BIG GUITAR BASS IN A TINY BOX

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Speaker Builder
THE LOUDSPEAKER JOURNAL

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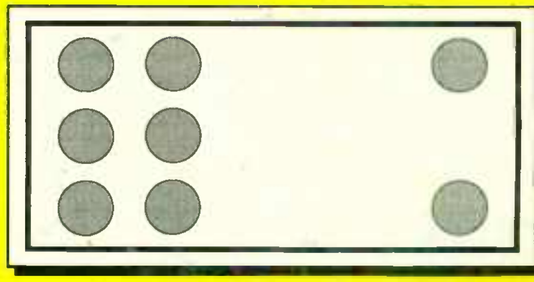

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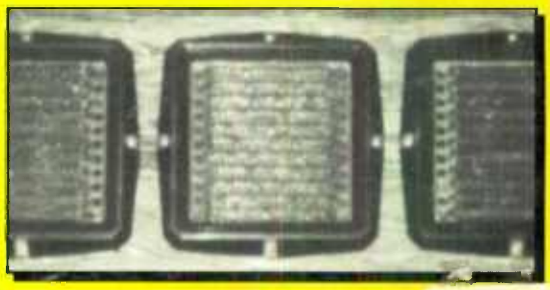

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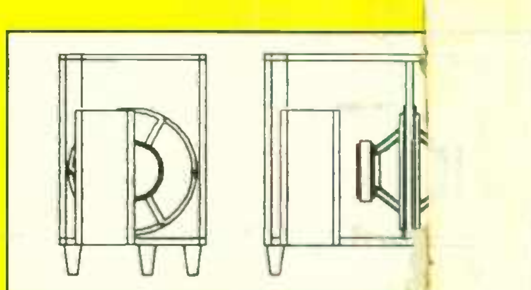

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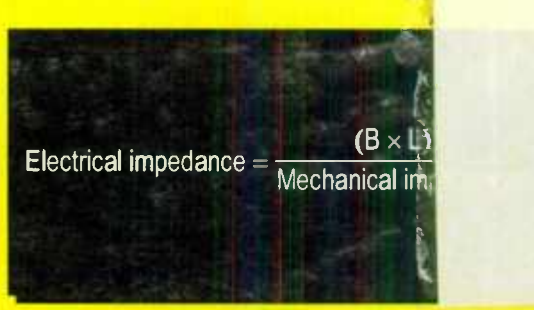

SCREWS GALORE FOR BOXES

Good News

⊃ PROSYSTEMS
The APS-40HF high-power tweeter from ProSystems uses an edgewound, flat-wire voice coil, made from copper-clad aluminum and suspended in a fully symmetric magnetic field, to achieve a nearly flat frequency response of 5–25kHz. Designed for rear mounting in enclosures made of 12 mm (½″) or 18 mm (¾″) materials, the APS-40HF handles 40W with an efficiency of 110dB at 1 m with 1W input. ProSystems, The AWS

Group, Inc., 65 36th St., Wheeling, WV 26003-1946, (304) 233-2223, FAX (304) 233-2258.
Reader Service #103

■ POLYDAX
The High Definition Aerogel (HD-A) in Polydax's new line of drivers results in an ultralight, extremely rigid cone that maximizes internal damping. The HD-A family contains three models, each of which features a nonresonant diecast Zamak chassis, high-loss, high-compliance rubber suspension, flat edgewound copper-wire voice coil, Kapton voice-coil former, and gold-plated terminals. Polydax Speaker Corp., 10 Upton Dr., Wilmington, MA 01887, (508) 658-0700, FAX (508) 658-0703.
Reader Service #101

Ω MCM ELECTRONICS
Thanks to expansion of its lines of computer and cellular products, plus the introduction of a selection of appliance-repair parts, MCM offers more than 1,000 new items to its customers. The latest edition of its catalog—which MCM will distribute free—contains 248 pages and lists more than 20,000 electronic parts and components. MCM Electronics, 650 Congress Park Dr., Centerville, OH 45459-4072, (513) 434-0031, FAX (513) 434-6959.
Reader Service #104

⊃ CELESTION
Celestion's new CSW Shield Active Subwoofer is fully magnetically shielded, and can be placed near a video monitor—or even, thanks to its low-profile design, *inside* many TV stands, monitor carts, and the like. The CSW's integral active two-way electronic crossover fully serves both input/output sets, and its fixed 100Hz high-pass return maximizes subwoofer/satellite integration for clear, uncolored midrange and fully realized imaging precision and depth. Celestion Industries, Inc., 89 Doug Brown Way, Holliston, MA 01746, (508) 429-6706, FAX (508) 429-2426.
Reader Service #105

℧ BULLFROG
Bullfrog's trapezoidal speaker systems, designed for small bands, DJ playback, on-stage monitoring, or sound-reinforcement applications, simplify installations in small spaces. All except the subwoofer cabinets feature titanium compression drivers, and each speaker is shielded by a 16-gauge grille. Bullfrog's own fiberglass constant-directivity high-frequency horns provide consistent dispersion. Bullfrog, Inc., 1503 Prairie Ave., South Bend, IN 46613, (616) 695-5948, FAX (616) 695-7623.
Reader Service #107

■ NORTH CREEK
Originally written to supplement North Creek's own kit manuals, the *North Creek Music Systems Cabinet Handbook* has evolved into a set of guidelines for designing and constructing exceptional cabinets for loudspeaker systems in general. The second edition (© September 1992) is now available. North Creek Music Systems, Rte. 8, PO Box 500, Speculator, NY 12164, (518) 548-3623.
Reader Service #102

Ω POLYDAX
The powerful, versatile TWO14R1 tweeter, newly introduced by Polydax, offers quick transient response with accuracy and precision. A Titanium composite diaphragm increases the dome's stiffness, and direct-drive technology couples the ferrofluid-cooled voice coil directly to the radiating diaphragm, optimizing the transfer of energy from electrical to the transmission of sound. Polydax Speaker Corp., 10 Upton Dr., Wilmington, MA 01887, (508) 658-0700, FAX (508) 658-0703.
Reader Service #106

■ KOSS
Koss has announced the expansion of its Hard Drivers line of computer speakers. The HD/100 and HD/50 now include microphone and headphone jacks, and all five speakers can be attached to Koss COM/10 computer speaker hanger to provide extra work space. All Hard Drivers are magnetically shielded to guard against data loss or monitor discoloration. Koss Corp., 4129 N. Port Washington Ave., Milwaukee, WI 53212, (414) 964-5000.
Reader Service #110

Good News

PSB INTERNATIONAL

Two new subwoofer models broaden PSB's low-frequency offerings. The PSB Subsonic III, designed for the most demanding audio and audio-video systems, boasts 180W over its full operating range, dynamic abilities approaching the 500W range, and enormous current capability. The supercompact PSB Alpha Subsonic delivers generous low bass (-3 at 45Hz; effective range 40–100Hz) from very little power (15W/channel–80W/channel). PSB International, Inc., 633 Granite Court, Pickering, ON, Canada L1W 3KI, (800) 263-4641.

Reader Service #108

ESOTERIC AUDIO

Esoteric is now the sole North American distributor for the Aliante Series of loudspeakers by Acoustical of Italy. Model One, a compact full-range system, reflects European standards of high performance, superior design, and top quality. The enclosure design is a bass reflex with a rear-facing, aerodynamically designed port, with four terminations for biwiring. Custom-made 1" metal alloy dome, ferrofluid cooled; cabinet finished with solid Italian walnut. Esoteric Audio USA, 44 Pearl Pentecost Rd., Winder, GA 30680, (404) 867-6300, FAX (404) 867-2713.

Reader Service #111

FRIED PRODUCTS

The new Fried Signature Series includes the model R/5 three-way loudspeaker system and three two-way systems: the floor-standing A/5, the Q/5, and Beta V—"a small speaker with a big sound," Fried claims. All feature diffraction-reducing grilles beveled inside and out, with solid five-way gold binding posts. Fried Products Corp., 1323 Conshohocken Rd., Norristown, PA 19401-2707, (800) 255-1014, FAX (215) 277-4390.

Reader Service #113

KEF ELECTRONICS

A trio of competitively priced Q-Series loudspeakers brings KEF Electronics' Uni-Q™ driver technology within reach of budget-minded audio- and videophiles. The new compact Q10, the compact floor-standing Q30, and the floor-standing Q50 feature KEF's Uni-Q driver, with a high-output, wide-bandwidth soft-dome tweeter at the apex of a polypropylene-cone woofer. All three are magnetically shielded to prevent color distortion, even at close range. KEF Electronics of America, Inc., 89 Doug Brown Way, Holliston, MA 01746, (508) 429-3600, FAX (508) 429-3699.

Reader Service #112

BRIGHT STAR AUDIO

The Big Rock III isolation platform™, one of three new additions to Bright Star's extensive Isolation Series devices, incorporates Bright Star's patented method of using sand to create a high-mass, high-absorption environment. The 29-lb slim-line Little Rock II stacking pod™ provides both damping and shielding, and the foam-lined Padded Cell isolation chamber™, designed to house noisy pumps, buzzing AC conditioners, and the like, can be used in place of the original plinth on a Big Rock II. Bright Star Audio, 2363 Teller Rd. #115, Newbury Park, CA 91320, (805) 375-2629, FAX (805) 375-2630.

Reader Service #114

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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

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About This Issue

Guitar speakers can require backbreaking labor to move from one gig to another. **Len Moskowitz** thought long and hard about combining better bass in a smaller box, producing a practical, high-performance, lightweight device. Details begin on page 10.

If you have wondered about the all-important impedances scattered around your system and given up on finding their exact value since you don't own an expensive bridge, **J.L. Markwalter** has help for your plight. The math is relatively simple and the results gratifying. Upgrade your access to system facts by turning to page 18.

When your old cabinets turn out to be your wife's favorites, what kind of drivers can meet the upgrade challenge? **Charles Pike** turned to an unusual driver format on special offering from one of the larger mail-order dealers. His adventure in pleats is documented for your pleasure starting on page 20.

Marc Bacon, like many speaker builders, evidently starts having an itch to improve before he is 80% through a project. Thus the original Danielle, first set out here in issues 4 and 5 of the 1992 series, inspired a new incarnation dubbed Danielle II. The "bigger sister" of the original is fully detailed beginning on page 24.

Matt Federoff faces the demand for excellent sound in the worst of environments: out of doors or in large halls. The bass challenge is, of course, the quantity of air needed to deliver the low octaves in an oversize space. Matt's named his answer the Birdhouse, and one look at the its multivented face tells you why. The 15″ driver inside the dual-chambered format more than holds its own with the two horns comprising the rest of the system (p. 36).

Technology's refinements for more and more specialized uses continue to proliferate. If you began speaker building with the conventional slotted wood screw, speaker builders **Bob Spear** and **Alex Thornhill** have a primer on all that is new about screw devices commencing on page 42. **Bob Wayland** follows their act with a compendium on glue and wood-mating methods (p. 46). Don't miss a user's short report on his adventures with VMPS's larger subwoofer. **John Bundy**'s opinions begin on page 53.

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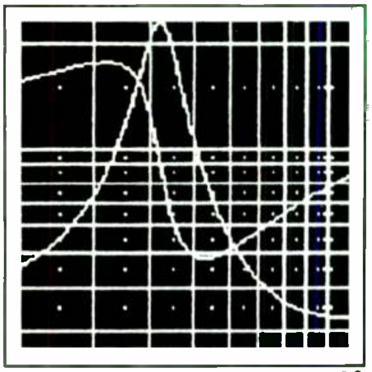

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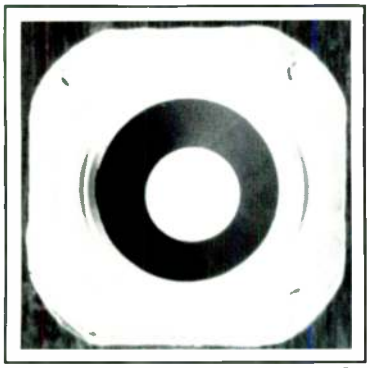

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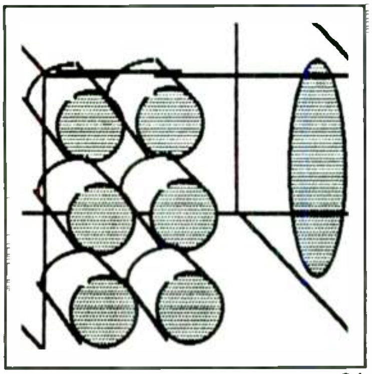

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DEPARTMENTS

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

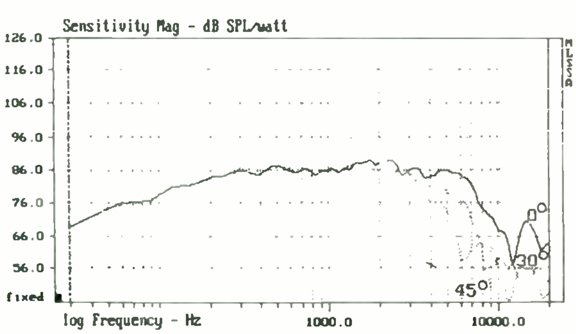
Specifications given are as after at least 45 minutes of high power, low frequency running, or 24 hours normal power operation.

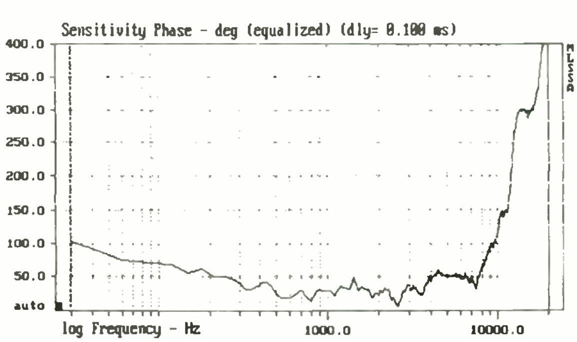
The 114-S is the first of Morel's new generation of woofers, featuring a powerful Neodymium magnet system which provides increased sensitivity, lower Qt and reduced distortion. For a 4" driver it is unique in having a large 54mm (2.125") diameter Hexatech aluminium voice coil.

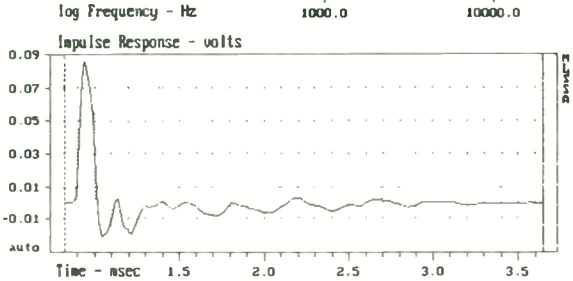
Benefits of this large voice coil diameter include a very high power handling capacity and lack of sound level compression. In addition, it allows the use of a very shallow cone profile. Coupled with the use of Damped Polymer Composite cone material and a rubber surround, this provides excellent dispersion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

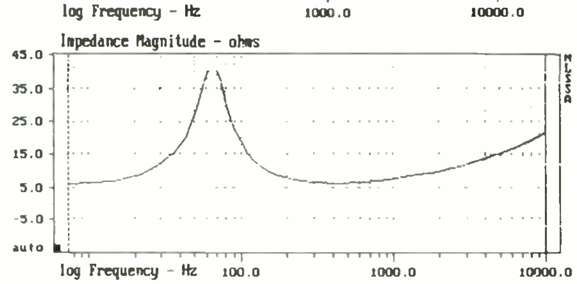
Frequency and phase response are very flat, while the roll-off is very smooth. The MW 114-S may be used either as a bass-mid range in 2-way systems, or as a mid-range in multi-way systems.

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.

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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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Editorial

Do We Need Postal Police?

One of the most serious frustration generators for a publisher is the US Postal Service (*sic*). Most readers of these magazines know by now that at least once a year I feel compelled by some circumstance or other to fire my popgun in the direction of the country's most inefficent, badly managed monopoly.

Monopoly? Yes, indeed. An 1872 law makes it a federal crime for any carrier other than the USPS to deliver a letter, unless it is "urgent." Now the USPS police are checking to make sure large companies that send letters overnight are acting legally. An Atlanta firm, Equifax, was recently fined $30,000 because the missives it sent for its clients didn't meet USPS standards of urgency. Other companies have also been fined for this grievous breach of the law protecting the Postal Service from competition.

Some of us might wonder why the courts, in their wisdom, dismantled a highly efficient, well-oiled monopoly and allowed a highly inefficient, bureaucratically managed monopoly to continue to exist—a monopoly that instead of doing its job properly, spends time and treasure harassing business people on the basis of a law that is 120 years out of date. Next we'll have USPS-badged snoopers knocking at our doors to have a look at our FAX logs. After all, FAXes are also letters, and presumably the burden of proof about their urgency would rest on the sender.

The power of FAX mail, either direct or through intermediate services, will surely also migrate to millions of home computers. With the price of an internal FAX/modem board now as low as $60—including software—it is reasonable to suppose that few will miss out on this convenience. You can send a message to Aunt Flo without leaving your den, and often for less than the cost of a postage stamp. Who will bother with paper, envelopes, stamps, and the postal system's glacial delivery pace?

Consider some other facts. The suicide rate among postal employees is one of the highest in any work group in the US. Thousands of postal workers are kept on "temporary," part-time status, sometimes for years, and work weekends and holidays without overtime pay. The USPS is supposedly no longer a government agency; but it appears that it can marshal the power of the government behind it when it chooses, while disdaining the rules the rest of us in business must observe.

Without incentives for the workers, and with bureaucrats making all business decisions, such an economy eventually fails: a fundamental premise of capitalism that was dramastically borne out by the collapse of the USSR. Why we continue to suppose that a government-subsidized agency with no profit motive, and little or no evident business sense, will provide the postal services this country must have is hard to understand.

The USPS attempts to compete with businesses like Federal Express and United Parcel Service but fails 23% of the time to fulfill its two-day Priority Mail service promises. I seriously question whether any business that uses delivery services today could survive if all we had available was the government's monopoly. Without alternative specialized, efficient, and competitive international delivery services, our deliveries to overseas customers would be far slower and more difficult.

We've had a lot of speculation about the coming of an electronic communications highway since the Clinton administration took office. I have no idea how much of our national communication has already shifted to electronic means, but in my small business the quantity of such interchanges increases almost hourly. As this happens in business generally, I suspect, the volume of what the USPS delivers will steadily decrease—just as its parcel business has. And rates will doubtless increase yet again, and again.

New Zealand recently privatized its postal system, with improvement in both service and efficiency. Britain is seriously considering privatizing the Royal Mail. Budget woes are causing numerous states and municipalities to consider privatization of many services, including such things as prisons. The basic flaw in any system run by bureaucrats is simple: a company executive checks the balance sheet for profit or loss; the bureaucrat checks the next year's budget to see whether it is larger or smaller.

We need an American, capitalist postal service that is truly a *service*, looking for ways to do a better job cheaper. We can no longer afford a bureaucratic anomaly left over from the 19th century, wallowing in its own ineptitude.—E.T.D.

A COMPACT BASS GUITAR SPEAKER

By Len Moskowitz

PHOTO 1: Front and side view of the cabinet.

I have been playing bass guitar since I was 11 years old. That makes it more than 25 years that I've been thumping away, holding down the bottom end of the rhythm section. Looking back I see the world has changed a lot during that period, but one thing has remained constant: bass guitar speaker bottoms are still huge, still weigh a ton, and are still a pain in the rear to haul around!

This realization struck me as good motivation to design a speaker bottom that was small and lightweight. But that wasn't all I wanted!

Most bass guitars have four strings, with the lowest being E_1 at 41.2Hz. Two recent developments are the five and six string basses, both having a low B string ringing out at 30.9Hz. My new bottom had to reproduce that low B cleanly.

