problem which the use of impulse testing can elegantly avoid or include as the operator desires.

A potential problem exists in separating the effects of linear frequency response from nonlinear distortion in the data with impulse testing (along with most classical methods). I have not found this effect to be very problematical, and it is easily investigated by varying the stimulus level and checking for response changes. The MLS variation on impulse response acquisition also provides a good measure of additional distortion immunity.

I agree that a good speaker should be able to do as well on an impulse as on a sine-wave test. With good-quality components and a properly conducted measurement, there should be little difference except in the cost and time expenditure.

IN YOUR PHASE

In his article "A Bi-Structural Enclosure" (*SB* 3/93, p.10), David Davenport mentions that when the woofers are mounted face-to-face, the outside driver is wired out of phase. Does it make any difference which driver is so wired?

Chuck Cocci
Dedham, MA 02026

Contributing Editor David Davenport responds:

Which of the two face-to-face drivers is wired out of phase does make a difference, as this determines the phase (or polarity) of the compound pair with respect to the phase of the drivers in the main speakers. The importance of the relative phase between different speakers in a system is manifested in the smoothness of the sound transition between those speakers. Other factors involved include placement and acoustic environment. You might experiment with reversing the subwoofer's phase to see if this makes a difference in the resultant sound.

BOX DESIGN

I have an idea for a valid and useful bandpass box design. Rather than use rear-sealed and front-vented volumes, replace the vent with a passive radiator. The advantages would include: filtering of above-band peaks; elimination of removable panel for woofer access (using a PR of greater diameter than the woofer) which would result in easier and more rigid construction; avoidance of long ports in small volumes.

Unfortunately, my understanding of box design is incomplete. I am unable to model the idea because I believe a passive radiator to be mathematically identical to a port that results in the same f_B. I am told this is incorrect. If someone could model this box type, it could prove quite useful. Of course, if the same f_B hypothesis is valid, no new model is necessary.

I also have a practical question regard-

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Audio Amateur

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- Borbely Power Amp Modules, Part I
- RIAA Network Limitations
- The Heat's Off
- High-Quality Headphone Amplifier

ing tuning such a box. How would one tune (i.e., add mass to) the PR in the final bandpass box? It would detract from the technique's usefulness to be forced to make a test box of equal volume to the front chamber.

Jason Aronowitz
Douglaston, NY 11363

Contributing Editor Robert Bullock responds:

Your suggestion of a rear closed-box and front passive-radiator-box bandpass system is one of the options included in my modeling program Bandpass BOXMODEL. *(Available from Old Colony Sound Lab, SOF-BPB1B5G, $50—Ed.)*

I have used this model in attempting to design such a system with a reasonable looking response curve, but as yet have been unsuccessful. The system is complicated enough so that it is by no means clear what the relationship between the parameters should be. The model cannot be sufficiently simplified without losing some essential design elements.

I suggest you try your hand at it. You may have better luck than I did.

KID STUFF

I wholeheartedly agree with Fred Jansky's guest editorial (*SB* 2/93), in which our youth seem to desire only entertainment, with little motivation to learn. But we can help.

Christmas presents are a good example. Not only are the prices of toys outrageous, but their lifespan is ephemeral. I have decided not to purchase toys any more. Instead, I gave an older nephew a set of wrenches. He was so happy with them that he assembled and disassembled his bicycle several times. I purchased a robot kit from *Nuts and Volts* magazine for my son, which required electrical and mechanical assembly. He later thanked me for the best gift he has ever received.

I have given others inexpensive multimeters, intercom kits, tool sets, and AM/FM radio kits. True, not every child will appreciate such gifts, but in my experience, most of the time kids are delighted to own something "real." When I do chores around the house, I usually ask my ten-year old for his tools.

I would advise fellow builders to allow children to help in their next project. With adult supervision, older kids can learn the joys of woodworking. Smaller children can help with trivial chores, like sorting out screws or electrical components, being a "third hand" during soldering, stuffing cabinets, and the like. True, it may slow your project somewhat, but the proud "I helped" look on your child's face provides a satisfaction second to none. And you know that the youngster is now addicted to the adventure of learning and being creative, not to a mind-numbing video game.

Fernando Garcia
Richardson, TX 75044

SORCERER'S APPRENTICE

David Davenport's article "A Bi-Structural Enclosure" (*SB* 3/93, p. 10) gave me many new ideas for building a subwoofer and offered some building techniques I had not previously encountered. While I enjoyed all three designs, as an amateur, I would probably find transmission-line enclosures difficult to build.

One of my major concerns is the actual crossover from a subwoofer/satellite system. As a hypothetical situation, let's say that my woofer's impedance is 4Ω and my satellite's is 8Ω. Let's also say that I am running my speakers through an integrated amplifier, and that my crossover must be passive. Lastly, my integrated amp is rated at 100W into 8Ω.

If my subwoofer/satellite is hooked up parallel so the speaker's impedance is around 2.6Ω, this could destroy my amp by drawing too much current. How can I remedy the situation and achieve a total speaker impedance between 6 and 8Ω? It seems that neither a series nor a parallel circuit will help. Could a 2.6Ω speaker be transformed into 8Ω through some electronic wizardry?

Finally, is it possible to purchase an entire crossover network? If so, who would carry it?

Paul Nemec
Highland Hts., OH 44143

Contributing Editor David Davenport responds:

The concept behind combining several speakers into a system is the same whether the driver handling the lowest frequencies is mounted in the same enclosure with the other drivers, or whether it is mounted in a separate enclosure and called a "subwoofer." No wizardry is involved—just sound technical principles.