In the old days, the star bass players like Carol Kaye and James Jamerson used dull sounding flatwound strings. They played through amps like the Ampeg B-15 Portaflex that had one 15″ driver in a too-small box, giving a pronounced peak in the mid-bass. This made bass guitars sound boomy and thumpy, and they lacked any significant frequency content above roughly 1kHz.

PHOTO 2: Front and other side view of unit.

Since the seventies, though, innovative bass players including Larry Graham, Sting, Geddy Lee, and Jaco Pastorius popularized techniques like slapping and popping, electronic effects, and the use of picks to increase definition and clarity. These pioneers favored roundwound strings that rang out brilliantly like a Steinway piano's low registers. My new speaker bottom had to reproduce that high end too.

Since I had to compete with guitar players playing stacks of Marshalls, this new bottom had to be reasonably efficient and loud. And finally, it had to be able to handle the roughly 200W of power that a standard bass amplifier like the Gallien-Krueger 400RB puts out. Oh, almost forgot: it couldn't cost an arm and a leg—just an arm.

"Well," I thought, "that should be a challenge!" And as you'll see, it was. Couldn't I buy a commercially made bottom that did what I wanted? Unfortunately, the answer was "no."

COMMERCIAL BOTTOMS

Perhaps the hottest ticket in small bass bottoms these days is SWR's Goliath Junior, a 3.4 $ft.^3$ box with two 10″ drivers and a horn tweeter. Eden's D210T and Peavey's 210TX have almost identical configurations and rival the SWR for popularity. Another popular manufacturer, Hartke, sells a bottom with two of their aluminum-coned 10″ drivers and no tweeter. Eden also offers another slightly more

ABOUT THE AUTHOR

Len Moskowitz is a systems engineer at Allied Signal Aerospace Company in New Jersey. He recently founded Core Sound, a company that builds and sells binaural microphones and digital audio distribution products. Len can be reached on Internet as moskowit@panix.com.

compact model, the D110T with one 10″ driver and a horn tweeter in a 2.6 ft.^{3} box.

All of these products have their F_3 down in the 60–80Hz region. They produce useful output down to the low E, but if you wish flatness you must equalize using electronics in either the bass guitar's on-board preamp or in the amplifier. If you yearn to reach that low B at performance sound pressure levels, expect to exceed the drivers' linear excursion limits and to encounter serious distortion.

Why don't these bottoms go lower? I've deduced that it's because their designers have chosen to trade off low-frequency extension for efficiency and power handling. To get efficiency, the designers chose drivers with powerful (and heavy) magnet structures. To get power handling they specified large/long voice coils and stiff suspensions. Both of these tend to raise a driver's f_S.

A 10″ driver with a sensitivity rated around 95dB (for 2.83V input measured at 1 m) and power handling above 200W will usually have an f_S well above 40Hz; an f_S in the 60s is common and some well regarded drivers are in the 90s. When I tried to find drivers that might offer reasonable response down into the 30s in a small box, I found that efficiencies were down in the low 90s or even the high 80s.

What about the high-frequency end of things? Hartke bottoms don't use a midrange or tweeter; they roll off severely above roughly 4kHz but still reproduce the bass guitar's overtones fairly well. SWR and Eden use horn tweeters and spec their systems up to 12 and 13kHz respectively. In my own critical listening I've decided that a bass bottom must reproduce frequencies up to roughly 5kHz; 7kHz is marginally better. Anything less than that and sound quality suffers. There's almost nothing coming out of a bass above that so there's little reason to go higher.

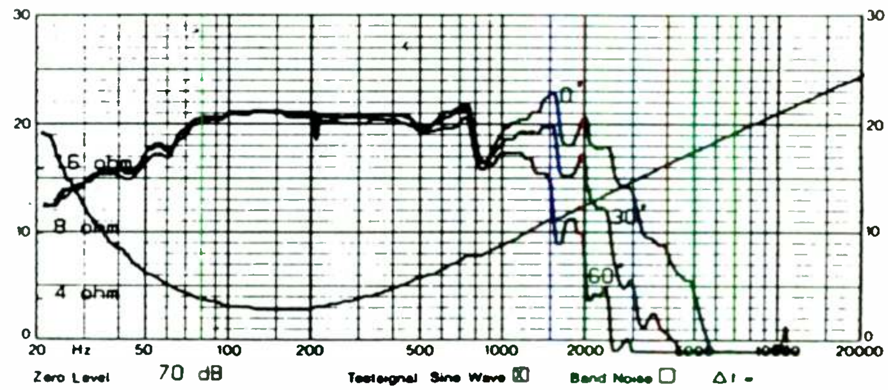

FIGURE 1: Peerless 1759 frequency response plot.

PICKING A WOOFER

I'd concluded that the manufacturers had the right idea in using a two-way design. A two-way keeps the complexity and component cost down. Also, professional usage tends to break things, so the simpler the better.

I first decided how big a box I was willing to lug around to rehearsals and gigs. I decided on 1.6 ft.^{3}, quite a bit smaller than even Eden's D110T. This prompted me to attempt to use a 10″ woofer; no 8″ woofer would be efficient enough at 30Hz and 12″ drivers would probably need a larger volume than the 1.6 ft.^{3}. So I did a survey of likely 10″ drivers using Warren Merkel's Perfect Box speaker system CAD software. (Perfect Box is shareware and available for download from Madisound's BBS and many Internet sites. If you use Perfect Box, don't forget to send some money to Warren.) I excluded drivers with foam surrounds based on my bad experiences with their very limited longevity.

The 10″ drivers specifically designed for musical instruments rolled off at far too high a frequency. That prompted me to broaden my search into auto sound and home audio drivers.

At first, a few auto sound drivers looked promising. One in particular, Stillwater Designs' Solobaric S-10, gave very good low-end response in small boxes along with outstanding power handling, but at the expense of efficiency (down below 87dB), impaired high-end response, and very high cost (over $200 retail per driver). I rejected other auto sound drivers for similar reasons.

Searching through the home audio offerings, I came across the Peerless 1759, a member of their premium CC line. The unit has an extra thick polypropylene cone, a rubber surround, good high-frequency response up to around 1kHz (*Fig. 1*), acceptable power handling (up to 220W maximum), a low f_S (22.4Hz), reasonable efficiency (91.4dB for 2.83V input at 1 m), and acceptable cost (commonly around $65). Also Peerless has a good reputation for consistency and quality. The 1759 is widely available from a number of distributors. I ordered mine from Madisound.

Perfect Box showed that with the 1759 in a 1.6 ft.^{3} fourth-order (ported) box tuned to 31Hz, I could expect an F_3 of 35Hz and an F_{10} of 24Hz (*Fig. 2*). At its 220W maximum power level it would put out a healthy 112dB SPL—not ear splitting but still seriously loud. And it would handle close to its maximum power down to below 30Hz. Pretty good so far.

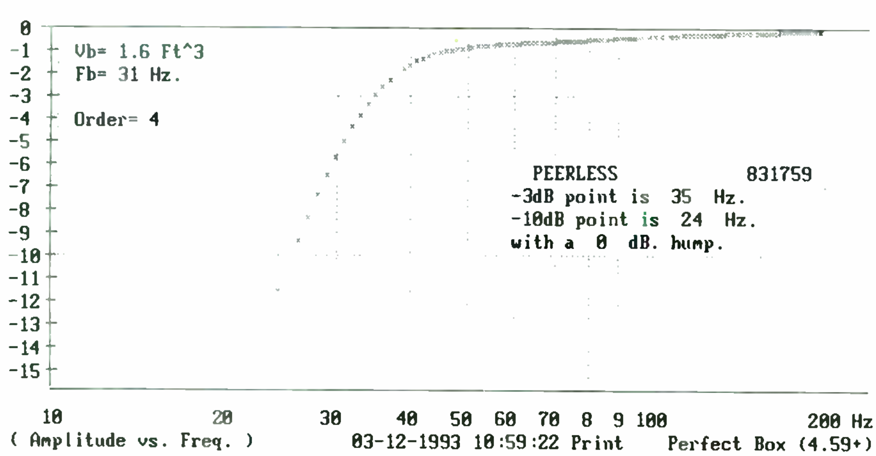

FIGURE 2: Peerless 1759 in ported 1.6 ft.^{3} box (Perfect Box).

EFFICIENCY

How did Peerless manage to give us a 10″ driver which goes low and is still reasonably efficient? One part of the answer is in the 1759's 4Ω voice coil. Based on how we measure efficiency, the 4Ω coil is an advantage. To understand this, let's take a little diversion into how efficiency is specified.

Ideally we'd like to be able to characterize efficiency with a single number for comparing drivers. The test procedures that produce the number should be standardized.

One way to standardize is to specify that the driver be stimulated with a known power

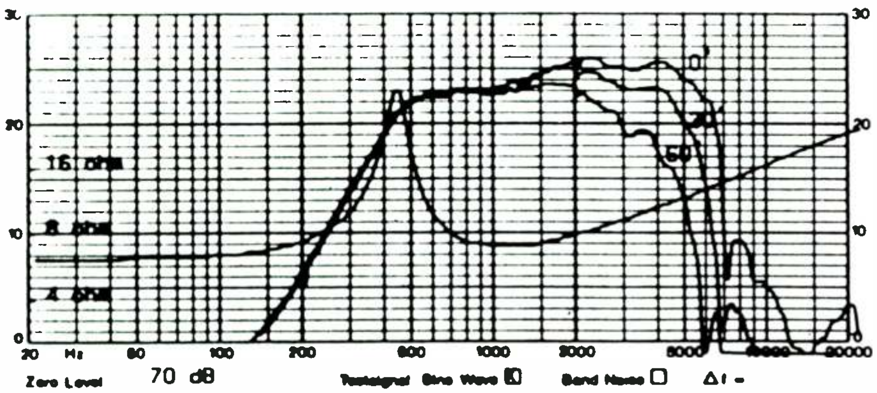

FIGURE 3: Peerless 1646 frequency response plot.

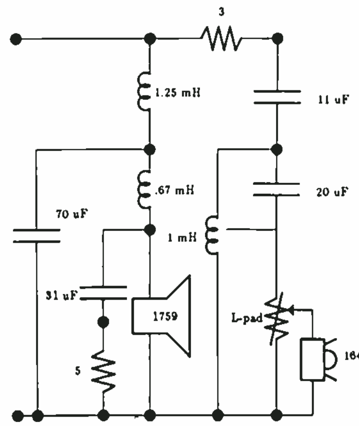

FIGURE 4: Crossover schematic.

(say 1W), and then to measure the sound pressure level at a fixed distance (say 1 m). If we could do this easily we'd have a convenient measure of comparison.

Unfortunately, to stimulate a driver with 1W, we need to know the driver's impedance. In the real world this isn't easy: at different frequencies the impedance varies. As the impedance varies, if we want to maintain the stimulus at 1W, the input voltage must vary. This gets complicated! It's easier to supply a stimulus that's a fixed voltage. Based on the assumption that most drivers are nominally rated at 8Ω, and that to produce 1W into 8Ω requires 2.83V, the standard practice became to use 2.83V as the stimulus regardless of the driver's actual impedance.

As a driver's impedance drops, that 2.83V input produces more than 1W. In fact, for a driver impedance of 4Ω, 2.83V produces 2W. So, if everything else is held constant and all we do is reduce a voice coil's impedance from 8Ω to 4Ω, we would add 3dB to its so-called efficiency rating.

The upshot is that when we reduce the voice-coil impedance we don't really increase the driver's efficiency at all, despite the higher "efficiency" number. All we do is make it possible to push more current through it for a given input voltage. But as long as our amplifier can provide enough current, the result is the same: we get a higher sound pressure level for a given input voltage. In many cases, modern amplifiers can source the current needed to adequately drive a 4Ω driver, so it makes sense to use one when we seek higher sound pressure levels. And I wanted high sound-pressure levels.

CHOOSING A MIDRANGE

The 1759 woofer starts trailing off at around 1kHz (*Fig. 1*). I required a midrange that could pick up there and carry the ball up to at least 5–7kHz. It had to be comparably efficient to the 1759. It had to be rugged and handle at least 100W. Its directivity pattern couldn't fall off too severely out to 30° off-axis, and it couldn't cost too much. Its resonance had to be at least an octave below my intended 1kHz crossover point.

Unlike the pro-audio designers, no self-respecting home audio speaker designer would use a piezo midrange (or tweeter), because of its unfavorable frequency response and directivity. But there are good reasons for its choice by many professional sound designers. Piezo drivers have a reputation for being nearly indestructible. They don't require much in the way of crossovers—a simple capacitor is often enough. They're also cheap.

Those considerations didn't enter into my choice. As a rule I think piezos sound terrible and I wouldn't think of using one in my new bottom. The deep-throated dynamic horns used in the SWR and Eden bottoms also sound rough to my ear.

In contrast, I've had particularly good experiences with treated fabric domes. A well designed treated fabric dome midrange can sound very good indeed. But domes are typically not very efficient and it takes special attention to design a dome driver that can handle high power.

Dome efficiency is typically in the high 80s. Their efficiency can be tweaked up a bit into the low 90s by using a short horn aperture to shape their directivity pattern. Dynaudio did this with its well-received D-28 tweeter and D-52 midrange. Power handling of more than 200W can be achieved if the design allows for adequate operating margins. I concluded that a well-selected midrange dome would live a long, healthy life in my new bass bottom.

Peerless had an appropriate driver, the 1646, to fit my requirements. It uses a 2″ treated fabric dome loaded in a short horn aperture resulting in a 93dB sensitivity rating and acceptable directivity. Its resonance is down at 454Hz and it's rated to handle 200W maximum. Its frequency response has a slightly rising character (*Fig. 3*) and is down roughly 3dB at 7kHz on-axis. At 30° off-axis its response at 5kHz is down around 4dB, rolling off severely from there.

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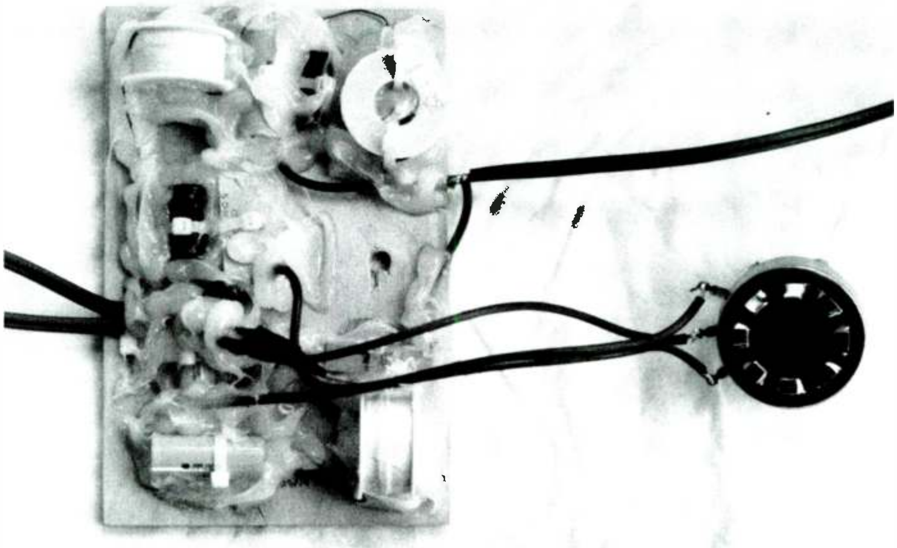

PHOTO 3: The passive crossover network assembly.

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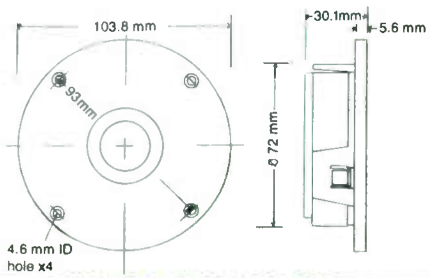
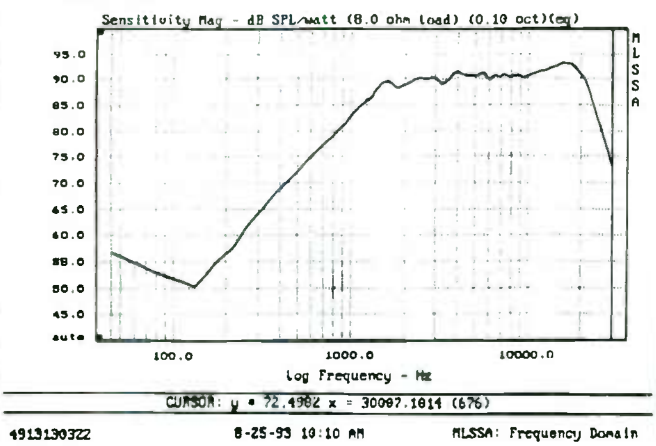
INTRODUCING SDT100-25/8F
SOFT DOME TWEETER



GENERAL INFORMATION			
Impedance	Z	8.0	.... Ohms
D.C. Resistance	Rdc	6.4	.... Ohms
Resonance Freq.	Fs	1600	.... Hz
Characteristic Efficiency Level	SPL	90.0	.. dB1W/1M
Power Handling	....	70.0	.... *W
Upper Frequency	....	20,000	.... Hz
Cone Material	Treated Fabric		
Surround Material	....		.... Supronyl
Total Weight	....	0.530	.... Kg
VOICE COIL			
Xmax	....		.... mm
Diameter	d	25.40	.... mm
Winding Length	h	1.72	.... mm
Layers	n	2.0	....
Former Material	....		.... Aluminum
Height of Gap	hg		.... mm
Inductance	....		.... mh
MAGNET			
Weight	....	0.227	.... Kg
Flux in Gap	0	0.292	.... mWb
Air Gap Energy	WL	130.0	.... mWs
Force Factor	BL		.... N/A
SUSPENSION			
Moving Mass	Mms		.... g
Mechanical Resistance	Rms		.... Kg/s
Suspension Compliance	Cms		.... mm/N
Emissive Diameter of Diaphragm	D		.... cm
Effective Piston Area	Sd	6.8	.... cm2

*Music Power



Guided by USA demands and European engineering, Versa-Tronics is proud to offer this fine tweeter. These guidelines have allowed us to introduce this exceptionally fine sounding dome tweeter. The latest in Ferrofluid technology and incorporation of the specially treated cloth dome allows for the finest in true uncolored, transparent sound along with an excellent response.

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Continued from page 12
I bought one from Madisound. It sounded good. I'd found a winner.

CROSSOVER

Then came the problem of designing an appropriate crossover for the two Peerless drivers. At first I considered bi-amping using an active 24dB/octave Linkwitz-Riley crossover, as I do with my Marchand crossovers in my home audio system. I discarded that idea because of a higher luggage load with the additional electronics. Another alternative was to omit a crossover, instead providing direct inputs for each driver. Many popular bass amplifiers, including the Gallien-Krueger 800RB, SWR 400, and Hartke 7000, provide built-in active crossovers and bi-amplification which could be a workable design choice. But then I would be unable to control the crossover points and the steepness of the rolloff. That could spell reliability and sound quality problems. Finally I decided to use a conventional passive two-way crossover.

In order to reduce interaction between the two drivers in the audibly critical crossover region I needed a high-order crossover with its attendant steep slopes. To keep the midrange driver away from its resonance region also dictated that I use steep slopes. In the end I chose an 800Hz crossover point and 24dB/octave acoustic slopes for both sections of the crossover.

I didn't have adequate resources to do the design so I asked Larry Hitch at Madisound to design it for me. Larry fired up LEAP, loaded the models for the two Peerless drivers, and came up with the circuit shown in *Fig. 4*. The crossover consists of an RC zobel impedance compensation network for the woofer, a resistor to lower the output of the midrange, and various LC networks to provide the high-pass and low-pass functions. The coils are all air-core types. The capacitors are a mix of film and nonpolarized electrolytics. The resistor is a sandblock type. I added an L-pad to the midrange for level control.

The whole system's projected acoustic response at crossover is shown in *Fig. 5*. (This plot isn't accurate for projecting low-frequency cutoff in the box I used.) Overall efficiency is roughly 90dB. (The impedance plot is shown in *Fig. 7*.) The project continued to look very promising.

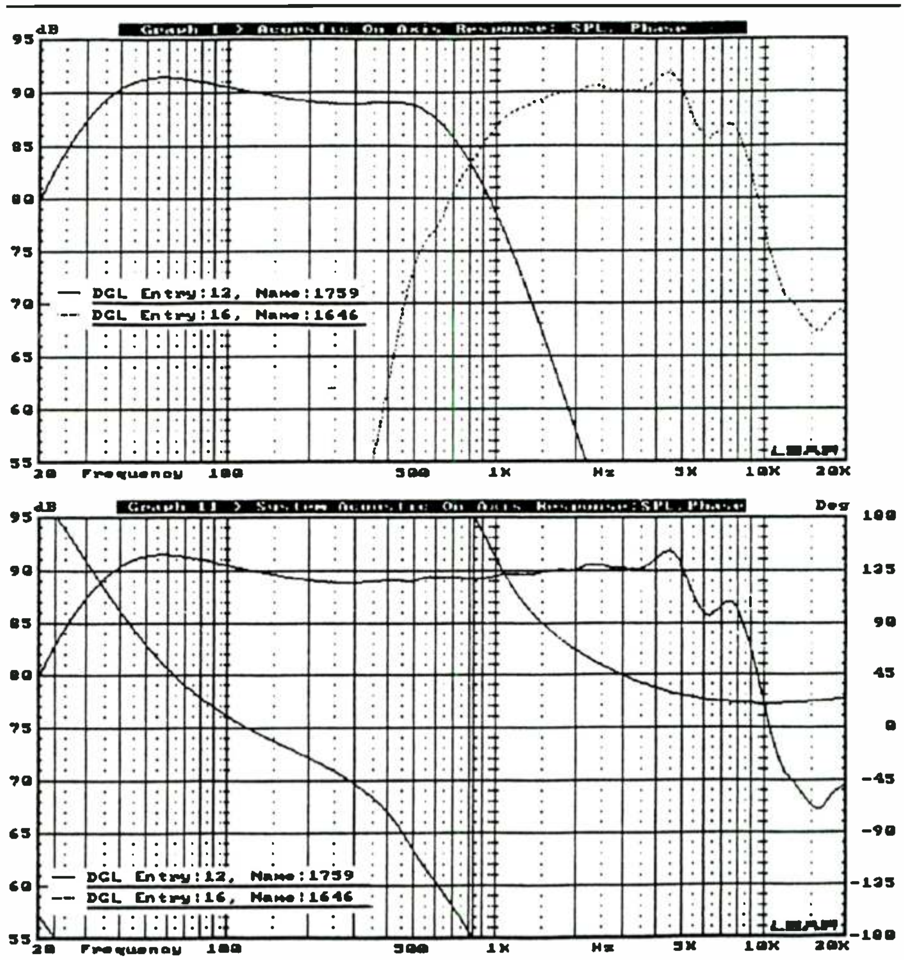

FIGURE 5: Predicted system frequency response at crossover (LEAP). The top graph shows the frequency division; the bottom graph shows the combined response and phase characteristics.

CONSTRUCTION AND MATERIALS

I made the box from ¾″ MDF using six panels and two small trim pieces. The dimensions of the pieces are shown in *Fig. 6*. For lightness, I originally contemplated vacuum pressing the cabinet panels from foam/epoxy glass as I'd done for the shell of an incomplete previous project, but decided that the focus of this project was the electronics and the cabinet's form factor—not light weight. I decided to accept MDF's weight penalty in exchange for ease of fabrication.

I assembled the cabinet using slow-setting (three hours) epoxy glue, holding the box together in the interim with three Pony #94 framing clamps. These clamps, made from long threaded rods and filled-nylon corner pieces, are indispensable for box builders. They're available from Albert Constantine and Sons in the Bronx, New York, and Leichtung DRI Industries in Warrensville, OH. After assembling the box I caulked the inside joints with Liquid Nails, a thick construction adhesive applied with a caulking gun.

I mounted the crossover elements on a piece of ¼″ aircraft-grade plywood. The components were mounted to the plywood using nylon ties and silicone caulk. Once the crossover was wired I installed it in the bottom of the cabinet using Liquid Nails. The completed crossover is shown in *Photo 3*.

After letting the adhesives set for a few days, the drivers were mounted using bolts and T-nuts with a bead of Mortite between the drivers and the baffle. I trimmed the 1646's plastic bezel slightly on two sides to fit the baffle. *Photo 1* shows the mounted drivers and the trimmed bezel.

FINISHING TOUCHES

These days most bass guitar bottoms are covered with synthetic carpet; one common brand is Ozite. I dislike the way that stuff feels and decided not to use it, though admittedly it does wear well and also damps panel vibra-

Continued on page 16

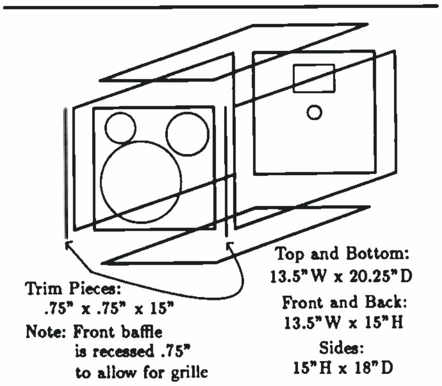

FIGURE 6: Cabinet part dimensions. Front baffle is recessed ¾″ to allow for grille.

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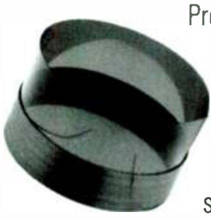

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DUPONT

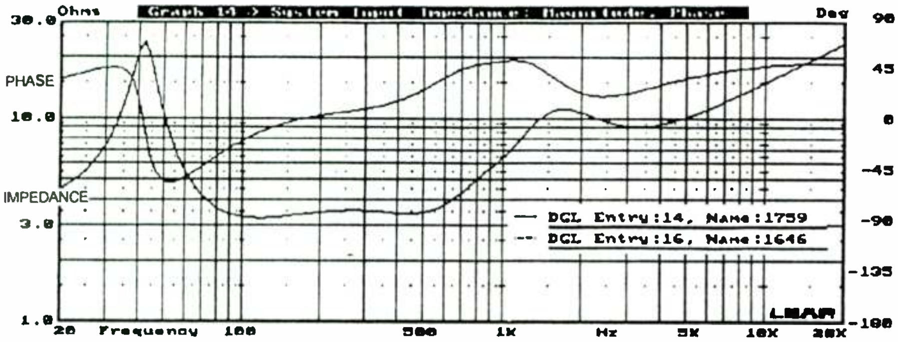

FIGURE 7: Impedance plot.

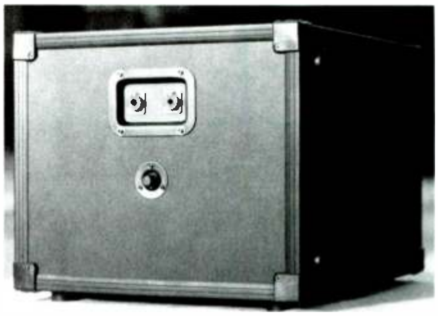
PHOTO 4: Rear view of the cabinet with connectors and level control.

Continued from page 14
tions. In comparison, the old fabric-backed vinyl material long used by amplifier manufacturers (Tolex was one brand Fender used), doesn't wear well at all.

I prefer a hard finish and chose to cover the MDF with Kydex, a long-wearing, textured sheet plastic. Kydex is harder and more durable than the ABS laminate sheeting commonly used on flight and road cases. I selected black but it's available from many major plastics distributors in many other colors. I glued it to the MDF with Weldbond contact cement, available at most hardware stores.

I filled the box with 1½ lbs of polyester pillow stuffing (roughly 1 lb/ft.^{3}) spread loosely within it. The stuffing adds to the apparent volume of the box and makes up for the volume lost to the driver's basket.

The port is a flanged 2¾" inside-diameter plastic duct, available from many sources. I got mine from Penn Fabrication; Parts Express and MCM Electronics have a similar part. My port's final length is the stock 5¼" long.

I mounted the crossover's L-pad to a small black steel cup set into a hole in the rear panel. A Radio Shack knob fits over its shaft. The 100W L-pad came from Madisound and the mounting cup is available from Umbra (part number 7005). I mounted the cup in the cabinet wall with cap screws, washers, T-nuts, and a bead of Mortite.

Most speaker bottoms use standard Switchcraft ¼" phone jacks on their connector plates. Having had my cord pulled out of the bottom more than once, I decided to fix that problem. I used two of Neutrik's ¼" locking phone jacks and mounted them in a steel cup I bought from Penn Fabrication (part number D0601K). I also mounted the cup just as I did for the L-pad. The cup had to be filed slightly to fit the Neutrik connectors, which provide a solid, secure electrical and mechanical connection. I also used their phone plugs to make a cable with which to connect the speaker bottom to my amplifier.

All of Neutrik's connectors are gorgeous, high-quality products. I bought the Neutrik locking jacks and phone plugs from my local Sam Ash Music in Paramus, New Jersey. Since the jacks can be a source of air leaks, be sure to fill any open ones with an unwired plug. You can see the Neutrik jacks, the cup, and the level control in *Photo 4*.

Handles are another of my bugs. I've had to lug speaker bottoms up unbelievably long flights of stairs and if I never see a cheap plastic well handle (the kind that is sunk into a hole in the cabinet), it won't be too soon. The plastic simply doesn't hold up under


PHOTO 5: Finished unit with custom grille in place.

heavy use. The metal ones, similar to the spring-down handles you see on flight cases, are nice (J.H. Sessions makes a standard one) but they require a large hole in the cabinet. This cabinet is small enough that I wanted to avoid compromising its structural integrity with too many large holes.

For medium-sized cabinets I've found that strap handles (*Photo 2*), as used on the older Fender amplifiers, look good and work well. They mount with two bolts and T-nuts and last forever. The model I chose is made from flexible vinyl that is reinforced internally with a steel strap. I chose an all-black model available from Umbra (part number 0312).

Like the musicians they work for, speaker bottoms travel a lot and are subject to a world of abuse. If you want them to live a long productive life, you must protect them. That means they must have edge and corner moldings. A bewildering variety of molding choices are out there. I chose a simple ¾" plastic edge molding and a coordinated corner molding. The edge molding slides into the corner molding making a neat and well-protected junction.

The corner moldings come in two styles: one with three complete surfaces for the speaker bottom's rear corners, and one with one surface cut away for the front baffle. I used four of each. The moldings are available from Umbra (part numbers 3144, 1402/1403). The edge moldings were glued on with contact cement while the corner moldings were held in place with ¾" black drywall screws.

In some performance venues (a rowdy bar, for example), if the musicians could choose to work behind a wall of steel protection, they would. Speakers' drivers need protection too. I used a perforated black steel grille. The grille has ⅜" holes and is sized to fit into the cabinet's front baffle area. The edges are folded over for ¾" on all four sides to provide stiffness. The grille is held down with five 1/4-28 black bolts, rubber stand-offs, and T-nuts. I specified the grille's dimensions to Umbra (part number 7300/7301); they cut and folded the grilles to order.

When I put my speaker bottoms down I expect them to stay put. To make that happen I mounted four large (1¾") rubber feet each on the bottom and the side opposite the handles, for a total of eight. These are reinforced internally with steel washers and mounted with bolts and T- nuts. They too are available from Umbra (part number 1606).

SUMMARY

This bottom cooks! When it comes to low frequency extension and overall sound quality, it easily outperforms every commercial bottom I've ever played. It solidly reproduces the low B on a five-string bass and also gives crystal clear highs. It won't blast you deaf but it is seriously loud; if you need even higher sound pressure levels you can simply use more than one bottom. The unit is easy to build, attractive, and promises to be durable. And lastly, it's very small (*Photo 5).*

In using MDF for the cabinet I decided on ease of construction in lieu of light weight as a goal. The completed cabinet weighs 48 lbs. By comparison, an Eden D110T weighs 42 lbs; a D210T weighs 60 lbs, as does the SWR Goliath Junior.

The materials cost of the speaker is modest. The drivers and crossover cost roughly $125. The accessories (moldings, jacks, handles, grille, hardware, and cups) add another $50 or so. The MDF, Kydex, adhesives, and Neutrik jacks add another $50 or so for a total material cost of roughly $225. For comparison, a good price for an Eden D110T is more than $325.

My goal for this bottom was to design and build a compact, relatively lightweight, reasonably efficient speaker bottom that could reproduce the full range of a five string bass without electronic equalization. Most important, it had to sound good. I believe I succeeded on all counts. I hope if you build this speaker that you'll enjoy it as much as I do.

SOURCES

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MEASURING SPEAKER IMPEDANCE WITHOUT A BRIDGE

By J.L. Markwalter

You don't need a bridge to measure the complex impedance of a loudspeaker or similar device. That's right. You can make the measurement while the device is in operation and you're not restricted to a single frequency, as you are with many impedance bridges. This is particularly desirable for loudspeaker work, since complex impedance data are needed over a wide range of frequencies to permit the proper design of crossover and impedance stabilization networks.

This method requires only a power resistor of an accurately known value, an AC digital voltmeter, a pocket calculator capable of handling trigonometric functions, a power amplifier, and an audio oscillator. The approach is known as the three voltmeter method, an old scheme used for measuring power transformer impedances.[1]

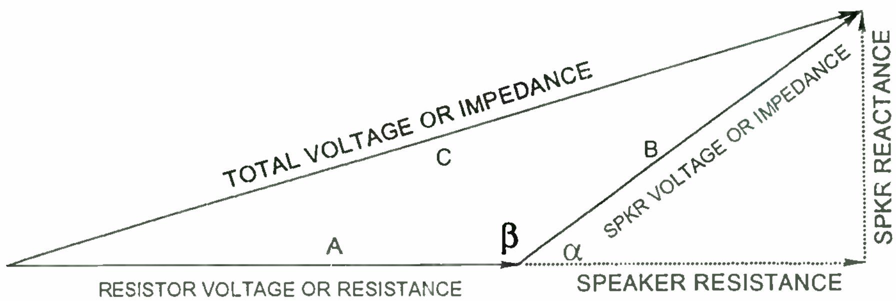

FIGURE 1: Vector diagram of measured voltages and derived speaker resistance and reactance.

THREE VOLTAGES

The device under test is operated in series with the resistor. You make voltage measurements across the resistor, across the speaker, and then across the two in series. If the speaker impedance is complex, as is generally the case, the voltage across the combination will always be somewhat less than the arithmetic sum of the other two voltages. The R and jX components of the impedance are determined trigonometrically from the three voltages read.

The vector diagram (*Fig. 1*) shows the relationship of the three voltages. Let A represent the resistor voltage; B, the speaker voltage; and C, the voltage across the series combination. Since this is a series circuit, the voltage across each of the two circuit elements and across the total is proportional to the respective impedance. Conversely, the impedance of each circuit element is proportional to the voltage drop across it. The impedance value (resistance) of only the resistance leg is known at the outset; thus, the speaker impedance is scaled from it.

COLDLY CALCULATING

You should first employ the law of cosines to calculate the obtuse angle β in *Fig. 1* using the three voltages, as follows[2]:

$$\cos\beta = \frac{(A^2 + B^2 - C^2)}{(2 \times A \times B)}$$

The speaker vector impedance magnitude B is that scaled from the resistance vector A above. The impedance angle is 180° - β; we designate it as angle α. The resistive component of the impedance is magnitude B × cosine α; the reactive component is magnitude B × sine α.

Here's a hypothetical example. Let's let:

Resistor voltage A = 2.031
Speaker voltage B = 1.811
Total voltage C = 3.617
Resistance = 10.07Ω

Thus:

$$\cos\beta = \frac{(2.031^2 + 1.811^2 - 3.617^2)}{(2 \times 2.031 \times 1.811)} = -0.7719$$

And:

β = 140.52

Next, you determine the speaker impedance magnitude by scaling the resistance value in proportion to the speaker voltage relative to the resistance voltage, as follows:

$$\text{Speaker impedance} = 10.07 \times \frac{1.811}{2.031} = 8.98\Omega$$

The speaker vector impedance is the magnitude just calculated, at angle α, which is 8.98∠39.48° Ohms. When you resolve the vector impedance into its components, you find:

$$\text{Speaker resistance} = 8.98 \times \cos 39.48° = 8.98 \times 0.772 = 6.93\Omega$$

$$\text{Speaker reactance} = 8.98 \times \sin 39.48° = 8.98 \times 0.636 = j5.71\Omega$$

If you wish, you can calculate the voice-coil inductance from the reactance, by using:

$$\text{Inductance} = \frac{\text{Inductive reactance}}{(2 \times \pi \times f)}$$

For example, if the above inductive reactance were 5.71Ω and were measured at 1kHz, the inductance would be:

$$\frac{5.71}{2 \times 3.1416 \times 1k} = 0.000909 \text{ Henry} = 0.909\text{mH}$$

INSIDE IMPEDANCES

The derivation of complex impedance values from the three measured voltages, although accurate, does not provide identification as inductive or capacitive. I drew the vector diagram while assuming the speaker impedance to be inductive in accordance with the CCW vector rotation convention. In loudspeaker measurements, the reactive component is usually positive (inductive) due to the voice-coil inductance.

However, the motional impedance induced in the voice coil can have a negative component (capacitive) which tends to cancel, or even dominate, the voice-coil self-inductive reactance. If the speaker impedance had a capacitive reactive component, vector

ABOUT THE AUTHOR

J. Laurence Markwalter graduated from Georgia Tech with BS and MS degrees in electrical engineering. He is a retired electrical/electronics engineer, a Life Senior Member of the IEEE, a member of the Audio Engineering Society, and a registered professional engineer in the State of Maryland. He is presently a part-time instructor in physics at the Anne Arundel Community College, Arnold, MD. His hobbies are photography and building hi-fi projects.

B would point downward and the reactive component be directed down instead of up.

The voice-coil terminal impedance is the sum of voice-coil resistance, voice-coil inductive reactance, and the motional impedance resistive and reactive components. Motional impedance is the mathematical result of the product of the voice-coil gap magnetic flux density × the length of voice-coil wire in the field; then that product squared; then that product divided by the total mechanical impedance on the voice coil, as follows[3]:

$$\text{Electrical impedance} = \frac{(B \times L)^2}{\text{Mechanical impedance}}$$

The mechanical impedance is complex in general. The reactive component of it may be a mass or compliance (the reciprocal of stiffness). If the speaker is mass-controlled, the reflected component of the motional impedance will be negative (capacitive), tending to cancel the self-inductive reactance of the voice coil.

Likewise, if the speaker is stiffness-controlled, the reflected reactance will be positive (inductive), adding to the voice-coil inductive reactance. In most cases the motional impedance is much smaller than the voice-coil self-impedance and no net change in the kind of reactive term will occur.

A simple test to determine whether the measured impedance is inductive or capacitive is to touch a nonpolar capacitor across the voice-coil terminals and observe whether the voltage increases and the resistor voltage decreases at the same time. If it does, the speaker impedance is inductive at that frequency. Conversely, if the voice-coil voltage decreases and the resistor voltage increases, the speaker impedance is capacitive. The capacitor value will have to be fairly large to obtain an observable change, possibly 20μF or more for low frequencies.