A properly designed passive crossover will meet your requirements. Don't worry about combining the separate driver impedances; part of the crossover's job is to isolate the drivers from each other. Unfortunately, the "one-size-fits-all" crossovers which are occasionally available via mail order are rarely adequate to a specific situation. To do the job right, you will need to custom design your own crossover.

Fortunately, plenty of literature is available to help you, especially *The Loudspeaker Design Cookbook* for starters. Several reviews in *SB* showing passive crossovers for subwoofers can also give you an idea of what's involved: my Focal SW35 subwoofer review in *SB* 1/87 (p. 42); and Gary Galo's review of the Audio Concepts Sub-1 subwoofer in *SB* 3/91 (p. 51). High-quality capacitors of the size you will need are very expensive, and inexpensive ones will audibly degrade the sound. This might be one of the factors which led Gary Galo to propose his bi-amplified alternative for the Sub-1 crossover ("Bi-Amping the Sapphire II Sub-1 System," *SB* 3/92, p. 24).

In any event, you are now where all of us "old timers" were when we started in this hobby. I encourage you to jump in with both feet and have fun learning as you go.

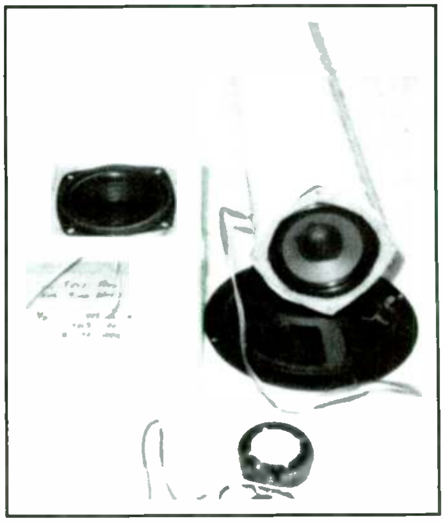

PHOTO 1: PVC pipe with Radio Shack driver.

RIDING THE WAVES

During correspondence with Bill Schwefel concerning his "Korean Wonders" (*SB* 3/93, p. 65), he offered the hypothesis that the "low coloration" we observed in the Isobarik-designed woofers was due to the extent to which the second woofer prevented the back wave from exiting the box. I proposed that a test of this hypothesis would be "a transmission-line Isobarik design, which should show little or no improvement over the single speaker design, since the back wave is absorbed in the line." Bill replied as follows:

"Your hypothesis about a transmission-line Isobarik peaked [sic] my interest and I decided to conduct a simple experiment. I found a 6′ section of 4″ PVC pipe . . . and bolted a 4″ Radio Shack driver (40-1022A) to one end (*Photo 1*). I stuffed the line with polyester fiberfill at a rate of 0.5 lb./ft.^{3} Then I mounted another Radio Shack 4″ driver (40-1022B) in a small 157 in.^{3} VAS test box. I hooked both woofers to a temporary crossover and patched in a 1″ tweeter, then sat back for some comparative listening.

I arranged the wiring so I could quickly switch from one woofer to the other and back again. I also varied the amount of polyester fiberfill in the sealed box from zero to 1 lb./ft.^{3} Finally, I removed the driver from the sealed box and did a comparison of the transmission-line single to a transmission-line Isobarik. Here are my conclusions.

1. The least colored sound, with solid bass fundamentals and little overhang, came from a single woofer mounted in a 6′ PVC transmission line.

2. The Isobarik in a sealed box sounded less colored than the single woofer in a sealed box, but it was somewhat more colored or boxy sounding in a direct comparison to the single woofer in a 6′ PVC transmission line.

3. The insertion of damping material in the sealed-Isobarik system reduced this coloration somewhat, but could not eliminate it in the way that the transmission line could.

4. Insertion of damping material in the sealed-single-woofer system reduced box coloration to a greater degree than insertion of the same amount of damping material in the sealed-Isobarik system. (This suggests that the inner woofer isolates the outer woofer from box-induced coloration).

I was not expecting the above conclusions. The clear winner of my tests was the transmission line. The only problem is that transmission lines tend to be much larger and longer than the other formats.

The other conclusion is that with any speaker system, despite design type or cost, the best sound will result when you lose the rear wave entirely. Yet the only way that I can think of doing this would be to cut driver holes in the exterior walls of your home and then let the rear wave shoot off toward infinity. Building transmission lines and Isobarik systems are currently the only practical way around these problems."

Alan P. Towbin
Bethany, CT 06524

FOCAL POINTS

I recently noticed Focal's "dual-voice-coil" technique for extending frequency response. It has apparently been around since 1979, but I can't find any other information regarding a design approach, such as sealed or aperiodic enclosure volumes, how or where to crossover, or even how far the response can be extended in the first place. This technique seems so beautifully simple. With two coils working one driver and providing twice the current, this would create much more output (sensitivity) and require a much louder tweeter.

I'd like to try a simple two-way, sealed or periodic box, with a relatively small driver, such as a 6½″ or a Focal 7″. Do the standard T/S calculations for determining box volume, f_3, and Q_{TS} still apply with this technique? Can any dual-voice-coil driver be used this way? My skills and knowledge limit me to simple designs, and I've always avoided vented designs due to their complexity.

Here in the Seattle area, the trend among high-end audio dealers seems to be two-way, vented, small-driver systems, without a subwoofer in sight. They're simple and sound great. The ones I have seen apparently do not employ dual voice coils.

I'm also confused about the use of dual drivers in one enclosure. I understand the effect on sensitivity of series or parallel wiring, but why can't two drivers, in phase, mounted closely together, yield a lower response than a single driver? Don't two 8″ drivers approximate the cone area of a 12″, yet respond to transients faster? Or is this a misconception that dates back to the sixties?