FINAL NOTES

Let me close with some additional general comments on speaker impedance measurements. Always be sure your speaker driver is mounted in its intended enclosure. Voltage data should be taken, and reduced, for frequencies spaced over the intended operating range. At least several frequencies should be close to the crossover frequency, both above and below.

There may be instances where the sum of the resistor voltage (A) and speaker voltage (B) virtually equals the total voltage (C). This indicates the speaker impedance to be a pure resistance, or nearly so; consider the reactive term to be zero. If voltage C appears to be greater than the sum of A and B, the calculated cosine would be greater than one, an impossibility. If the sum appears to be only slightly greater than one, say –1.02, there is probably a slight instrument error and β should be considered 180°.

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2. *Standard Mathematical Tables*, 23rd ed., CRC Press, p. 236.
3. Olson, H.F., *Acoustical Engineering*, Van Nostrand, 1957, p. 126. Available as BKPA1 for $49.95 plus $3 S/H from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458; (603) 924-6526; FAX (603) 924-9467.

THE DYNAPLEAT

By Charles T. Pike

After reshuffling my loudspeakers for the umpteenth time recently, I had two enclosures left over, each 48" tall by 8.5" wide by 13" deep. My wife asked casually what I was going to do with them and I said that I would probably store them in the crawl space under the house or throw them out. (I did not mean this, but I thought it would please her.) She replied that these were her favorite enclosures (news to me) and that it would be a shame to discard them.

A word to the wise usually being sufficient, I started pondering how the cabinets might fit into my system. I quickly realized that I desperately needed a new pair of rear-channel speakers for my surround system and these cabinets, fitted with some full-range drivers, would fill the bill perfectly.

Parts Express offered some interesting full-range flat-panel speakers, I vaguely remembered. I dug out my catalog collection and there it was: "6 in.^{2} full range.... Unique 'Dynapleat' construction offers exceptional sound image localization. Frequency response: 100–15kHz, 4Ω impedance. Power handling: 35W RMS, 50W maximum. SPL: 84dB 1W/1m." Could this be audio nirvana for $10.50? I called and ordered twelve of the drivers, sight unseen, then sat back for several weeks of impatient waiting and speculation about their construction.

When they arrived I was pleasantly surprised to find that they are true area drivers. The construction is similar to the pre-World War II "Blatthaller" loudspeaker McLachlan describes in *Loud Speakers,* except that a multiturn voice coil replaces the single conductor and of course permanent magnets replace the electromagnet.[1]

Figure 1 is a cross-sectional view showing loudspeaker construction. The diaphragm is molded with long, narrow pleats and the voice coils are wrapped around the pleats. Eleven bar magnets are mounted on the back plate, centered in each pleat. The back plate is slotted and covered with a fibrous material that provides acoustic resistance to lower the Q.

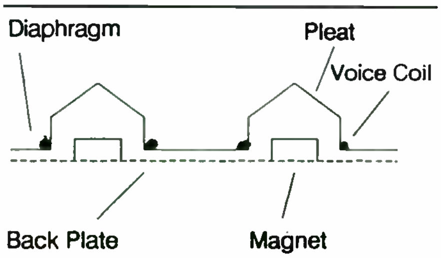


FIGURE 1: Cross-section of Dynapleat loudspeaker.

Figure 2 is an impedance curve of one unit, which was used to calculate a Q_{MS} of 0.8 and a Q_{ES} of 2.2, using the method described by Dickason.[2] These numbers appear reversed from typical values for standard moving-coil drivers because of the large air gap between magnets, which results in a relatively weak magnetic field and the acoustic resistance mentioned above (which lowers Q_{MS}). The V_{AS} was measured to be 19 liters from the rise in resonant frequency that occurred when the speakers were installed in the cabinets.

DESIGN

Figure 3 shows the low-frequency response calculated using "Quick Box." Since the

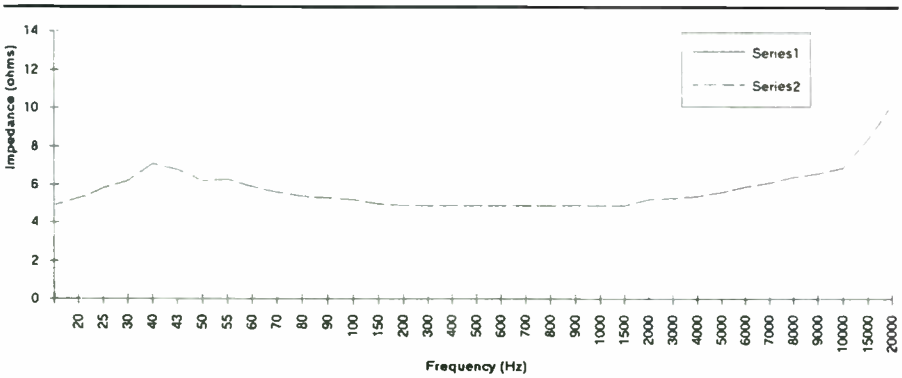


FIGURE 2: Impedance versus frequency for a single Dynapleat driver.

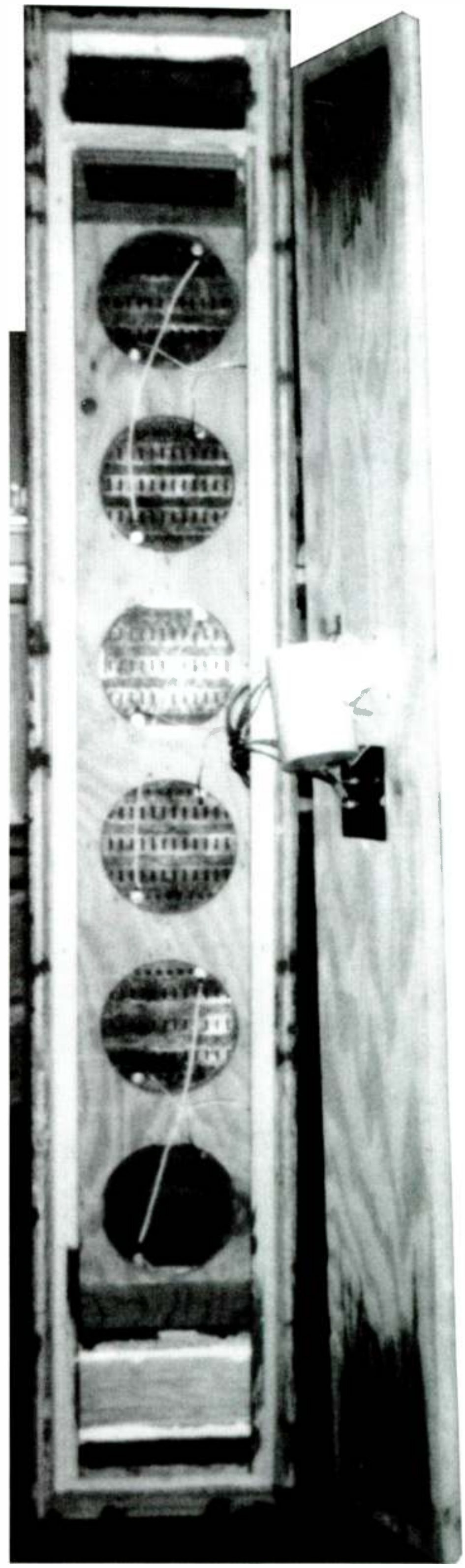
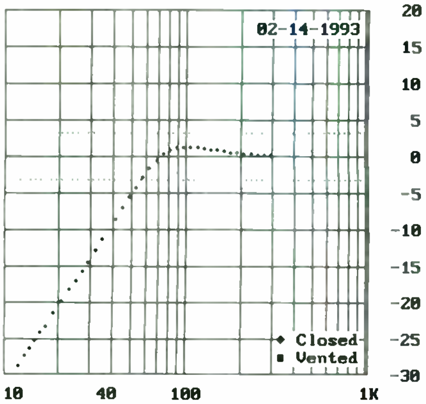


PHOTO 1: Rear view of system before stuffing.

ABOUT THE AUTHOR

Charles Pike has been a music lover and audio enthusiast for 40 years, during which time he has designed and built his own loudspeakers and amplifiers. His favorite music, he tells us, is baroque and classical. He holds an MS in physics from Fairleigh Dickinson University, and spends his time professionally designing lasers for military applications.



Closed Box Design

Alpha	2.11
Fs	43.0 Hz
Fc	75.0 Hz
F3	57.0 Hz
Qts/Qtc	0.59/ 1.00
Rg	0.2 ohms
Vb	9.0 Liters
	0.3 Cu.Ft.
	549.2 Cu.In.

FIGURE 3: Frequency response of Dynapleat driver in 9-liter box calculated using "Quick Box."

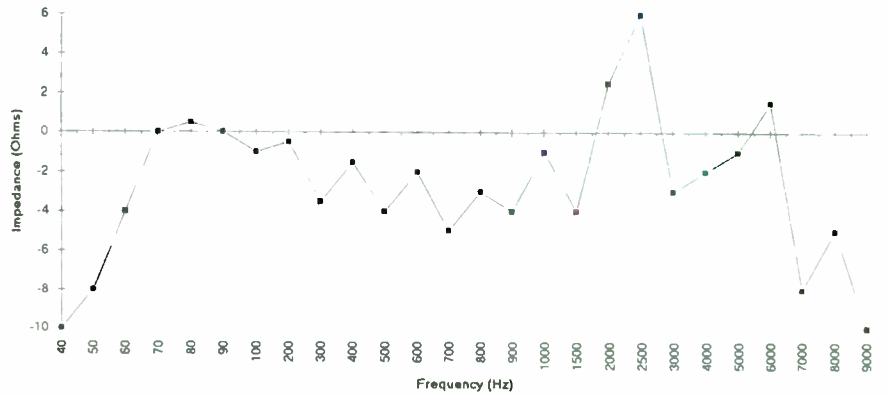


FIGURE 4: Initial frequency response of Dynapleat drivers in cabinet.

speakers were to go into an existing cabinet, it was fortunate that the low-frequency response was only about 1dB up at 100Hz, which I find acceptable. The low-frequency cutoff is about 60Hz, which is adequate for all but the lowest frequencies.

Figure 4 shows the frequency response of the system with six Dynapleat units mounted in the 54-liter-volume cabinets described above, using a Radio Shack sound-pressure-level meter located 3–4″ from the speaker diaphragm. No data is shown above 7kHz because the meter rolls off at this frequency. The data at high frequencies may be subject to question because of cancellation that may occur due to the diaphragm size. A transverse scan of the diaphragm, however, with the meter located 1/8″ from the surface, indicated that the emitting area is only about half the width of the diaphragm at high frequencies. Therefore, I believe the measurements to be valid. The large peak at 2.5kHz is a resonance in the drive units and the smaller peaks mostly indicate cabinet resonances.

A trap circuit, consisting of a 60μF capacitor and a 70μH inductor in parallel, was designed to eliminate the peak at 2.5kHz. *Figure 5* shows the calculated response of the trap circuit, using the Microcap III circuit-analysis software.

CONSTRUCTION

For the cabinets I constructed a simple box to the dimensions given above, using 3/4″ plywood. (Plywood can easily be stained to give a reasonably acceptable appearance.) I used glue blocks only to support the removable rear panel. Wherever the screws show, I used brass for a better appearance. The original cabinets had ducted ports, which I blocked for use with the Dynapleat drivers. The final version of the system used three or four 4′ lengths of 3.5″ fiberglass 14″ wide to stuff the cabinets, most of it cut into 4″ cubes. I doubled over the final length and laid it on top of the rest of the fiberglass. In mounting the drivers I used wood screws to the front of the cabinet, with the long dimension of the magnets oriented parallel to the 48″ dimension.

Figure 6 is a wiring diagram of the system. Nine of the drivers had DC resistances of about 4.5Ω and three had resistances of about 3.5Ω. To make a symmetrical arrangement, I mounted the lowest-resistance drivers near the center of the array and the higher-resistance units at the outside. Any good-quality film capacitor should be satisfactory in the trap circuit; I used a surplus 60μF polyester type.

The inductor is approximately 2½ layers of number 18 magnet wire on a Radio Shack solder spool with a form diameter of 1 1/8″ and a length of 1 1/8″. (I buy the smallest quantity of solder available on these spools, remove the solder and save it, and use the spools for coil forms.) Larger-diameter wire is inappropriate for the inductor, because its approximately 0.1Ω resistance sets the Q of the trap circuit.

Wind a few extra turns of wire on the form and then measure the resonant frequency of the inductor in parallel with the capacitor, using an audio oscillator and an AC voltmeter and removing turns from the inductor until the circuit resonates at 2.5kHz. Connect one end of the inductor and capacitor that make up the trap circuit directly to one of the gold-plated five-way binding posts that were used for connectors.

Photo 1 is a rear view of the completed system before stuffing, showing the trap circuit connected to one of the five-way binding posts. *Photo 2* is a front view of the completed system.

MEASUREMENTS

Figure 7 shows the frequency response of the final Dynapleat system, measured with a Radio Shack sound-level meter and corrected using the frequency-response curve supplied

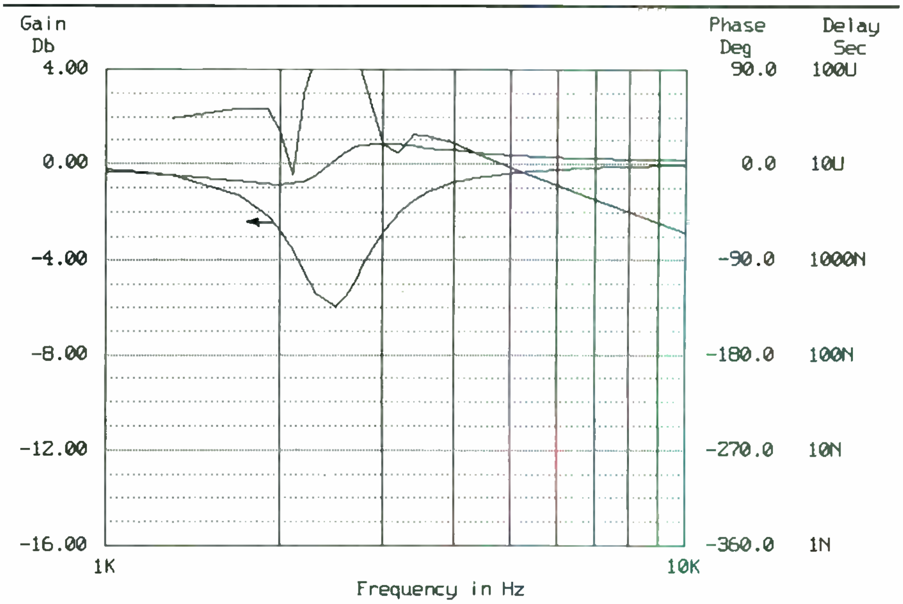


FIGURE 5: Calculated frequency response of trap filter circuit.

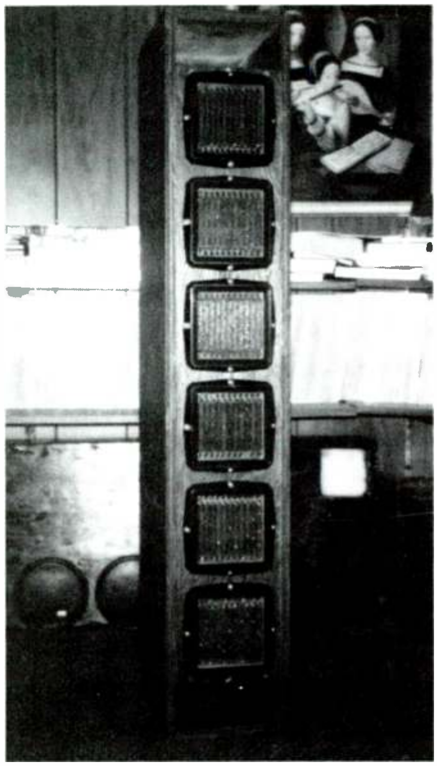


PHOTO 2: Front view of completed system.

with the meter. The large peak at 2.5kHz has been eliminated by the trap circuit and the smaller peaks have been suppressed by the increased fiberglass density in the cabinet, resulting in a very smooth response. Using an octave-band-spectrum analyzer, I made a rough measurement of response over the full spectrum to 16kHz. With the microphone 12" from the speaker response measured flat ±2dB to 16kHz.

SOURCE

Parts Express International, Inc.
340 E. First St.
Dayton OH, 45402-1257
(800) 338-0531
FAX (513) 222-4644

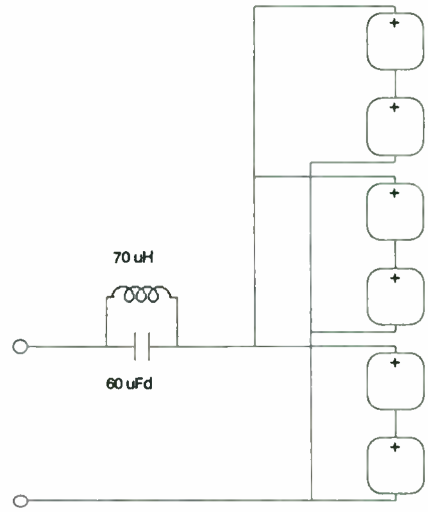


FIGURE 6: Wiring diagram.

LISTENING TESTS

Because of the large driver area the speakers are somewhat directional, and if they are pointed toward the central listening position the "stereo seat" becomes extremely narrow. If they are "toed in," however, so that the axis of the lefthand speaker points to the righthand side of the desired listening area and vice versa, stereo imaging is excellent over the whole area.

For listening tests, I used a JVC XL-Z1050TN CD player, a home-designed and -built preamplifier, and a 300W/channel power amplifier. The superb imaging of these systems was immediately apparent; I could pinpoint the location of each instrument and voice in the space between the loudspeakers. The frequency response is

Continued on page 70

REFERENCES

1. McLachlan, N.W., *Loud Speakers*, Dover Publications, 1960.

2. Dickason, V., *The Loudspeaker Design Cookbook*, Marshall Jones Co., Francestown, NH, 1987.

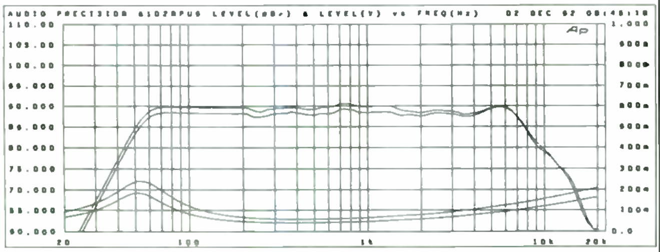
FIGURE 7: Frequency response of completed system.