I've exhausted my resources of books and periodicals and can't get any more help from Focal. Any information will be greatly appreciated.

Thomas M. Hanser
Kirkland, WA 98034

Education

continued from page 9

readers. And this is only a small sample of do-it-yourself publishing and business outside our increasingly effete, helpless country.

Any engineered design is only validated when it is built. Building any kind of device with your own two hands is highly educational—and glorious as well. The leaders of this new effort could do worse than to start with getting engineering's brains and hands back in touch with each other.—E.T.D.

*If you have suggestions to share with those spearheading this laudable Wiley effort, send them to S. Spilka, John Wiley & Sons, 605 Third Ave., New York, NY 10158-0012, or FAX them to (212) 983-0529.

Software Report

continued from page 57

discover some "glitches" (somewhere between a nitpick and a bug) and these will be addressed. With nearly 500 copies on the market, I must say that I have yet to hear of most of Mr. Koonce's issues. (Oh, for the day of bug-free computer programs.)

As for decimal place values, we felt the "1.25234 ft.^{3}" type of accuracy is a ridiculous approach, since speaker design is often a "10%" science. Driver-to-driver parameter values are typically ±3% off the assembly line, and, once you model the resulting performance effects, these differences are usually heavily masked, if not inaudible, doing A-B listening tests.

Regarding our software routines, these are very much protected by both the Bosch Corporation and our code writer, so I cannot expose the performance in good faith. We are planning an upgrade including things such as displacement-limited power and variable "S" values for bandpass boxes. Our polled users in the beginning stage were initially fearful of such features but eventually changed their minds.

I could go on and on here, but I hope I have emphasized the use of Blaubox as a "Swiss Army knife" and not a "mainframe-driven medical laser." They each have their place.

Classified

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COMPLETE SPEAKER SYSTEMS AND KITS from 5″ two-way to 12″ three-way, sub-woofers, high-definition systems. Oak, black piano, and texturelac finishes. FACTORY DIRECT PRICING. ***SPEAKER-WORLD TECHNOLOGY*** (510) 490-5842, FAX (510) 490-1961. T5/93

HAFLER HEADQUARTERS IN PENNSYLVANIA! Featuring the highly-rated TransNova Power Amplifiers (*Stereophile* Class B), new FET preamplifiers; professional power amps with balanced inputs. Free shipping. Call or write. ***AUDIO ARTS***, RD 2, Wernersville, PA 19565, (215) 693-6740. T3/94

MONARCHY DAC, $695 w/bal out, level 1 MOD, $259 ($159 kit), Digital cable, $75, 2-way monitor w/ accuton tweeter, $1,795 ($1,195 kit), Room Acoustics handbook, $14.95, ***MACH 1 ACOUSTICS***, RR2 Box 334A, Wilton, NH 03086, (603) 654-9826. T1/94

COMING SOON!

TC SOUNDS makes no-compromise drivers with linear motor-structures (underhung), high-compliance linear mechanical systems, and stiff lightweight composite polymer solid diaphragms. Individual T/S-parameters, 5.5",8",10",12",15",18" call (619) 622-1212

ACT AUDIO GIVES GOOD SOUND! Computer analysis of your listening room. Send SASE for details. ***ACT AUDIO***, 619 Moon Clinton Rd., Coraopolis, PA 15108. T4/94

ACT AUDIO COMPUTER SYSTEMS. Custom configurations for your design needs. Lowest Prices. Ship anywhere in USA. Send your wish list, we send quote. ***ACT AUDIO COMPUTER SYSTEMS***, 619 Moon Clinton Rd., Coraopolis, PA 15108, FAX (412) 264-0677. T4/94

ALL SPEAKERS RE-CONED. New 12″ woofers $36, wire, grills, headphones, warranty repairs, more! Nice prices, free catalog, ***TRI-STATE LOUDSPEAKER*** (412) 375-9203. T5/93

FOR SALE

JBL 2235H 15″ woofers, three hours use, with original boxes, $295/pr. Dynaudio Variovents, $25/four. (503) 343-1413.

Two pairs Accuton C2-11 tweeters, $90/ea.; two Audio Control C-131, mono, equalizers ($529), $300/ea. All in excellent condition. Leigh, (904) 378-7485.

Techron Tef system 12 Time Delay Spectrometry (TDS) analyzer with software, manuals, and B&K 4007 calibrated studio mike (worth $1,000) included. This is a state of the art speaker/room measurement system! Paid over $11,000 five years ago. Asking $3,495 for complete system. John Murphy, (619) 480-8961, M–F 8:00–5:00 PST.

SPEAKER BUILDER CLASSIFIED ORDER FORM

PLEASE PRINT IN CLEAR BLOCK LETTERS OR TYPE. SPELL OUT EACH WORD. NO ABBREVIATIONS.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	42	44	45	46	47	48	49	50

❑ For Sale ❑ Wanted ❑ Trade, indicate number of insertions_____

For Sale ads are to *sell* personal equipment or supplies. **Wanted** ads are to *find* supplies, equipment or services. Both are "not for profit" ads and will only run once unless they are resubmitted. **Trade** ads are for any business or private party selling something for a profit.

Ad copy: A word is any collection of letters or numbers with a space on either side. **Illegible ads will be discarded.**

Price: All ads are $1.00 per word. Deduct 5% on a 6X contract for **Trade** ads. Ten dollar minimum per insertion. **Payment must accompany ad. No billing.**

Subscribers receive *free* **For sale** and **Wanted** ads up to 50 words; .20 each additional word. Only one ad per category, per issue.

Please include your name, address and telephone number.

Please charge to my MasterCard/Visa:

CARD NUMBER EXP. DATE

❑Check/Money Order Enclosed

Subscription Account Number: A❑❑❑❑❑❑❑

NAME

COMPANY

STREET & NO

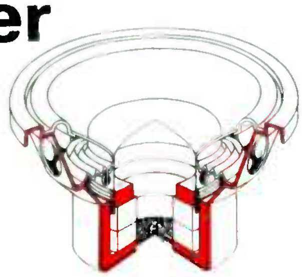
CITY ST ZIP

PHONE

Reader Service #14 ➡

MW 114-S

Neodymium Magnet DPC Cone 4" Woofer



Specification

Overall Dimensions	Ø118mm (4.64") x 58mm(2.29")
Mounting Baffle Hole Diameter	Ø95mm (3.75")
Magnet System	Pot Type, Vented, Neodymium Magnet
Nominal Power Handling (Din)	150W
Transient Power - 10ms	800W
Voice Coil Diameter	54mm (2.125")
Voice Coil Type/Former	Hexatech Aluminium
Frequency Response	55-7000 Hz
FS - Resonant Frequency	65 Hz
Sensitivity 1W/1m	87 dB
Z - Nominal Impedance	8 ohms
RE - DC Resistance	5.6 ohms
LBM - Voice Coil Inductance @ 1kHz	0.47 mH
Magnetic Gap Width	1.25mm (0.050")
HE - Magnetic Gap Height	6mm (0.236")
Voice Coil Height	12mm (0.472")
X - Max. Linear Excursion	3mm
B - Flux Density	0.88T
BL Product (BXL)	6.75
Qms - Mechanical Q Factor	2.32
Qes - Electrical Q Factor	0.36
Q/T - Total Q Factor	0.31
Vas - Equivalent Cas Air Load	3.18 litres (0.113 cu. ft.)
MMS - Moving Mass	7.00gm
CMS	807μm/n
SD - Effective Cone/Dome Area	53cm² (20.86 sq. in.)
Cone/Dome Material	DPC (Damped Polymer Composite)
Nett Weight	0.500 kg

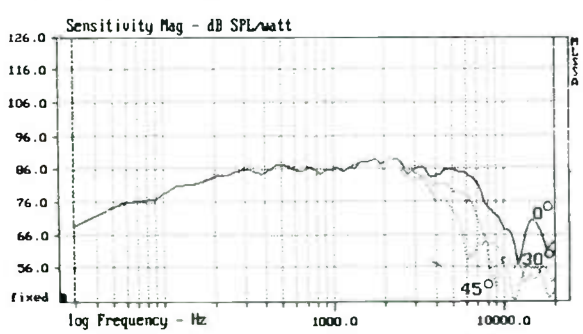
Specifications given are as after at least 45 minutes of high power, low frequency running, or 24 hours normal power operation.

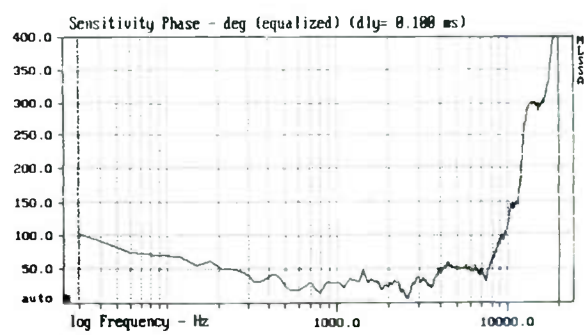
The 114-S is the first of Morel's new generation of woofers, featuring a powerful Neodymium magnet system which provides increased sensitivity, lower Qt and reduced distortion. For a 4" driver it is unique in having a large 54mm (2.125") diameter Hexatech aluminium voice coil.

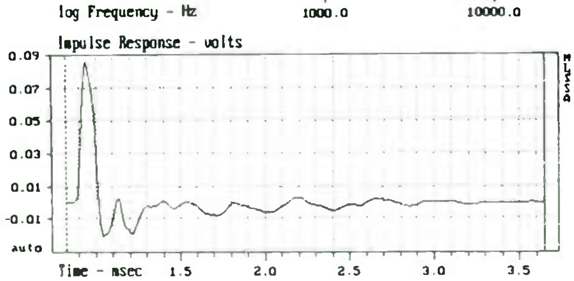
Benefits of this large voice coil diameter include a very high power handling capacity and lack of sound level compression. In addition, it allows the use of a very shallow cone profile. Coupled with the use of Damped Polymer Composite cone material and a rubber surround, this provides excellent dispersion (off-axis response), resistance to cone break-up (even at high sound pressure levels) and lack of colouration.

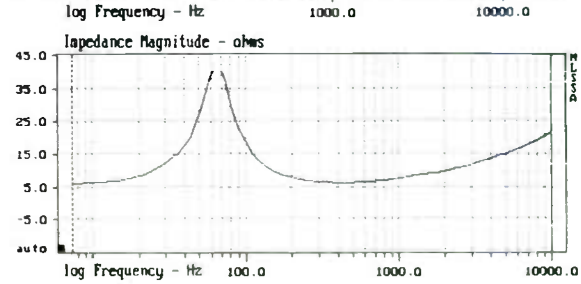
Frequency and phase response are very flat, while the roll-off is very smooth. The MW 114-S may be used either as a bass-mid range in 2-way systems, or as a mid-range in multi-way systems.

The vented magnet system is encased within a steel chassis, which improves efficiency and shields the magnet, virtually eliminating stray magnetic fields. The MW 114-S is ideal not only for high quality hi-fi, but also TV, video and surround-sound applications.









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

morel

high fidelity range

morel (U.K.) **ltd.**
11 Foxtail Road
Nacton Rd. (Ransomes)
Industrial Estate
Ipswich, IP3 9RT
England
Tel: (0473) 719212
FAX: (0473) 716206

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

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CLASSIFIED INFORMATION

Four types of Classified Advertising are available in *Speaker Builder*:

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

WANTED: Help readers find equipment or services.