Madisound 5102R
4.5" Polypropylene Bass-Mid 4 or 8 Ω

Rubber Surround

	5102-4	5102-8
Fs (Hz)	50	52
Rscc (Ω)	3.28	4.73
VcL (mH@1K)	0.09	.12
Qms	1.50	1.41
Qes	.32	.33
Qts	.26	.27
Mmd (g)	6.13	6.5
Cms (µm/N)	1508.44	1353.76
Vas (Ltrs)	8.77	7.87
Efficiency (2.83V / 1m)	90	87
Xmax	1.5mm pk	
Power	50 w	
Magnet	12 oz	
Voice Coil	1" 2-Layer Kapton	
Cone	Black Poly	
Surround	Rubber	
Cutout/Depth	4.25"/2"	
Price	**$20.00**	

	Vented		Sealed	
	4 Ω	8 Ω	4 Ω	8 Ω
VB ltrs	2.1	1.9	1.4	1.3
FB Hz	75	78	-	-
F3 Hz	90	95	134	137
Port Diameter	1"	1"	-	-



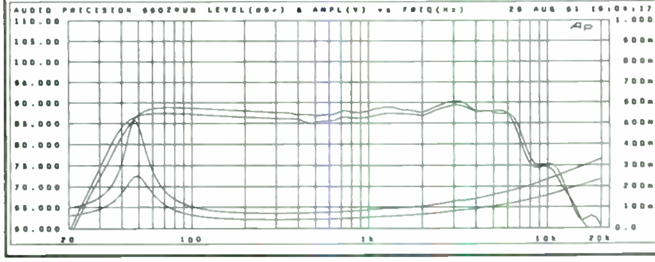
Madisound 5502R
5.25" Polypropylene Woofer 4 or 8 Ω

Rubber Surround

vented pole piece

	5502R-4	5502R-8
Fs (Hz)	48	48
Rscc (Ω)	3.64	6.53
VcL(mH@1K)	.391	0.576
Qms	2.89	3.98
Qes	.47	.52
Qts	.40	.46
Mmd (g)	7.68	7.01
Cms (µm/N)	1349.5	1473.1
Vas (Ltrs)	13.8	15.1
Efficiency (2.83V / 1m)	89	87
Xmax	2.5mm pk	
Power	50 w	
Magnet	12 oz.	
Cone	Black Poly	
Surround	Rubber	
Voice Coil	1" 2-Layer Kapton	
Cutout/Depth	4.87"/2.25"	
Price	**$25.50**	

	Vented		Sealed	
	4 Ω	8 Ω	4 Ω	8 Ω
VB ltrs	12	14	7	11
FB Hz	49	48	-	-
F3 Hz	50	49	80	71
Port Diameter	1.5"	1.5"	-	-



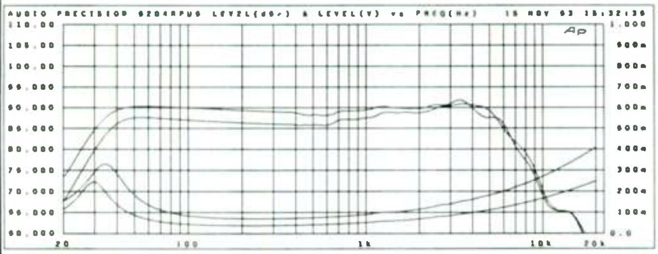
Madisound 6204R
6" Polypropylene Woofer 4 or 8 Ω

Rubber Surround

vented pole piece

Fs (Hz)	26.8	34.2
Rscc Ω	3.41	6.36
VcL mH@1K	.45	.70
Qms	2.68	1.80
Qes	.369	.457
Qts	.324	.364
Mmd (g)	11.3	13.3
Cms (µm/N)	2877.7	1524.5
Vas (ltrs)	71.9	38.3
Efficiency (2.83V / 1m)	90	87
Xmax	3.5mm pk	
Power	50 w	
Magnet	12 oz.	
Cone	Black Poly	
Surround	Rubber	
Voice Coil	1" 2-Layer Kapton	
Cutout/Depth	5.62"/2.87"	
Price	**$27.00**	

	Vented		Sealed	
	4Ω	8Ω	4Ω	8Ω
Vb Ltrs	30	23	19	14
F_3 Hz	40	42	58	66
Fb Hz	33	38	-	-
Port Dia	2"	2"	-	-
Length	5.7"	5.6"	-	-



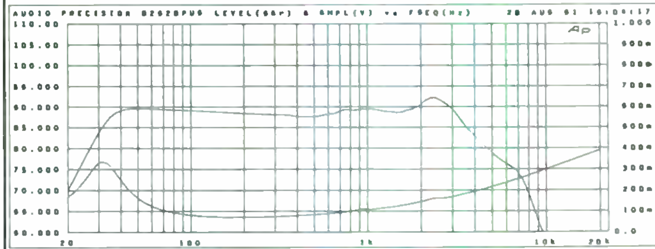
Madisound 8252R
8" Polypropylene Woofer 8Ω

Rubber Surround

vented pole piece

Fs	31.6Hz
Rscc	6.35Ω
VcL @1K	.885mh
Qms	2.06
Qes	.45
Qts	.37
Mmd	23.6g
Cms (µm/N)	989.6
Vas	68 Liters
Efficiency (2.83V / 1m)	89db 1w/1m
Xmax	4.5mm pk
Power	75 w
Magnet	20 oz.
Cone	Black Poly
Surround	Rubber
Voice Coil	1.5" 2-Layer Kapton
Cutout/Depth	7.12"/3.37"
Price	**$36.00**

	Sealed	Vented	Vented
Vb Liters	26	34	42
F_3 Hz	60	43	39
Fb Hz	-	33	35
Port Dia	-	2"	2"
Length	-	5"	3.2"



Madisound Speaker Components; PO Box 44283, Madison WI 53744; Tel:608-831-3433, Fax: 608-831-3771

Reader Service #8

THE DANIELLE II

By Marc Bacon

I designed the Danielle II speaker system in response to reader requests following my two-part article on the Danielle system (*SB* 4/92 and 5/92). That system was designed around D'Appolito's now famous MTM (midrange-tweeter-midrange) array using SEAS 11-FGX woofer-midranges and a Morel MDT-30 tweeter, with the bass section handled by a Zalytron-supplied Precision TA305F clone. Readers responded to my expressed wish to use FOCAL drivers for a better system.

A quick check of the FOCAL 4″ midrange line-up, however, showed that I could not make an easy substitution. FOCAL's drivers are designed to be used as pure midranges rather than as woofers. I set myself another goal: to develop a high-sensitivity, very high-resolution speaker with an open midrange and relative insensitivity to room boundaries, with a special view toward low-power tube amplifiers. *Table 1* lists the specifications. I also designed a matching high-sensitivity subwoofer system as a pair of end tables, using the classic Vieta L120/F3 woofers in a bandpass push-pull configuration (specifications in *Table 2*).

CONFIG CHOICES

As with all speaker systems, design begins with configuration and driver selection. I chose the "Allison" configuration, which places a requirement of a crossover between 300 and 400Hz with at least a third-order crossover. This allows the woofer to work near a known boundary—the floor—while the wavelength of the sound the midranges produce is less than the distance to the nearest boundary, thus sidestepping the floor/wall bounce that disturbs the power response of most speakers.

The new FOCAL "V" line, using polyglass cones, conveys midrange very musically, with none of the sometimes ragged edge of Kevlar® and carbon fibers or the smearing of polypropylene. At the suggestion of ORCA president Kimon Bellas, I chose the 10V01 woofer, a driver specifically designed for high impact at the expense of reaching below 50Hz. While people accustomed to listening to true low bass would be dissatisfied, the drivers do fine for all but organ music, providing a sensitivity of 93dB/1W/1m.

A large-ribbon voice coil, a negative half-round surround for linearity, a heavy die-cast frame with a large magnet, and superlative workmanship show the technology and quality control that went into this driver. Listening to unmounted drivers above 6″ in diameter is usually disconcerting, but the 10V01 passed the test. It has an unusually clear, natural upper bass/lower midrange, which is a must for crossing over at 400Hz to a high definition midrange.

NO TINKLE

For the range 400Hz–3.9kHz, I chose the FOCAL 4K111 4″ midrange drivers. At the lower crossover point, excursion limits are no

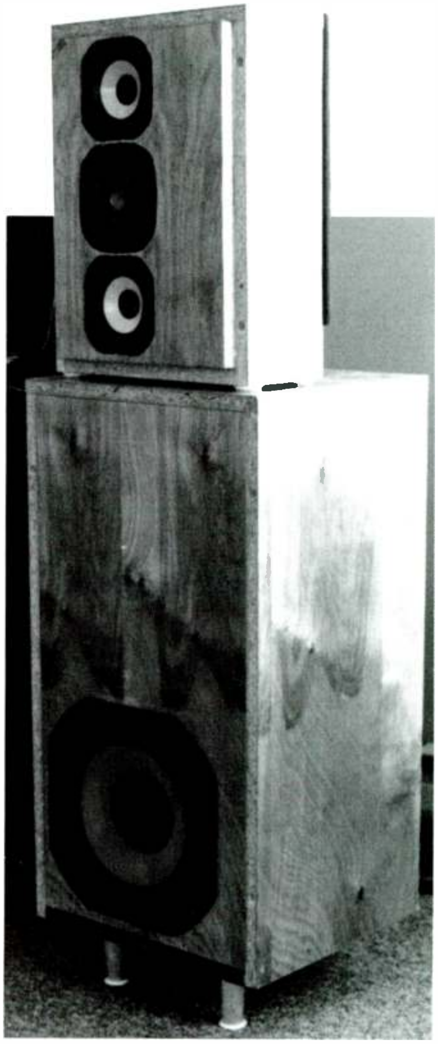


PHOTO 1: A close-up of the woofer and MTM modules with the grilles removed.

ABOUT THE AUTHOR

Marc Bacon is an American father of two making his home in Quebec. He is the author of two speaker design programs and several *SB* articles, and spends a good deal of his spare time designing and building speakers. Marc works in Montreal as manager of engineering and quality assurance for a manufacturer of heavy platework.

TABLE 1

THE DANIELLE II SPECIFICATIONS

SENSITIVITY
93dB 1W/1m
70kHz ±1dB
50Hz–22kHz ±3dB
approx. 6Ω nominal impedance

150W program power
Vented box f_3 = 50Hz, f_B = 45Hz
Sealed box Q_{TC} = 0.6

"Allison" driver spacing
"D'Appolito" MTM array
Ported towards floor
Dipole midrange

DRIVERS
Polyglass 10″ woofer
(2) Kevlar 4″ midrange
1″ TWS concave dome tweeter

CROSSOVER (acoustic slopes)
420Hz third-order Butterworth
3.9kHz fourth-order Linkwitz-Riley
SCR caps, Intertechnic coils

DAMPING
ORCA Black Hole

Bracing/internal resistance system to minimize cabinet flexing and standing waves.

Dipole dimensions optimized for minimizing diffraction effects.

ORCA binding posts

Three-point support system

TABLE 2

SUBWOOFER SPECIFICATIONS

SENSITIVITY
93dB 1W/1m
28–70Hz ±3dB
S = 0.7
4Ω nominal impedance

400W program power

(2) Vieta 13″ subwoofers push-pull in sixth-order bandpass box

DAMPING
ORCA Black Hole
ORCA binding posts
Three-point support system

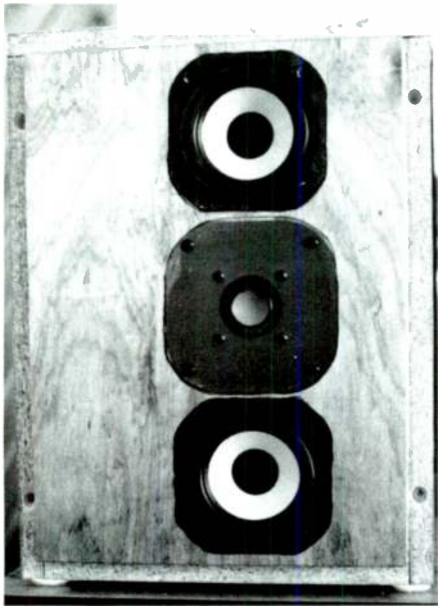


PHOTO 2: The MTM dipole unit. Note off-center driver mounting.

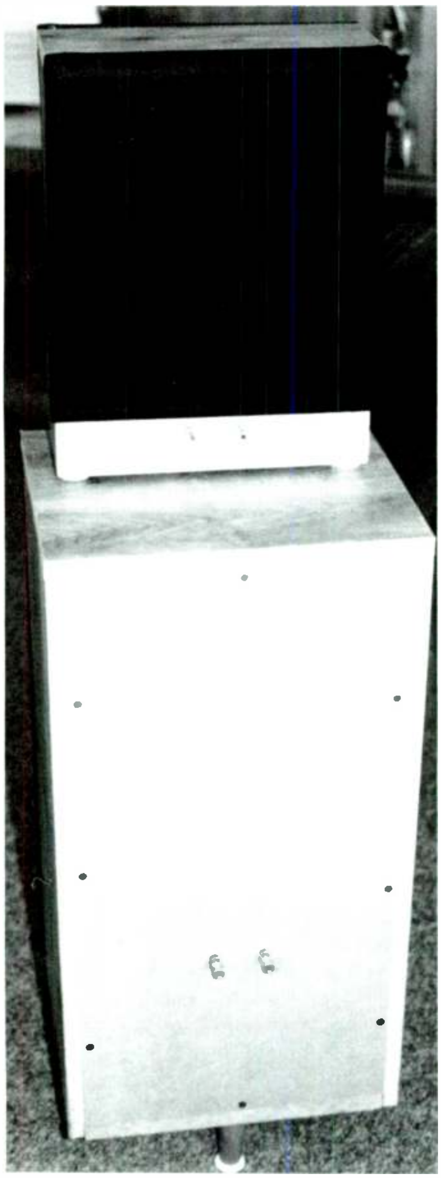


PHOTO 3: Rear view of the Danielle II, showing binding posts. Port is toward floor.

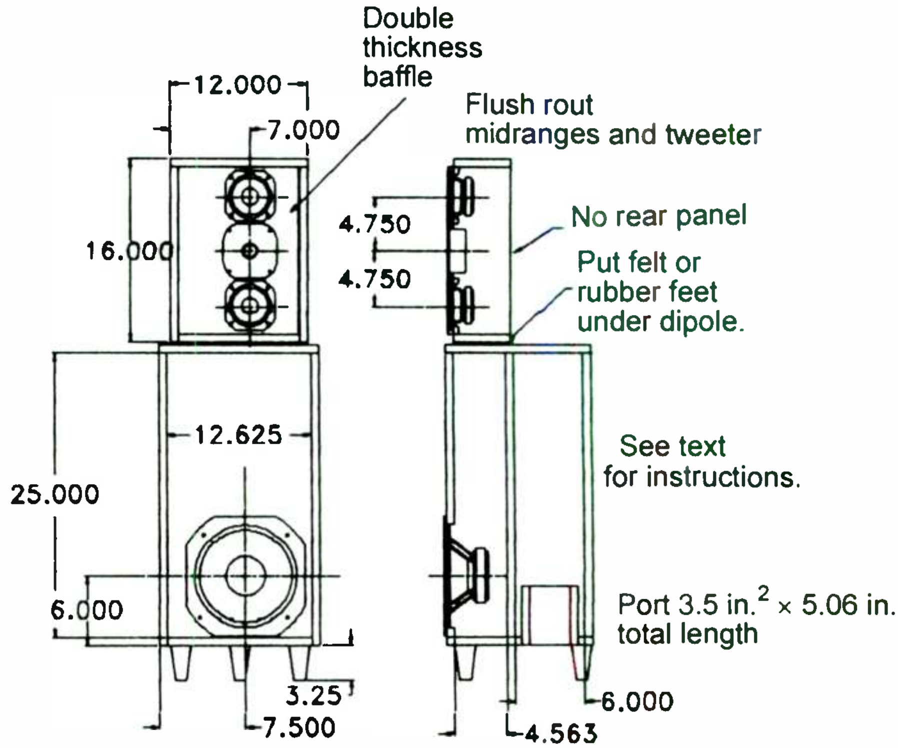


FIGURE 1: The Danielle II box design.

problem, even with an open-back dipole arrangement that doesn't provide excursion limitation. These drivers are very special indeed—extremely light woven Kevlar sandwich cones, a decompressed spider, a large magnet, and yellow cones that my 6-year-old thinks look great.

These drivers aren't easy to mate to the rest of the system, however, and should not be used in acoustic suspension enclosures. The cones are extremely sensitive to rear reflections. I tried suspending one on a string, then passing my hand behind the cone. The effect, though slight, was clearly audible. When used as dipoles or in tapered transmission lines, the FOCAL 411 drivers come as close as I've ever heard to electrostatic speakers, while conserving the sensitivity and impact of cone drivers.

To match the 93dB/1W/1m sensitivity of the low end, you have just two tweeter options: a horn-loaded tweeter or one with a very high magnetic flux and a light cone. I chose the FOCAL T120TiO2, based on my experience with its smaller relative, the T90TiO2. The magnet system on the FOCAL T120 series is huge, defining the 120 mm faceplate size. However, the concave dome works as designed, providing the even off-axis response required for good imaging. These drivers, while lacking the "tinkle" of other metal dome tweeters, are very neutral; never harsh, always precise. I prefer the somewhat sweeter sound of the smaller T90 drivers, but the difference is extremely subtle, and the T120 drivers have tremendous dynamic range.

Thus the tonal balance of the system was set, with analytical definition the best way to describe the critical midrange and treble, and a neutral, smooth sound below 400Hz. The tonal subtleties, though small, serve to characterize the overall sound in a way we have not yet learned to measure easily.

3-TIPPED

I chose a dipole midrange, for its airiness and the lack of reflection it gives to the sound and for the increased ambience. The midranges and tweeter are mounted in the now classic D'Appolito fashion (although not in strict accordance with Mr. D'Appolito's original criteria).[1] Not only is the driver spacing higher than one wavelength at the crossover frequency, but the acoustic slopes are fourth-order Linkwitz-Riley, not third-order as Mr. D'Appolito suggested. The array still serves its purpose of localization of a phantom center image with precise control of horizontal frequency response and reduction of floor and ceiling reflections (*Photos 1* and *2*).

The speaker is set off the floor, with a port directed toward the floor for added bass reinforcement, virtually eliminating the need for a subwoofer for all but organ music, cannons, and the like. I used sawed-off bed legs for supports—not exactly state-of-the-art spikes, but adequate for the task. I mounted the speaker on three points, for

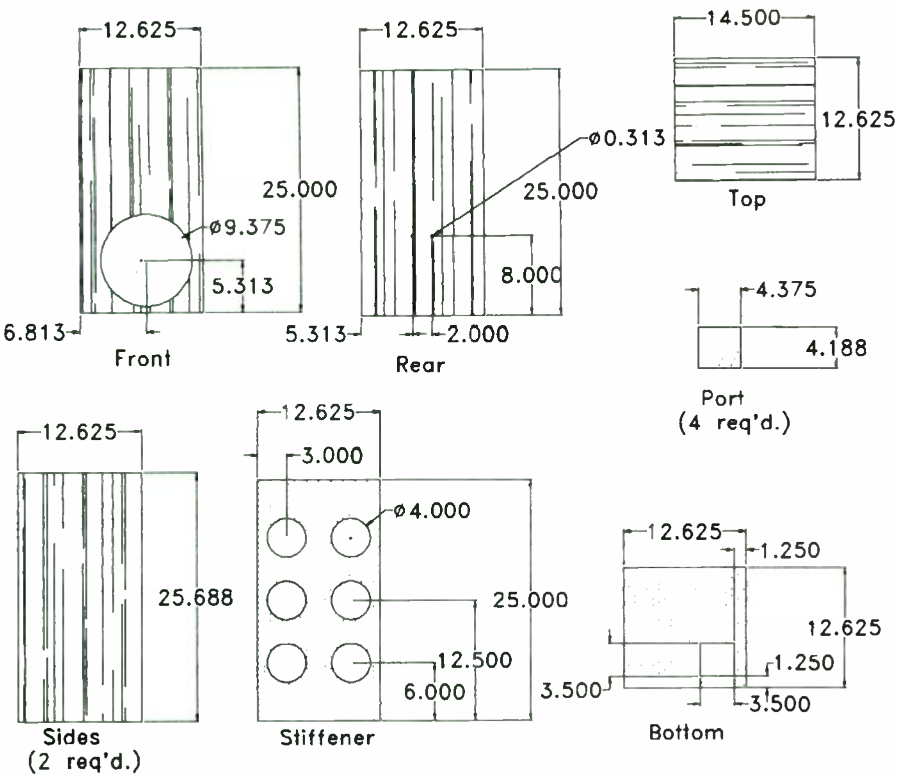


FIGURE 2: Cutting guide for the woofer box components (all material 11⁄16" thick).

as we all learned in geometry, three points determine a plane (*Photo 3*).