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

CLUBS: Aid readers in starting a club or finding new members. Specific guidelines apply to *Club* advertising. Please write to the Ad Department for terms. Don't forget, include a #10 self-addressed stamped envelope.

PRICING

All advertising is $1.00 per word, $10 minimum per insertion. Deduct 5% for a 4x contract. Please indicate number of insertions. Payment MUST accompany ad. *No billing for word classified advertising.*

AD COPY

A word is any collection of letters or numbers with a space on either side. *No abbreviations*; please spell out all words. Count words, not letters. Ad copy should be clearly typed or printed. Illegible ads will be discarded.

SUBSCRIBERS

Receive *free For Sale, Wanted,* and *Club* advertising; 50 words maximum; each additional word just $.20. Please only one ad per category, per issue.

Please include your name, address, and telephone number. If TRADE please indicate number of insertions on the ad. All free ads are run only once, then discarded. Ad questions, copy and copy changes cannot and will not be answered on the phone. All correspondence must be in writing addressed to:

Speaker Builder
Classified Department
PO Box 494
Peterborough, NH 03458-0494

Audio Concepts SapphireII-SubI system, oak, mint, with stands, boxes, manuals, $1,050, you pay shipping. Jay (816) 785-5262.

EV 15" woofers, cast baskets, 4Ω from Klipschorns, $150/pr; DB Systems active crossover, 800Hz, $150; Precision Fidelity C7 preamp, near mint, $150; JBL LE-85's, NOS, $375/pr.; Revox G36III, very nice, original $425; Sound Technology 1500A, with tapes, disk, etc. BO. Chris (501) 664-8705.

Audio equipment for sale, call John Del Signore (518) 692-8282. Seck MKII-18 channel recording console and power supply with case, $1,700. Whirlwind Custom 100' Smoke, 18 channel, $200. Two Biamp EQ-230, 15 band, ⅔ octave, graphic equalizer $200/ea. Three-way (4 Cabinet Design) P.A. system set up for bi-amped operation. Passive L-R crossover at 5K low crossover ability from 300–800Hz. Components include: JBL 15" woofers, Audax 7" mids and EV, ST-350 horn tweeters. Wide range response from 35–20kHz with high definition and power handling, $1,600.

Dynaudio D21, $40/pr.; D28 $50/pr.; D52 $60/pr.; D54 $70/pr.; JVC ribbon, $40/pr.; AR Partners 4" PP, $60/pr.; ¾" 3A, $40/pr.; ¾ AR-11, $50/pr.; Morel MDT-28, $40/pr.; Radio Shack 4" original 1022, $20/pr.; Viva M10MD-39, $30/pr.; Peerless TP-165FG, ½", $30/pr. Shipping extra, contact George, (216) 581-6707 (W), 5095 Boulder Creek Drive, Solon, OH 44139.

AR 10 pi speakers, $400; AR 3A bass drivers, (new) $125/pr.; Advent woofers, (new surrounds) $80/pr.; Advent tweeters, $40/pr.; JBL 104H3 mids $50/pr.; JBL LE-25 tweeters, $50/pr.; Hafler 220 amp, $250; HK Citation eleven pre, $100; HK Citation 12 amp, $125. All plus shipping, Dean, (210) 497-7453, (Texas).

JBL 4466A horns, $150/pr.; Triplett SPL meter, $100; Philmore VU meters, panel-mount, new, $25/ea., fourteen for $280. Renkus Heinz 60° CD horns, 2", $150/pr.; Altec 511 horns, $80/pr.; Custom made 10 band sweep notch EQ, $150. EAW UB-42 underbalcony speaker, $250. Tom, (914) 526-4022.

ARC LS-1, $900, Classic 30, $1,600, $2,300/both; Boulder 250 AE, $2,300/pr., $1,300/ea. (list $2,700/ea.); Rane AC-22 with cover, $200; Tad 1601, $300/pr. Steve, (203) 397-3888.

HP331A distortion analyzer, $75; Spyden stereo bydirectional ribbon microphone, $600 new, never been used, asking $300. Ultra analog DAC D20400, finest 20-bit D/A converter in the world, never been used, two months old, $295 new, asking $150. Two Entec SW-1 subwoofer cabinets, no electronics, no speakers, asking $400. Ashby, (305) 846-9076.

Magnaplanar Tympani 1-D, $679/pr.; Sony HFP-200 beta hi-fi processor (MTS), $125; Sony SLHF-860D, $515; Sony MDP-200 (as is with remote), $199; ADS 4" woofers, $35/ea. I rebuild Strathearns, $100/ea. Michael Marks, 2334 Morgan Lane, Dunn Loring, VA 22027, (703) 641-5824.

Panasonic leaf tweeters, EAS 10TH400A, $50/pr. Focal T120ti02 coils, $25/pr., never been used. Eugen Nedelcu, 5730 28th St., Sacramento, CA 95824.

Polypropylene caps, 4MFD 200V Rel-Cap, $7/10; 6MFD 200V Rel-Cap, $12.50/10; 8MFD 200V Ultra-Cap, $15/10. Choke, 4.75mH, $1.50/ea. Resistors, 15Ω, 225W dummy load, $3.95/ea., plus shipping. SASE for list of other items. Steve Slater, 3045 Orange Ave., LaCrescenta, CA 91214, (818) 248-0416.

Tektronix 1710B waveform monitor, like new, $700; Honeywell 5600C transport to build your dream reel-to-reel, 10½" reel size, seven speeds, capstanless servo controlled, constant torque, remote control. Will handle ¼" to 1" tape A "reel" machine, $400. Best offers considered. Andy, (313) 437-8285.

Focal T-90ti, $60/pr.; Versatronics 4" Kevlar woofers, $75 (four); cabinets for above in black laminate, $50. Klipsch KG-2 tweeter, passive radiator, crossover, all $30. Superphon preamp and 100W per channel amp, $550. Black mini-monitor cabinets, $40/pr. Rick, (919) 662-5253.

Dynaudio 30W100 12" woofer with 4" v.c., mint, $199; Peerless 831858 8" dual v.c. woofer, mint, $49. Both woofers have less than than 10 hours time; pair new SEAS 25TAC/GW H417 1" aluminum dome tweeters, $39. Paul, (210) 695-9082, or FAX (210) 695-2372.

Pair of vintage speakers KEF model K-2 Celeste MKii's made in England, sold by Radio People Ltd., Kowloon, Hong Kong. Size 6½ × 18 × 11 with serial numbers. These are rare and unusual collector items in excellent condition. They work fine and sound good. Will pack and ship, $225. (305) 931-7131.

Apature interconnects: LSD Digital 1 meter new, 2 meter used = $65/both; new Audiolink (3) – 2 meter, + (4) 1 meter = $55/all 7; Advent 101 Dolby with manual = $30; *Stereophile* magazine 26 Issues Volumes 13—present, some missing $30; Marantz 250M power amplifier $275. (414) 458-2057, 4–8 p.m., CST.

Altec 292-8A midrange horn drivers, 1.4" throats, Almco, heavy, $250/pr.; Pioneer 3080 laser CD player, one of the best, $500; Pioneer EQ, $75; range expander, $50; pair EV 1503 pro three-way speakers, $600; EV RE34' mike, $100; Thorns 135 turntable, $50; trades possible. David, (914) 688-5024.

Pass A-40 parts, four channels available, circuit board, semiconductors and Lambda Darlington outputs, $150 for everything. Perforated aluminum plates for ESL cells per Hermeyer design *TAA 2/77*, 80 pieces sheared 7" × 18" perfectly flat, $150. WJ-1A preamp boards, servo. Nick Mastrobuono, 50 Copperfield, Sarnia, ON, N7S 5K8, (519) 336-9160.

Jantzen 130 electrostatic modules, four 5" × 5" panels/unit, including schematic and brochures, $150/pr.; two pair Dynaudio 17W-75XL, $50/ea.; one pair MB Quart 1" titanium tweeters, $50/pr.; one pair Focal T-90ti tweeters, $50/pr. All excellent condition. Paul Champlin, 1016 Quail Gardens Ct., Encinitas, CA 92024, (619) 632-7463 (H), (619) 598-4344 (H).

Delac 510 drivers, crossover board and parts as featured in *SB* 3/91 by Ralph Gonzalez. Original article and owners manual. Drivers include four SEAS 4.5" drivers and two SEAS .75" tweeters, $125 postpaid. Call Mr. Willes, (800) 227-6121, weekdays, 9–5 CST.

B & W LM-1, panel mount version, $95 (one only); Philips AD10100/W8AH 10" woofer, $15 or $30 with cabinet; Realistic 2" × 6" horn piezo 40-1379 tweeters, $18/pr.; B & W MR100 4" 8Ω Bextrene Midrange, $25/one; TP26 1" 8Ω dome tweeter, $25/one. Jerry Feldstein, Apt #3, 705 E. 189 St., Bronx, NY 10458, (718) 364-3485 7–10 p.m. EST, no machine.

Aria 5's with finished cabinets, matching stands and black grilles, $300. Audio Concepts AC-10, 10" woofers (four), $150. Unfinished cabinets for ARIA 5 and 2 AC-10 combination with crossovers. Excellent build quality, $150/pr., $500 for the lot. (414) 242-5502.

Symdex Epsilon Signature Loudspeakers, B1 wireable, $3,500 list, sell for $2,500. Call Kurt (312) 248-5936.

Two JBL 2220A 15" 8Ω drivers, new $250. Two Renkus-Heinz SSD-1800-8 compression drivers, 8Ω, with 1kHz horns, new, $250. Vendor will pay shipping. (705) 743-0511 between 7:00 & 10:00 p.m., EST.

Pair of SpeakerLab SK's, identical to the Klipche Klipchcorns 103db 1W 250W max., 8Ω, $900. Kenwood KR9600 receiver, 160W per channel, 8Ω, 200W, 4Ω. Both in excellent condition, $500. Larry, (502) 447-3423 after 5 p.m.

Speakerlab K-horn bass section with Marchand Electronic crossover, $550/pr., (San Francisco Bay area only). Eminence 15" woofer aluminum die cast frame, $100/pr. All in excellent, like new condition, you pay shipping. Jim Pann, 3245 South Ridge Dr., Richmond, CA 94806, (510) 223-6986, leave message.

WANTED

Any information for 10" Becker poly drivers, 910A208, 2481440. Don Wallace, 1904 Papeete Dr., Plano, TX 75075, (214) 812-2804.

One 8V416 and one 10V516 Focal driver, pair AC-10 or Peerless 831727 woofers, Adcom ACE-515 line conditioner. James Annal, 9216 S Harding, Evergreen Park, IL 60642.

If cheap, one only of each: Wharfdale Diamond II; Dynaudio D21; Allison1 midrange tweeter; will trade MB 1", 2" titanium dome units (only one each); Jerry Feldstein, 705 East 189th St., #3, Bronx, NY 10458, (718) 365-6343. Will return calls.

Advent receiver, model 300, in good working condition and physically sound. Will pay cash or swap for other audio gear or other items of interest. Tom Krehbiel, 465 Woodward Ave., Buffalo, NY 14214. (716) 838-5348, collect calls okay.