Hence, although it can tip over more easily than if supported on four legs, the speaker doesn't rock at all, unlike a four-point suspension system used on a not-quite-flat floor. (The overall box configuration is as shown in *Fig. 1*; the cutting lists in *Figs. 2* and *3*.) Note the direction of wood grain when cutting out the pieces.

The center partition stiffens the woofer box and controls large-signal response and standing waves. One of the problems with Thiele/Small theory as related to ported boxes is the Helmholtz resonator concept, which states that the mass of air in the port resonates with the elasticity of air in the box at a given frequency, with a very high Q. This is true for small signals; but large ones require a finite time to compress the air spring in the corners of the box most remote from the woofer.

BASS CONTROL

The tendency, therefore, is for the box to behave like a much smaller one under higher drive levels. Furthermore, if one of the cabinet dimensions, port dimensions, or distances between the cone and the port is a harmonic of the box tuning frequency or a multiple of another dimension, standing waves will cause audible colorations in the sound.

One solution is that used in the Danielle II: forcing the sound from the woofer to travel along different path lengths to the port, while still leaving ample room for the air to move inside the box. This tends to reduce standing waves and to avoid the high-level short-circuiting of the box volume, while providing some resistive damping. The result is a distinctly well-controlled bass that sounds more like an aperiodic design than a typical ported system.

The subwoofers use Vieta L120/F3s, my favorite drivers for moving a large amount of air with low distortion to low frequencies in a small box. At 11 lbs each, with a hefty magnet, machined aluminum die-cast frame, inner/outer voice-coil winding, and thick PVA/cotton cone, they look more like industrial motors than high-fidelity speakers. They are designed to move air, and they do it with incredible ease, at times resembling air compressors rather than speakers. At 200W RMS each, and using two drivers per side in a push-pull configuration, they are all but indestructible.

3-LEG PORT

The subwoofer boxes are designed as bandpasses, with high efficiency and good transient response (S = 0.7) the primary objectives. As a result, they achieve 93dB for a 2.83V input at 1 m in a 70-liter box, while still achieving a respectable 29Hz-3dB point and a 12dB/octave rolloff. Achieving high sensitivity, small boxes, and decent bass extension with good transients has a down side—a relatively low high-frequency cutoff.

These boxes, specifically optimal for the

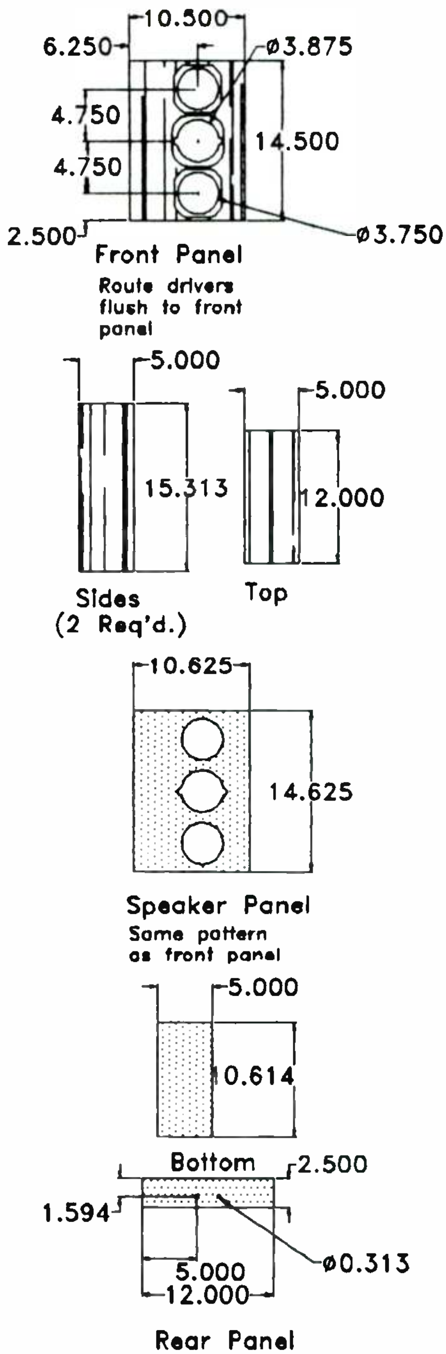


FIGURE 3: Cutting guide for dipole (all material 11⁄16" thick).

Danielle II or another system requiring only the octave below 60Hz, would be disappointing to somebody who wanted to pair them to small satellites that have a required 80Hz or higher crossover.

The drivers are mounted in push-pull for a reduction in harmonic distortion (already low for the Vietas) and wired out of phase so as to move together. The port is once again vented toward the floor, with a three-point support system (the rest of the bed legs).

BATS DAMP

I used three sets of ORCA-supplied heavy-

Continued on page 28

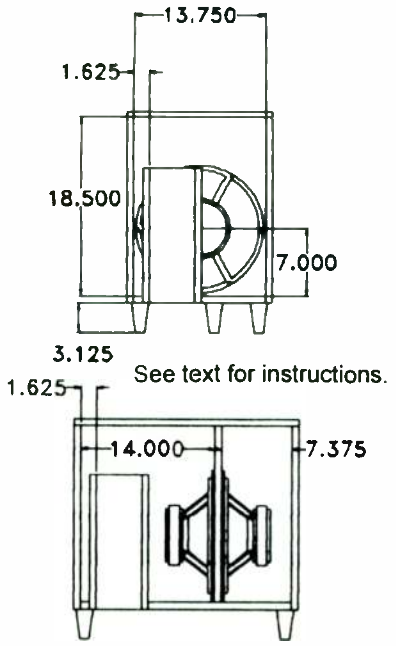


FIGURE 4: Subwoofer/end table cross-section.

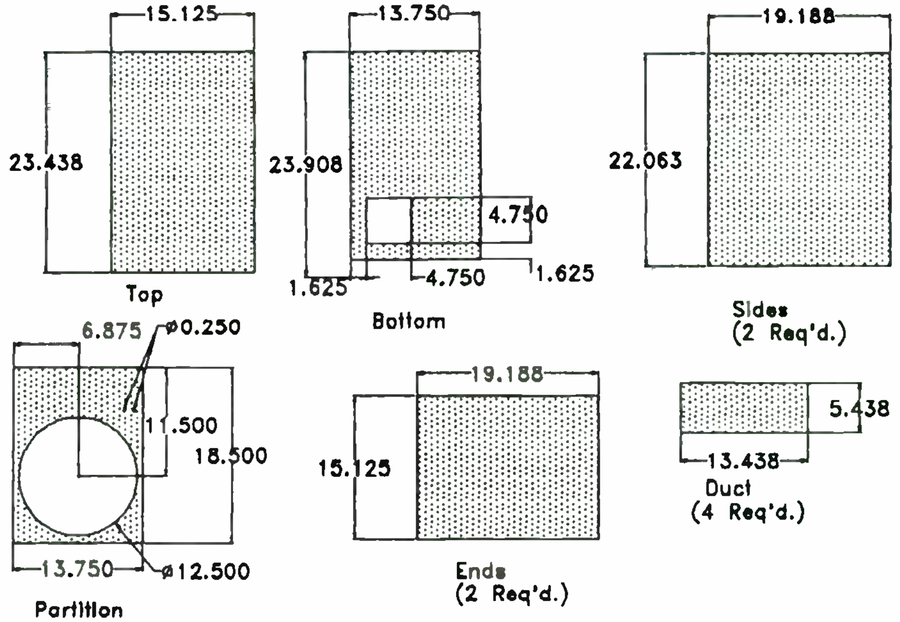


FIGURE 5: Subwoofer cutting guide (all material 11⁄16″ thick).

Continued from page 26

duty binding posts for each side: one pair for the MTM array, one for the woofer box, and one for the subwoofer. I much prefer the small drilled hole these posts require, and their high mechanical strength, to any D-cup binding posts I've used. *Figure 4* shows the overall subwoofer configuration; *Fig. 5* the cutting list.

I used one sheet of Black Hole damping mat per woofer box and one sheet per subwoofer box. The material consists of a limp ⅛″ heavy vinyl barrier bonded to a thin foam septum, which is in turn bonded to another barrier layer, then to a 1″-thick open-cell foam with a dimpled porous surface layer. The entire mat can be cut to size with shears and a linoleum knife, and is held in place with PSA (pressure-sensitive adhesive).

For the woofer box, cut one sheet of Black Hole material to line the front cavity and apply it to the partition behind the woofer as well. Use the rest of the sheet in the rear cavity. Avoid using it near the port. Use ¾″ square cleats in all corners. Glue and caulk all joints and backs of drivers.

The port of the subwoofer is 4.75 in.^{2} × 14.125″ long. Use ¾″ square cleats in all corners. Glue and caulk all joints and driver flanges. Wire out-of- phase, and put binding posts under the subwoofer. Use one sheet of Black Hole for lining, taking care to line the closed box first, and then the open box with the remainder.

This somewhat costly barrier system provides a clean, easy, duplicable way of achieving a surface barrier with damping and broad-band absorption with a minimum of volume loss. Although the pad is over 1″ thick, the net loss of volume is equivalent to a ¼″ thick pad, or the combined thickness of the vinyl barriers. I much prefer Black Hole to messy tar products, questionable "magic" compounds brushed or sprayed into the enclosure, and foams or fibers of unknown and unduplicable densities.

CUTTING GARBAGE

I built the crossover in separate parts for each driver set, using 14-gauge stranded wire and soldering throughout. Capacitors were all SCR polypropylene, except for the subwoofer and the capacitors in parallel with the woofer. For those who cringe at purchasing 75µF of polypropylene capacitors, 60µF of electrolytic capacitors in parallel with 15µF of polypropylene should work, although the electrolytic capacitors may deteriorate over time. *Table 3* is the crossover parts list.

I used heavy-gauge Intertechnik coils and paralleled resistors as required to achieve desired wattages. None of this is cheap, but the result is worth it. Many otherwise good speakers suffer from skimping on crossover components. Although a good crossover may cost as much as the woofer itself, it makes no sense to use low-quality components. *Figures 6, 7,* and *8* show the crossover design.

The subwoofer section uses a series bandpass circuit designed to complement the tuning of the bandpass box. Addition of a series-resonant circuit to a bandpass subwoofer serves to cut off damaging DC offset, low-frequency garbage and rumble, and high-frequency output that could otherwise be transmitted through the port, and to broaden the bandpass range.

AVOID SYMMETRY

The woofer section consists of an LCR trap designed to reduce the effect of the impedance peak and permit a simple second-order electrical crossover to the midranges. The varying impedance of the woofer and midranges through the crossover range serves to create a third-order Butterworth acoustical crossover centered at 400Hz. As in several of my previous designs, I used CALSOD and the Loudspeaker Design Powersheet extensively in

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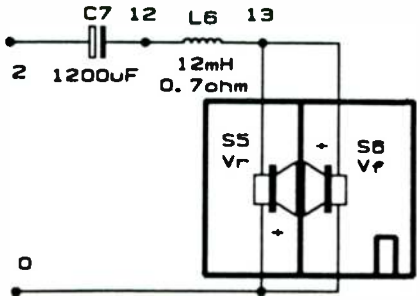

FIGURE 6: Crossover, subwoofer section.

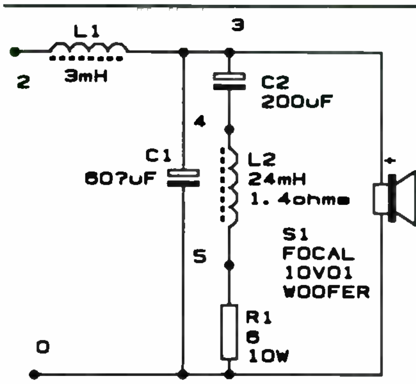

FIGURE 7: Crossover, woofer section.

Continued from page 28

developing the system in order to simulate and optimize the crossover. It would be nearly impossible to use a passive crossover in this range designed from cookbook formulas, as the interaction between the woofer, the box, the midranges, the dipole rolloff, and the voice-coil inductances are much too complicated to predict.

Modeling of the crossover required taking into account the effective width of the dipole, by measuring the path length from the back of the midranges around the rear edge of the sides to the front face, then assuming a 6dB/octave rolloff added to the midrange response. I used a fourth-order Linkwitz-Riley filter between the midranges and the tweeters. Its transient characteristics are the best among fourth-order filters, with excellent tweeter protection and stable vertical image.

When combined with the drivers' own natural rolloffs, the electrical sections look more like 12dB/octave bandpass filters and an 18dB/octave tweeter section. As neither the midranges nor the tweeter are forced to operate with any power through their resonances, I did not include any parallel LCR filters.

To balance sensitivities and adjust bass tuning I used a 0.1Ω simulated line resistance and included the series resistance of all coils. I mounted the MTM array off center to reduce the effect of the 6dB diffraction loss at lower frequencies. Mirror-imaged pairs helped preserve the overall image, and I offset the 10″ woofer somewhat to avoid symmetry in the box and so spread the effect of standing waves.

CORRUGATED CROSSOVERS

The rear of the dipole received no damping treatment. I used 1 1/16″ exotic plywood throughout on the main speakers and simply doubled the thickness of the dipole faceplate, while routing the speaker shapes to avoid high-frequency aberrations. By making the front panel 3/4″ less on all sides than the dipole, I could use 3/4″ quarter-round molding for the grille frame, with practically no projection above the surface and a resulting

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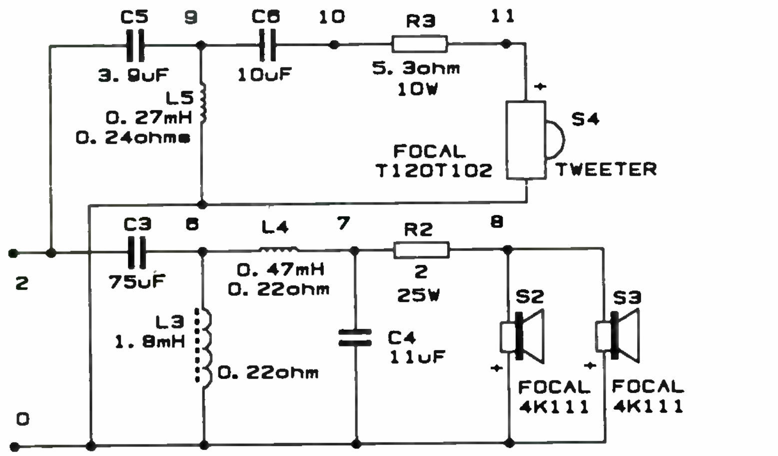

FIGURE 8: Crossover, midrange/tweeter sections.

TABLE 3

DANIELLE II CROSSOVER PARTS LIST

QTY	REF	DESCRIPTION
Capacitors		
1	C1	60μF
1	C2	200μF
1	C3	75μF*
1	C4	11μF*
1	C5	3.9μF*
1	C6	10μF*
1	C7	1,200μF
Inductors		
1	L1	3mH, 0.24Ω**
1	L2	24mH, 1.40Ω**
1	L3	1.8mH, 0.22Ω***
1	L4	0.47mH, 0.22Ω***
1	L5	0.27mH, 0.24Ω**
1	L6	12mH, 0.70Ω Intertechnik
Resistors		
1	R1	6Ω, 10W
1	R2	2Ω, 25W
1	R3	5.3Ω
Miscellaneous		
3	S1–3	FOCAL
1	S4	TWEETER
1	S5	Vr
1	S6	Vf
Notes		
*		SCR Polypropylene
**		Iron-core Intertechnik
***		Air-core Intertechnik

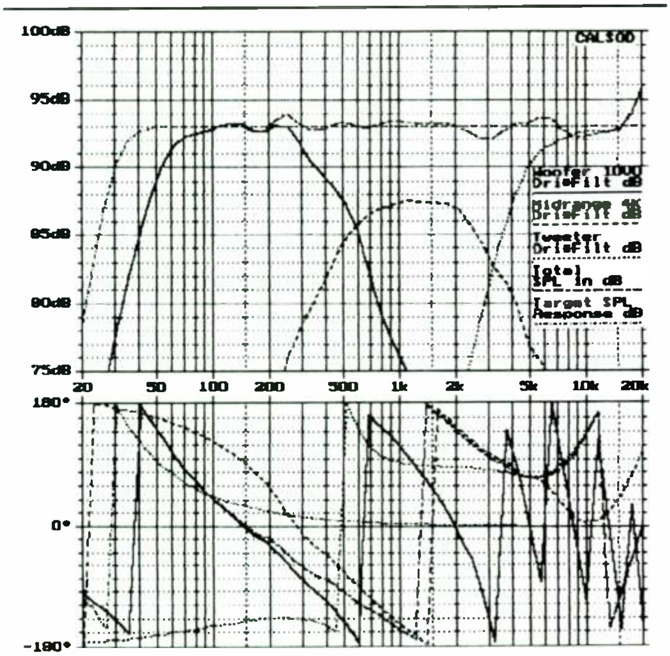

FIGURE 9: Vented box, no subwoofer, SPL response.

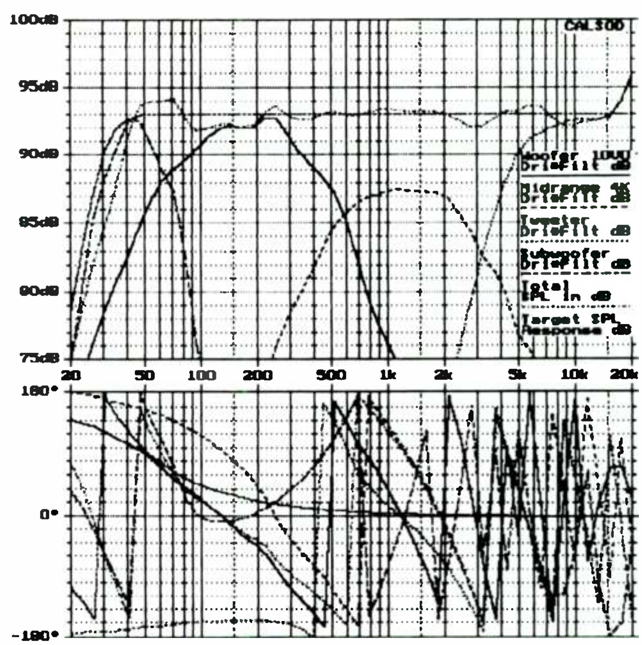

FIGURE 10: Sealed woofer and subwoofer, SPL response.

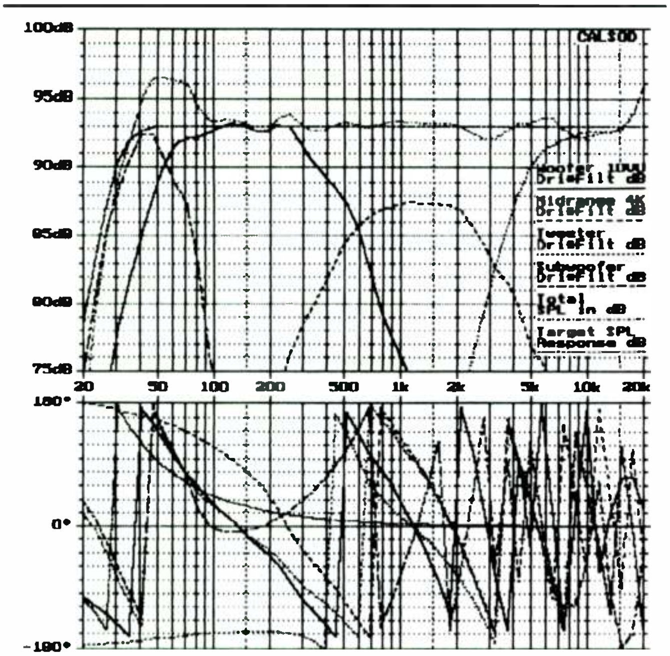

FIGURE 11: Vented woofer and subwoofer, SPL response.