EV speakers: SP15, SP15B and SP8B, Contact Fred Sutton,(310) 316-4406, or write: 1230 S. Helberta Ave., Redondo Beach, CA 90277.

One or more Dalesford D30/110 5¼" woofers, preferably *not* in good condition. Perry Sink, (708) 678-8650 (day), (708) 616-1973 (eve).

Garrard 301, 401, SME RMA 309, 3012 Arm Ortofon SPU. Heath WA-W1 amp, Dynaudio D-54. Raul Gil, 180 Union Ave., Belleville, NJ 07109, (201) 751-5959.

Buying SEAS H400 aluminum tweeters, will pay $30/pr., or will trade directly for Panosonic tweeters; Accuton C44 tweeter, will pay $150/pr.; Rotel 9806X amp, will pay $300–400, depending on condition. Eugen Nedelcu, 5730 28th st., Sacramento, CA 95824.

CLUBS

THOSE INTERESTED IN AUDIO and speaker building in the Knoxville-East Tennessee area please contact Bob Wright, 7344 Toxaway Dr., Knoxville, TN 37909-2452, (615) 691-1668 after 6 p.m.

AUDIOPHILES IN THE DAYTON/SPRINGFIELD, OHIO AREA: We are forming an audio club. Please contact me if you're interested in construction, modifications, testing, recording or just plain listening to music. Ken Beers, 1756 Hilt Rd., Yellow Springs, OH 45387, (513) 767-1457.

ARIZONA AUDIOPHILE SOCIETY Located in Metropolitan Phoenix is a growing and active club in the pursuit and reproduction of recorded music. New members are welcome. Meetings are last Tuesday of each month. Receive monthly newsletter and biannual journal. Club discounts with local high-end audio dealers. Send inquiry to Arizona Audiophile Society, PO Box 13058, Scottsdale, AZ 85267, or call Bob Williams, (602) 944-5929.

AUDIO SOCIETY OF MINNESOTA Now in its 15th consecutive year! Serving the many and varied interests of audiophiles in the upper midwest. Monthly meetings, tours, audiophile concerts, special guests. For information and a sample of our latest newsletter, write ASM, PO Box 32293, Fridley, MN 55432 or call our 24 hour "Audio Hotline," (612) 825-6806.

WASHINGTON AREA AUDIO SOCIETY Meetings are held every two weeks, on Fridays from 19:00 hours to 21:30 hours at the Charles Barrett Elementary School in the city of Alexandria, Va. Prospective members are welcome but must register in advance in order to be admitted to the meetings. No exceptions please. If interested please call Horace Vignale, (703) 578-4929.

THE LOS ANGELES AREA LOUDSPEAKERS DESIGNERS GROUP If you're just starting out or an experienced builder and would like to share ideas on speaker design and listen to each others latest creations, give us a call. Geoffrey (213) 965-0449, Edward (310) 395-5196.

MEMPHIS AREA AUDIO SOCIETY being formed. Serious audiophiles contact J.J. McBride, 8182 Wind Valley Cove, Memphis, TN 38125, (901) 756-6831.

THE CATSKILL AND ADIRONDACK AUDIO SOCIETY invites you to our informal meeting. Join our friendly group of audio enthusiasts as we discuss life, the universe and everything! Tubers, Transistors, vinyl canyons or digital dots. No matter what your level of interest, experience, or preferences, you are welcome. Contact CAAS at (518) 756-9894 (leave message), or write CAAS, PO Box 144, Hannacroix, NY 12087. See you soon!

CONNECTICUT AUDIO SOCIETY is an active and growing club with activities covering many facets of audio—including construction, subjective testing, and tours of local manufacturers. New members are always welcome. For a copy of our current newsletter and an invitation to our next meeting, write to: Richard Thompson, 129 Newgate Rd., E. Granby, CT 06026, (203) 653-7873.

ELECTROSTATIC LOUDSPEAKER USERS GROUP is now a world-wide network for those interested in sharing valuable theory, design, construction, and parts source information. If you are interested in building, or have built, your own SOTA ESL we invite you to join our loose-knit organization. For information, send a SASE to: Barry Waldron, 1847 Country Club Dr., Placerville, CA 95667.

LONDON LIVE D.I.Y. HI-FI CIRCLE meets quarterly in London, England. Our overall agenda is a broad one, having anything to do with any aspect of audio design and construction. We welcome everyone, from novice to expert. For information contact Brian Stenning, 081-748-7489.

THE ATLANTA AUDIO SOCIETY is dedicated to furnishing pleasure and education for people with a common interest in fine music and audio equipment. Monthly meetings often feature guest speakers from the audio manufacturing and recording industry. Members receive a monthly newsletter. Call: Chuck Bruce, (404) 876-5659, or Eddie Carter, (404) 847-9296, or write: A.A.S., 4266 Roswell Rd. N.E., K-4, Atlanta, GA 30342-3738.

THE BOSTON AUDIO SOCIETY the nation's oldest (founded 1972), seeks new members. Dues includes the monthly meeting notice and our newsletter, the *BAS Speaker* (6 times/year). Recent issues cover Carver, a/d/s; the founder of Tech Hi-Fi; Photo CD; plus visits from famous speaker designers; listening tests; measurement clinics; research investigations; and more. Back volumes available. Membership includes engineers, journalists, consultants, and music-loving audiophiles like yourself. For information write to PO Box 211, Boston, MA 02126-0002, USA.