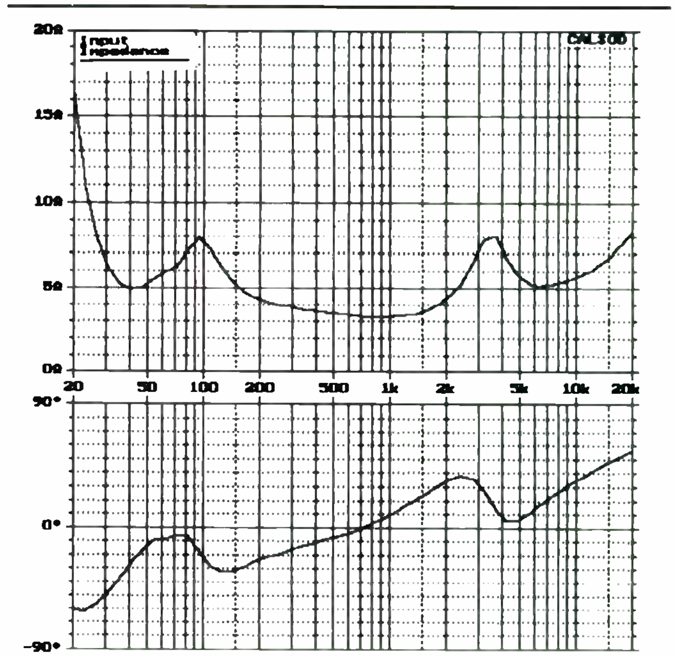

FIGURE 12: Vented woofer, no subwoofer, input impedance.

Continued from page 30
rounded edge for diffraction control. The grilles do have an audible effect on the highest frequencies (above 5kHz), but not serious enough to harm any but the best recordings.

The crossover components were mounted using hot glue (great stuff!) on individual pieces of heavy cardboard (a good use for speaker-driver cartons). It is important when laying out a crossover to ensure that the inductors are mutually orthogonal and well away from the driver's magnets, and that the capacitors cannot vibrate in any way and so act as microphones.

I glued the midrange and tweeter sections to the sides and bottom of the dipole, the woofer section to a side wall behind the partition, and the subwoofer section to the main divider panel. The binding posts were mounted on the rear of the two parts of the main speaker and on the bottom of the subwoofer.

THE SINGLE BOX

If you are seeking similar performance in a more esthetic single box, try the following (untested) solution. Build a box with a center partition as I did, and with the same panel width as the MTM array (12″). Choose box dimensions to permit the tweeter to be at ear height, and use open 6″ PVC tubes running from behind each midrange to the rear of the box, with progressively denser wool stuffing in the tubes. Make sure that the tubes are completely sealed from the woofer section and are mounted excentric to the midranges, in order to avoid reflections back to the cone from the side walls.

You will have to adjust the high-pass section of the midranges slightly to compensate for the added path length (and fuller sound in the 300–400Hz range), and be very careful with stuffing in order to avoid pipe resonances at multiples associated with the rear tube length. (Because I was interested in a duplicable design, I traded off some esthetics for the difficult stuffing problem.) Unless you have the patience of Job in experimenting with cabinet damping to avoid rear reflections, I do not recommend using the midrange drivers in an acoustic suspension enclosure. They are wonderful as dipoles, but should not be used otherwise except in the above-mentioned hybrid dipole/transmission line arrangement.

In my double-box configuration, isolate the MTM array from the woofer box with either rubber feet or felt furniture pads. Esthetics were not a problem with bottom-mounted ports, so I chose rectangular ports made of ½″ presswood, with careful attention to Augspurger's recommendations.[2] They do displace a bit more volume than round ports, but are easy to make and don't vibrate.

RESPONSE

The overall predicted response is excellent, as you can see by referring to the attached CALSOD graphs. A quick description follows: *Figure 9* is the overall system response with no subwoofer and the vented box. *Figure 10* shows the overall system response including the subwoofer, with the woofer port blocked to create an acoustic suspension design. *Figure 11* illustrates the overall response for the system with the woofer acting in its ported enclosure, combined with the subwoofer.

Figures 12, 13, and *14*: The impedance curves for situations described in *Figs. 9, 10,* and *11* respectively. Note that the position with the most bass output has relatively low impedance in the extreme bass. This was not a problem with my amplifier, but might be for some.

CRITICAL EARS

Since I didn't have access to LMS or MLSSA, I took the speaker systems, less the subwoofers, to Bourget Stereo, an audio store that has been in business since 1957, catering to the high-end audio market. There, I left the speakers with four audiophiles accustomed to listening to live music and to some of the best reference systems in the world. The four men listened to the Danielle II in comparison to several top-of-the-line Rogers, McIntosh, KEF, Ellipson, P.E. Leon, and Quad electrostatics.

Their findings were unanimous—the Danielle II is a definite contender in this class, beating all the others in definition, with

Continued on page 34

REFERENCES

1. Joseph D'Appolito, "A High-Power Satellite Speaker," *SB* (4/84): 7.
2. G.L. Augspurger, "New Guidelines for Vented-Box Construction," *SB* (4/91): 12.

SOURCES

ORCA
1531 Lookout Dr.
Agoura, CA 91301
(818)707-1629
FAX (818) 991-3072

Zalytron Industries Corp.
469 Jericho Turnpike
Mineola, NY 11501
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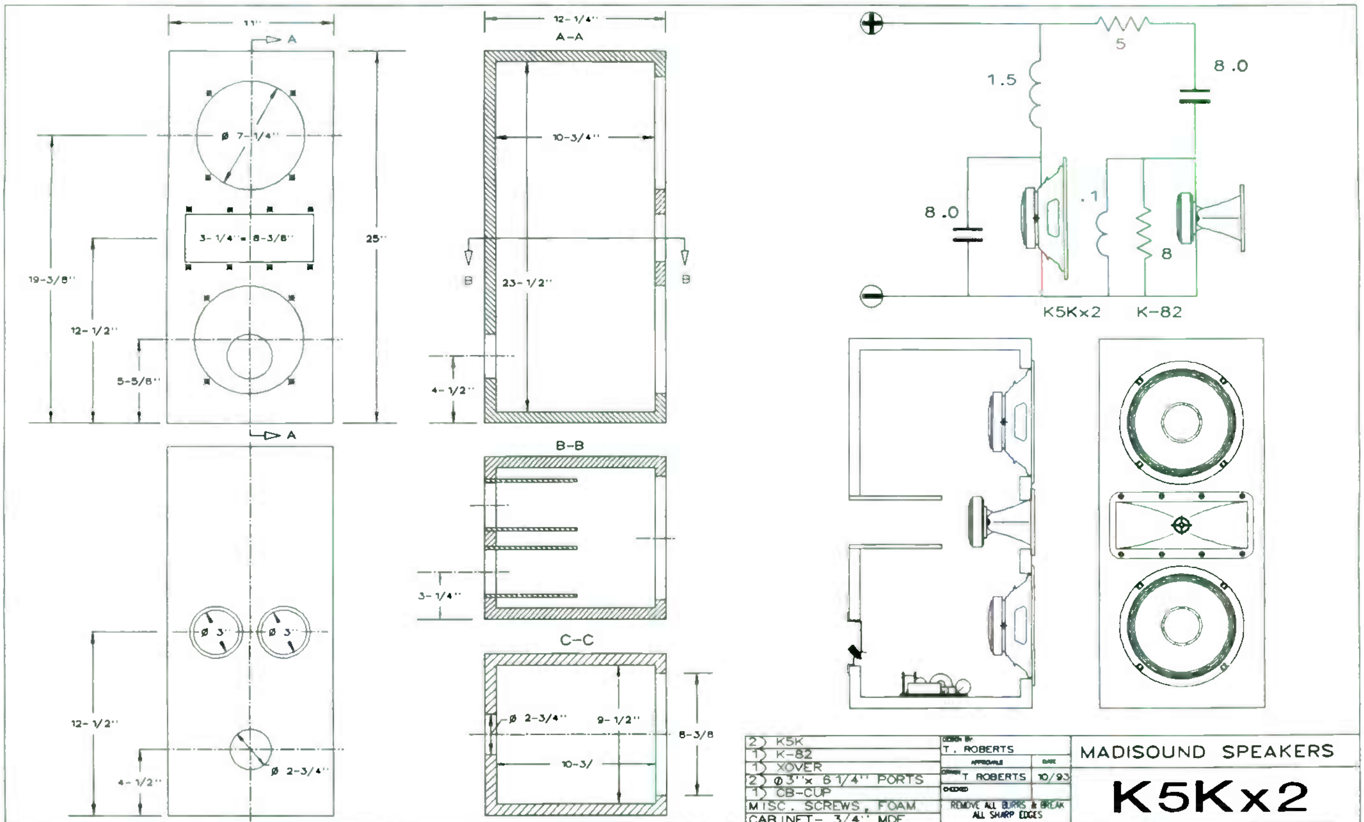
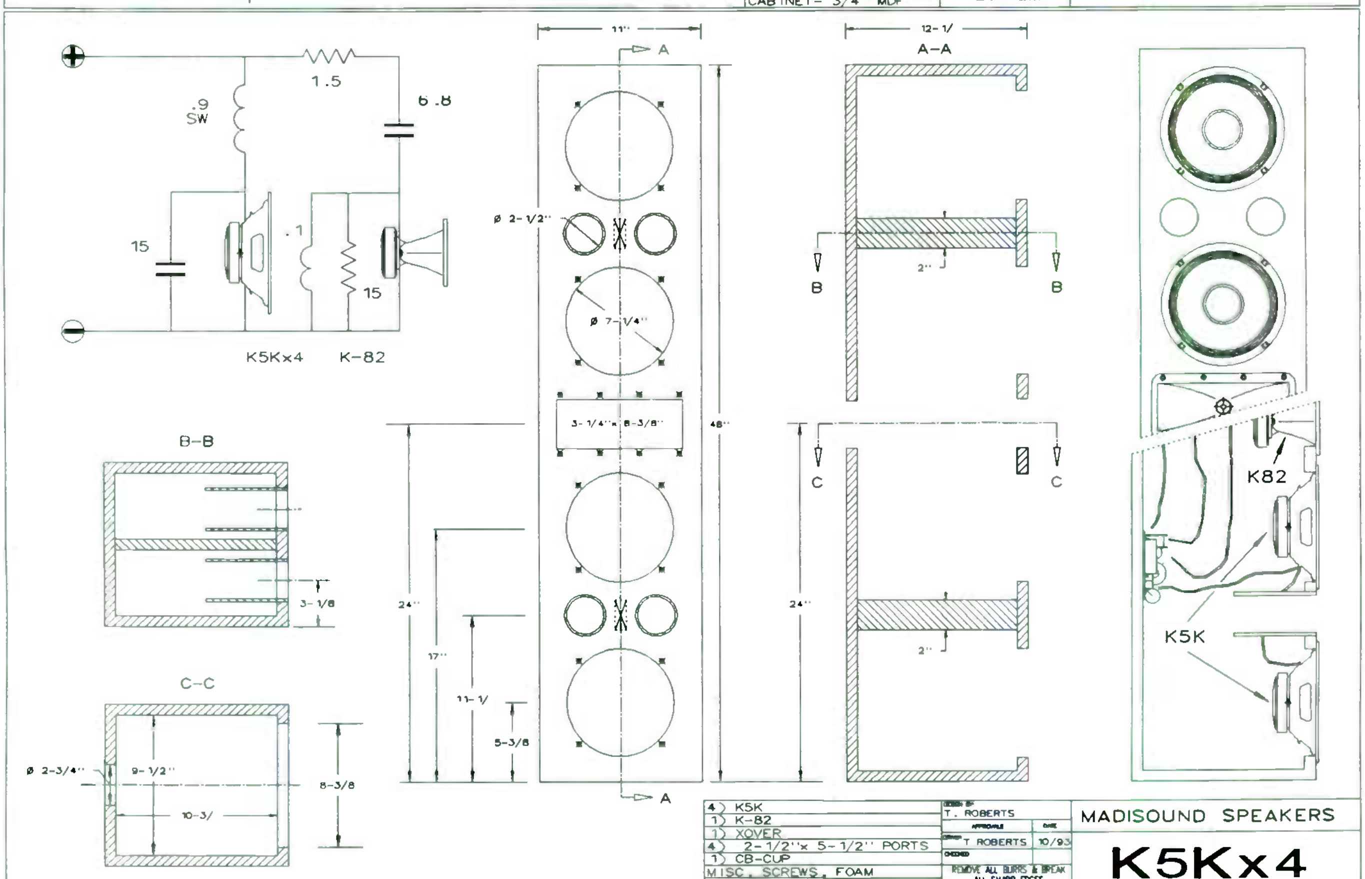

A–A
B–B
C–C
K5Kx2
K–82
2) K5K
1) K–82
1) XOVER
2) Ø 3" x 6 1/4" PORTS
1) CB–CUP
MISC. SCREWS, FOAM
CABINET– 3/4" MDF
T. ROBERTS
10/93
REMOVE ALL BURRS & BREAK ALL SHARP EDGES
MADISOUND SPEAKERS
K5Kx2


K5Kx4
K–82
A–A
B–B
C–C
K82
K5K
4) K5K
1) K–82
1) XOVER
4) 2–1/2"x 5–1/2" PORTS
1) CB–CUP
MISC. SCREWS, FOAM
CABINET– 3/4" MDF
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MADISOUND SPEAKERS
K5Kx4

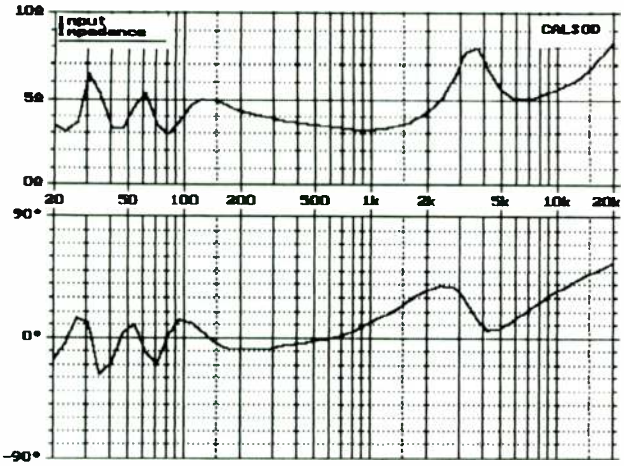

FIGURE 13: Sealed box and subwoofer, input impedance.

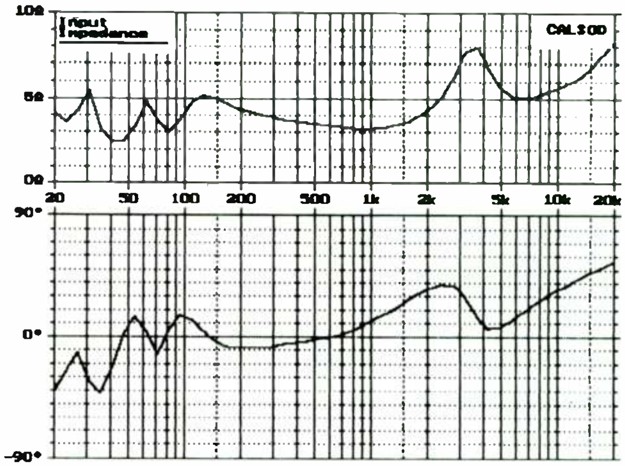

FIGURE 14: Vented box and subwoofer, input impedance.

Continued from page 32

special excellence on piano music and vocals. All four listeners praised the speakers' open quality, as well as the richness of the midbass, attributable to the dipoles and Allison configuration.

The only criticism they had (apart from my less-than-perfect woodworking) was a slight raggedness around 4kHz, which gave a thin edge especially noticeable on violins. The P.E. Leon Integrale speakers beat the Danielle II system in this area, but they couldn't match the tonal quality in the midbass. I attributed this aberration on violins to the specific timbre of the Kevlar midranges, and chose not to compensate by affecting the crossover in this region, as the system was designed to complement tube amps, which convey less of an edge to the music.

THE DANIELLE II KIT

The Danielle II speaker system is available in kit form from distributors of ORCA products. The basic kit includes:

- 2 FOCAL 10V01 polyglass woofers
- 4 FOCAL 4K111 kevlar midranges
- 2 FOCAL T120TiO2 tweeters
- 2 Black Hole damping pads
- 16 grille fasteners
- 4 pairs of ORCA binding posts
- A reprint of this article

The crossover components are available from many suppliers, and you can experiment on your own. Try to use series resistances equal to those shown in the schematics. The

Continued on page 70

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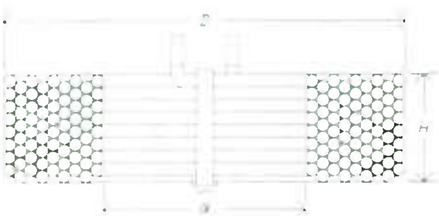

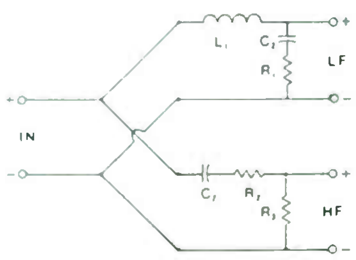

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THE BIRDHOUSE: A Sound-Reinforcement Subwoofer

By Matt Federoff

Perhaps the most demanding application for sound reproduction is live concert production. The signal source is not a pure CD but live performers, unpredictable and often erratic. The venue can be anywhere, from a half-filled concert hall to an overflowing backyard. And if the sound isn't right, no matter what the cause, rest assured that the blame will fall on the hapless sound engineer, who must attain and maintain clarity, articulation, and wide-range sound at extreme sound-pressure levels.

And yet there is something terribly addictive about live work. I've spent years "riding the board," and I hope that this project will ease the plight of other sound engineers out there in their quest for the "perfect" bass enclosure.

What is the perfect bass enclosure? First of all, it must be efficient. Sound reinforcement deals in power amounts that are beyond the ken of the home enthusiast, and to squeeze out every bit of power, particularly in the low end, the enclosure must be efficient. A difference of 3dB in enclosure output is equivalent to doubling (or halving) amplifier power. Second, it should have a narrow bandwidth. Yes—*narrow*. That may seem odd when conventional wisdom dictates as wide a bandwidth as possible. But full concert production invariably utilizes active crossovers, and any acoustical rolloff will aid the electronic rolloff and boost efficiency. Third, it should be sturdy, to withstand the rigors of the road. Finally, it should be as small and light as possible. Of course it should have solid bass response as well.

All these requirements seem to fly in the face of each other, and many sound engineers have sought in vain to find the elusive "holy grail" bass enclosure that has all these characteristics. A look at commercially available enclosures reveals a shocking lack of engineering that is either good or innovative. Two styles are common—a poorly aligned bass-reflex system or a gigantic folded horn that would need a forklift to move.

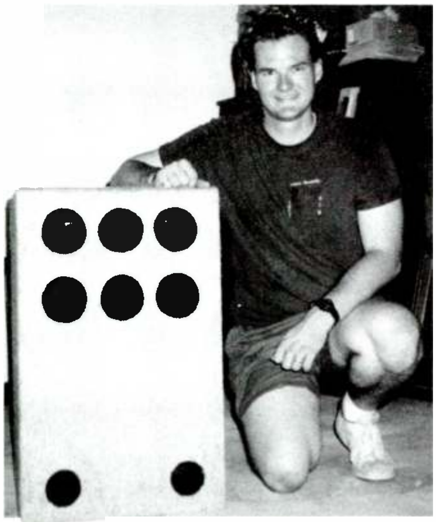

PHOTO 1: The completed cabinet with carpet covering.