THE COLORADO AUDIO SOCIETY is a group of audio enthusiasts dedicated to the pursuit of music and audiophile arts in the Rocky Mountain region. We offer a comprehensive annual journal, five bi-monthly newsletters, plus participation in meetings and lectures. For more information, send SASE to: CAS, 11685 W 22nd St., Lakewood, CO 80215, (303) 231-9978.

NEW JERSEY AUDIO SOCIETY meets monthly. Emphasis is on construction and modification of electronics and speakers. Dues includes monthly newsletter with high-end news, construction articles, analysis of commercial circuits, etc. Meetings are devoted to listening to records and CDs, comparing and A-Bing equipment. New members welcome. Contact Frank J. Alles, (908) 424-0463, 209 Second St., Middlesex, NJ 08846; or contact Bob Young, (908) 381-6269, or Bob Clark, (908) 647-0194.

PACIFICNORTHWEST AUDIO SOCIETY (PAS) consists of 60 audio enthusiasts meeting monthly, second Wednesdays, 7:30–9:30 p.m. at 4545 Island Crest Way, Mercer Island, WA. Be our guest, write Box 435, Mercer Island, WA 98040 or call Bob McDonald, (206) 232-8130 or Nick Daniggelis, (206) 323-6196.

PIEDMONT AUDIO SOCIETY Audio club in the Raleigh, Durham, and Chapel Hill area is meeting monthly to listen to music, demonstrate owner-built and modified equipment, and exchange views and ideas on electronics and speaker construction. Tube and solid state electronics are of interest and all levels of experience are welcome. Kevin Carter, 1004 Olive Chapel Rd., Apex, NC 27502, (919) 387-0911.

THE INLAND EMPIRE AUDIO SOCIETY (soon to become) **THE SOUTHERN CALIFORNIA AUDIO SOCIETY—SCAS** is now inviting audiophiles from all areas of Southern California and abroad to join our serious pursuit for that elusive sonic truth through our meetings and the **IEAS'** official speaker, *The Reference* Newsletter. For information write or call, Frank Manrique, President, 1219 Fulbright Ave., Redlands, CA 92373. (714) 793-9209.

IF YOU ARE an "Organ Music Lover" and like to test your audio system, **SFORZANDO** has room for a few more members. We have about three thousand "Live," on-the-spot, cassette tapes that are not available in the stores. We are happy to lend them to you via the mail. Just ask EA Rawlings, 5411 Bocage St., Montreal, Canada, H4J 1A2.

THE HI-FI CLUB of Cape Town in South Africa sends a monthly-newsletter to its members and world-wide subscribers. To receive an evaluation copy of our current newsletter, write to: PO Box 18262, Wynberg 7824, South Africa. We'll be very pleased to hear from you.

TUBE AUDIO ENTHUSIASTS. Northern California club meets every other month. For next meeting announcement send a self-addressed, stamped #10 envelope to Tim Eding, PO Box 611662, San Jose, CA 95161.

THE WESTERN NEW YORK Audio Society is an active, long established club located in the Buffalo area. We issue a newsletter and hold meetings the first Tuesday of every month. Our meetings attract many prominent manufacturers of audio related equipment. We are involved in all facets of audio—from building/modifying to exposure to the newest high-end gear, and the chance to hear more types of music. For information regarding our society, please write to WNY Audio Society, PO Box 312, N. Tonawanda, NY 14120.

ESL BUILDERS GROUP is a new address for people who have built or want to build ELECTROSTATIC LOUDSPEAKERS and ASSOCIATED (TUBE) DRIVERS, or are just interested. We will concentrate on ESL-related building projects but also look at the theoretical aspects of acoustics and electronics. Interested? An answer is ensured, if you include some kind of compensation for postage and handling. Write to: Gunter Roehricht, Buhler STR.21, 7030 Boblingen, Germany.

SOUTHEASTERN MICHIGAN WOOFER AND TWEETER MARCHING SOCIETY (SMWTMS). Detroit area audio construction club. Meetings every two months featuring serious lectures, design analyses, digital audio, A-B listening tests, equipment clinics, recording studio visits, and audio fun. The club journal is *LC, The SMWTMS Network*. Corresponding member's subscription available. Call (313) 544-8453 or write David Carlstrom, SMWTMS, PO Box 721464, Berkley, MI 48072-0464.

THE PRAIRIE STATE AUDIO CONSTRUCTION SOCIETY. (PSACS) meets every other month. Meetings feature audio construction, design, and analyses, blind listening tests, equipment clinics, autosound, lectures from manufacturers and reviewers. PSACS, PO Box 482, Cary, IL 60013, call Tom, (708) 248-3377 days, (708) 516-0170 eves.

HI-FI COLLECTOR/HOBBYIST seeks "living letters"/audio pen pals from other states to correspond via reel-to-reel tape. Non-commercial strictly; make up short monologues on subjects from vintage technology, with regional FM excerpts for background or equipment samples, from personal tales of yard sales scavaging success, repair/restoration tactics and strategies, favorite service centers, general ways to handle the burgeoning obsession with arcane hi-fi gear. All correspondence on 3", 5", 7" reels (¼" tape) will be cheerfully answered and tapes returned via parcel post. James Addison, 171 Hartford Rd., Apt. #7, New Britain, CT 06053.

MONTREAL AREA SPEAKER BUILDER looking for others interested in speaker design and construction from small to large systems. Feeling like I'm the only one. Prove me wrong! Andrew McCree, 4701 Jeanne Mance, Montreal, PQ H3V 4J5, Canada, (514) 281-7954.

DO YOU LIVE NEAR LAWRENCE KANSAS? I am a student at the University of Kansas looking for other speaker builders within driving distance. I would like to exchange ideas and listen to other homebrew systems. Michael Marmor, 1520 Lynch Court #2, Lawrence, KS 66044, (913) 843-8993

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