One enclosure works wonderfully in certain situations unique to sound reinforcement, however. The acoustic bandpass enclosure has its adherents (car-audio freaks who ascribe to it almost magical qualities) and its detractors ("audiophiles" who deride a perceived lack of transient response). Like any other, it has great advantages and real drawbacks, but for live concert work it is ideal.

The bandpass box is a high-efficiency, narrow-bandwidth design. The completely enclosed structure provides unparalled cone protection, and the internal baffle greatly increases structural rigidity and sturdiness. With proper design, a tremendous amount of bass power can be obtained from a (relatively) small box, and the designer can control the efficiency, bandwidth, and rolloff characteristics. Bandpass designs also increase power handling. All you've got to do is design it.

ABOUT THE AUTHOR

Matt Federoff is a bilingual biology teacher in Tucson, AZ. He is 25, married, and has an 18-month-old daughter. He has been building speakers since he was 13, and has been a professional sound engineer for five years. His current ambition is to develop speaker-design software for the Apple IIGS.

DRIVER SELECTION

The first task in any design is selection of an appropriate driver. A surprising number of enthusiasts don't realize that bandpass enclosures require a different set of criteria for driver selection. While the conventional wisdom holds that designs based on Thiele/Small theory required a driver with a low Q value, a close look at Jean Margerand's article "The Third Dimension: Symmetrically Loaded" (*SB* 6/88, 1/89) shows that speakers with a high Q value will give lower bass and more efficiency in a small box. This is borne out in computer modeling. So what we need is a driver with a high Q, low F_S, low V_{AS}, and extremely high-power handling. After much searching, I settled on the Carvin PS-15C, a superb and surprisingly affordable 15" driver. Its specs are as follows:

$F_S = 36.3$Hz
$V_{AS} = 9.515$ ft.^{3}
$Q_{ES} = 0.469$
$Q_{MS} = 5.77$
$Q_{TS} = 0.434$
$R_E = 5.7$
power handling = 400W

I have put my cabinets through some serious use, and can testify to the accuracy of that 400W rating. The price of the PS-15C in the 1993 Carvin catalog was $99.00, so all around it was the perfect choice.

DESIGN

For increased efficiency and cone damping, which in turn increase power handling, I decided on a double-vented bandpass design (sixth-order asymmetrical). No calculator model exists for this design; you must use computer modeling to realize it. I used Band-

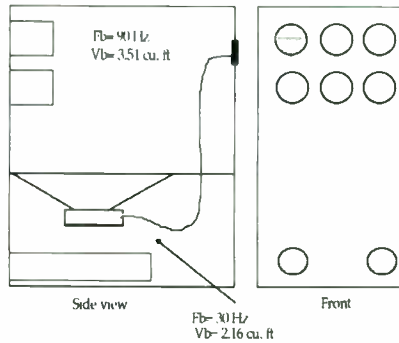

FIGURE 1: Basic enclosure concept.

pass Boxmodel, by Robert Bullock and Robert White, which for its price is a powerful program. Documentation is minimal, but Mr. White's helpfulness over the phone made up for it.

In the absence of any guidelines for this design, I was forced to work by trial and error. I devised a rough way to align box and driver. Use Margerand's calculator model to design a single-vented box, using your driver with an S value of 0.7. (I have written an Applesoft BASIC routine that emulates the process.) Then enter the data you generate into Bandpass Boxmodel, and with a little adjusting of the box volumes and tuning, you will (with luck) come up with a double-vented design of about the same physical size that plays about 3–4Hz lower and about 3dB louder.

Because this cabinet is intended for use with an active crossover in a triamp setup, it includes no passive crossover. You could theoretically use an induction coil to provide some passive rolloff, but that would turn the system into a seventh-order design, which you would have to take into account in the computer modeling. Bandpass enclosures typically sound awful when run straight through, so I recommend using a crossover of some kind.

Figure 1 gives a basic idea of the loudspeaker design. *Figure 2* shows the projected magnitude response. The 3dB down point is about 50Hz, which is more than sufficient for 99% of live work. This design may seem to have very little infrasonic energy. That is partly intentional.

Live sound rarely calls for the reproduction of extreme low-end material. Rock bands rarely use pipe organs and cannons. What you really need is a kick drum with a solid and very loud kick. The fundamental of a kick drum is around 80Hz, and the range of greatest efficiency gain covers that nicely, while limiting the very deep infrasubsonics that cause hard-to-eradicate feedback problems. With a good microphone in the kick, this enclosure delivers plenty of clear, solid punch.

Figure 3 shows the sound-pressure level (SPL) output with 400W input, the dashed line being the reference efficiency of the driver. In *Fig. 4*, note the SPL response with 50W input. This demonstrates the great efficiency of the enclosure. With careful equalization, even a moderately powered setup can deliver solid bass.

TUNING

This box is difficult to tune. The front box is large, and must be tuned to a high frequency; the rear box is small and must be tuned to a low frequency. In addition, all vents must be as large as possible to accommodate the large volumes of air that will be moved.

Of the dozens of formulas I've seen for tuning boxes, G.L. Augspurger's approach in "New Guidelines for Vented-Box Construc-

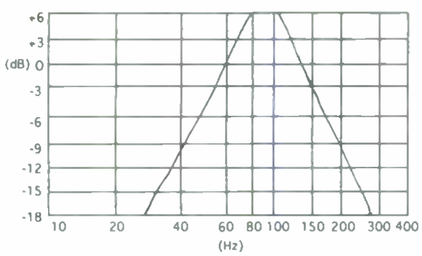

FIGURE 2: Magnitude response of cabinet.

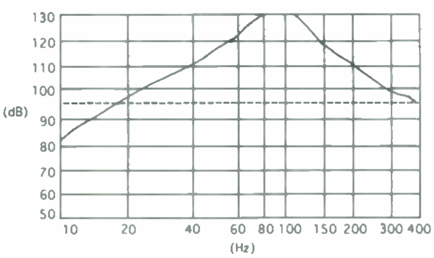

FIGURE 3: SPL at 1 m, 400W.

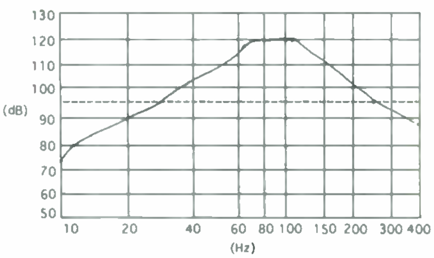

FIGURE 4: SPL at 1 m, 50W.

PHOTO 2: The "Compact Impact" triamp system.

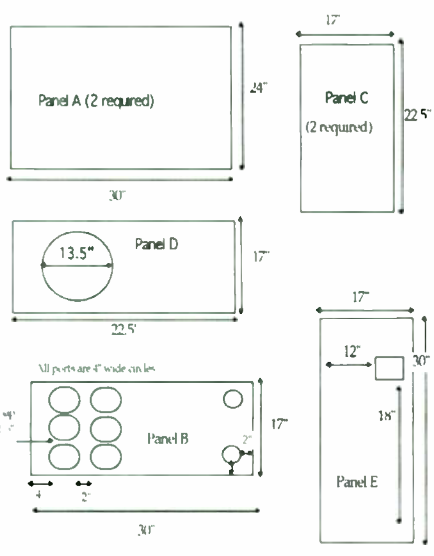

FIGURE 5: Panels required for construction. All these panels can be cut from a single sheet of ¾" plywood.

tion" (*SB* 2/91, p. 12) especially impressed me; so I used his Applesoft BASIC program VNTWRK to reconcile all the contradictory requirements. The rear box was straightforward enough, with two 15-inch-long 3" pipes tuning the box to 30Hz. The front box was tougher. I was tempted to use just one large, simple vent, but I wanted to retune the box, and to protect the driver inside. After much fiddling, I settled on six 4" PVC vents, each one-inch-long. For retuning, I simply changed the length of one and left the other five alone.

This number of vents makes for extra work on the front panel, but gives the necessary area for air to move freely (and this box moves some serious air at full power). It does give the cabinet a very unusual appearance, however—which is doubtless what inspired an acquaintance to dub it the "birdhouse."

BUILD IT

Constructing the box is straightforward; I built a pair over two weekends with simple power tools. *Figures 5* and *6* show details on panel size and placement. I used ¾" AB grade plywood for its great strength and light weight. If you plan to make this cabinet part of a permanent installation, make it out of MDF, but otherwise save yourself (and your back) considerable grief and go with the plywood. If you are feeling ambitious, you can angle the internal baffle to make the internal walls nonparallel, but I think any internal reflections would be above the cutoff of the active crossover (200Hz, 24dB/octave). I used 1½" drywall screws and Liquid Nails to join the panels together (per Robert Spear and Alex Thornhill's suggestion in "Tools, Tips, & Techniques," *SB* 6/91). These materials make for a very sturdy cabinet.

1. Ask the lumberyard to make the big cuts for you. The vertical drop saw they will probably use is much more accurate than most home table saws, and will make construction easy.

2. Use 1" × 2" furring strips to make a "map" on one panel A (which we'll now call the bottom panel [*Fig. 7*]).

3. Cut the speaker hole into panel D and then mark and drill the holes for the driver (use the driver itself as a template). Attach it to the bottom board (*Fig. 5*).

4. Now put on the sides (panels B and E), using glue and screws liberally to attach each panel to as many others as possible.

5. Glue and nail two furring strips on one panel C (*Fig. 8*) and attach it to the bottom panel so it completes the back box. (The other panel C will become the service access panel, and also complete the front box.)

6. Place the partially completed structure so that the bottom panel is really on the bottom. Run a bead of adhesive along the top of the vertical panels, and then place the other panel A on top of the structure to complete the enclosure (except for the access panel). This is easier to do with two people. Then start driving screws, as many as you can, to join the panels together (a power screwdriver helps).

7. Now place furring strips around the opening of the cabinet to form the cleats that will support the access panel. Be sure to use good-quality strips, because the long screws will split poor-quality stock. Using the strip already in place on the bottom panel as a guide, glue and nail the cleats in place.

8. Drill a hole in the baffle to accommodate the wire (*Fig. 1*). I placed the jack plate in the front box, where the pressure will be lower, because it is virtually impossible to seal the plate completely.

9. Cut the holes for the ports (panel B). A saber saw makes short work of this.

10. Cut the ports to length (again, a saber saw makes this easy) and fit them into the holes. Later, when you are satisfied with the tuning, use Liquid Nails to set them permanently.

11. Cut the hole for the jack plate in panel E (I got mine from the MCM Electronics catalog; use whichever one fits your needs, and size the hole accordingly) and install the plate. Cut a 5' length of cable and solder it to the plate. Then feed the cable through the drilled hole in the baffle. Shoot some caulk into the hole to seal it.

12. Line the back box with one inch of fiberglass. I left the front box unlined for maximum efficiency, since any soundwaves that could be reflected are above the crossover point.

13. Solder the cable to the driver, and install the latter in the cabinet. (Purists insist on T-nuts, but drywall screws work fine.) Run a bead of caulk around the outside of the driver for a good seal.

14. Use a 9V battery and a short length of cable to verify the operation and polarity of

Continued on page 40

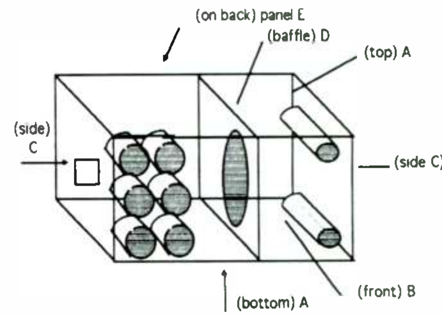

FIGURE 6: Detail of panel placement. All strips are placed so that ¾" space is left from each edge.

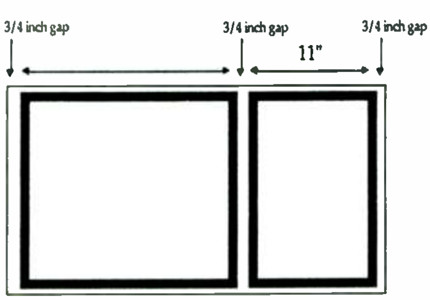

FIGURE 7: Detail on furring strip "map" on bottom panel. All strips are placed so that ¾" space is left from each edge.

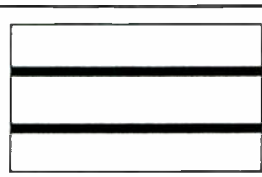

FIGURE 8: Furring strip placement.

SOURCES

Carvin Corporation
1155 Industrial Ave.
Escondido, CA 92029
(800) 854-2235
Drivers

MCM Electronics
650 Congress Park Dr.
Centerville, OH 45459-4072
(800) 543-4330
Jack plates, cable, and so on

Old Colony Sound Lab
PO Box 243
Peterborough, NH 03458
(603) 924-6371
Design software

NHT 1259

NOMINAL IMPEDANCE	6 ohm
MUSIC POWER	300 W
FREQUENCY RANGE	19-1000 Hz
SENSITIVITY (2.83 V)	90 dB
EFFECTIVE CONE AREA	507 cm2
VOICE COIL RESISTANCE	3.4 ohm
VOICE COIL INDUCTANCE	1.2 mH
VOICE COIL DIAMETER	50 mm
VOICE COIL HEIGHT	34 mm
AIR GAP HEIGHT	8 mm
XMAX	13 mm
FREE AIR RESONANCE	19 Hz
MOVING MASS (MMS)	121 g
FORCE FACTOR (BI)	9.6 TM
MAGNET WEIGHT	59 oz
QMS	2.6
QES	.56
QTS	.46
VAS	190 LTRS
KRM	28.89
KXM	26.67
ERM	.584
EXM	.647
Recomended sealed box volume	70-100 LTRS

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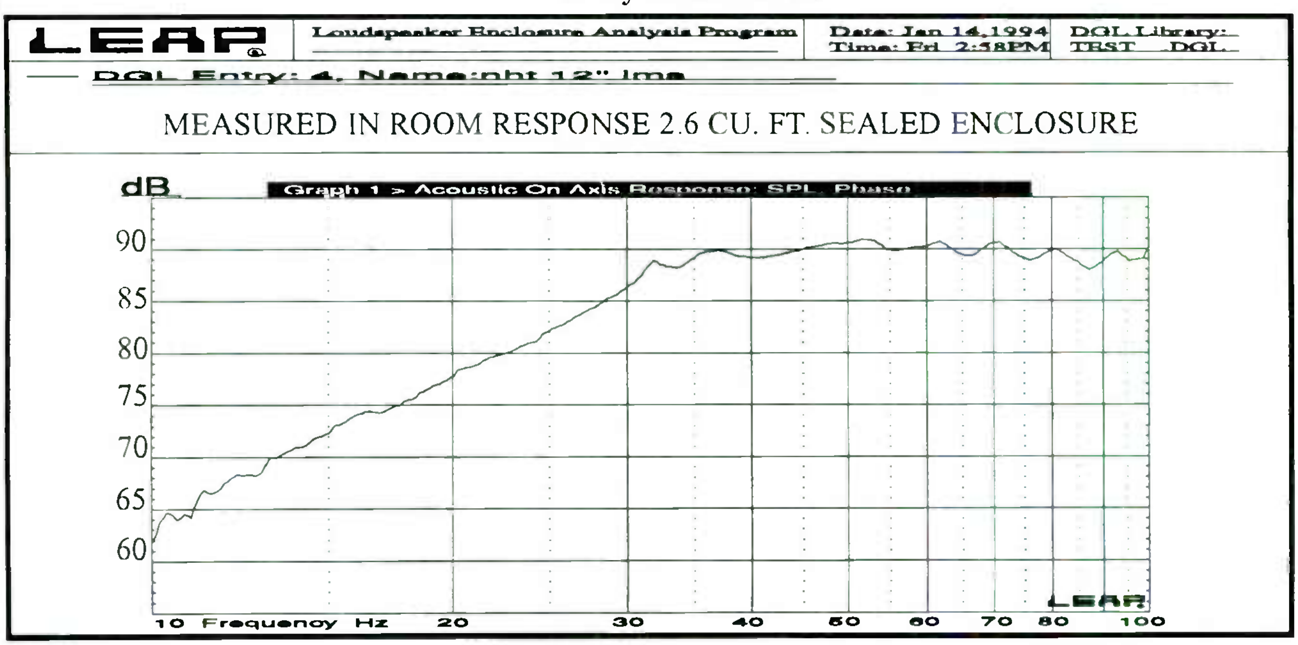
Price: $149.00/each



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Continued from page 38

the driver. (The connection that produces an outward movement of the cone should determine that the positive battery terminal is connected to the positive [+] driver terminal.)

15. Now make the screw holes in the remaining panel (the access panel). Use a 1/8" drill bit to make the holes.

16. Run a bead of windshield sealant around the cleats. This substance, which you can find at auto-supply stores, is great—it doesn't dry out, so you can get back in if you need to (Jerry L. McNutt and Mike Aughtman, "Jimmy Needs Deeps Bass," *SB 3/91*). Then, using a mallet or hammer wrapped in a towel, tap the access panel into place and screw it down, using 2" drywall screws.

17. Let the whole thing dry overnight.

The first thing you'll notice is that this is not a large cabinet. (*Photo 1* shows the author and the cabinet. I'm the one on the right.) Pick it up, and you'll be pleasantly surprised. It weighs less than 50 lbs. You can paint it if you wish, but I suggest covering it with utility carpet or Ozite (Home Depot sells stuff called Oceanfront that is excellent and very inexpensive). But how does it sound?

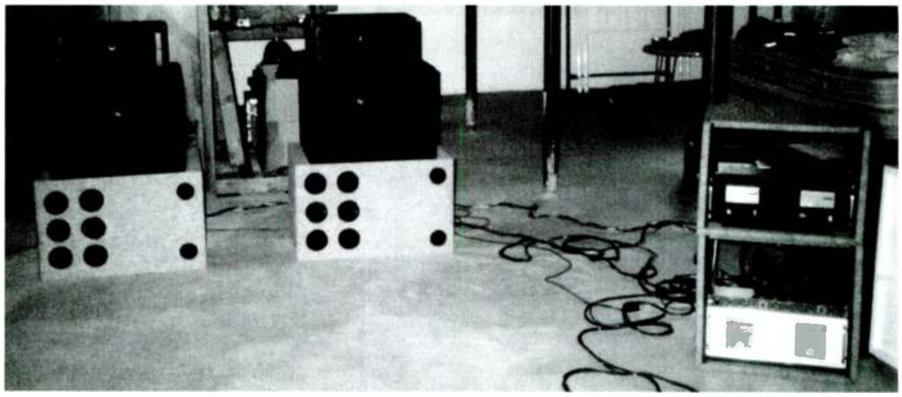

PHOTO 3: The test setup with both triamp stacks.

TESTING

The cabinet was combined with a horn-loaded midrange and titanium diaphragm horn tweeter (ElectroVoice EV-12M and DH-1201 respectively) in what I call the "Compact Impact" system (*Photo 2*). The crossover was a Rane-AC22, utilizing 24dB/octave Linkwitz-Riley filters. Two Phase-Linear 700B amplifiers (350W/channel RMS into 8Ω) provide the power. The crossover points were 200Hz and 2.5kHz. *Photo 3* shows the entire setup.

A test CD and sound-level meter showed the enclosure's response to be quite close to what I predicted, but the real test came a few weeks later when I used this exact setup at a festival of Mexican music. The client was skeptical of my system's small size, but all doubts vanished when the first band took the stage. The sound was fantastic, the kick was tight and solid, and the bass was prominent without being overbearing or muddy. I've never received more accolades than I did that night, and it's so nice to say, "I did it myself."

CONCLUSION

I have found my holy grail—a very small, light cabinet that puts out a great deal of bass. While this cabinet would not be appropriate for all applications, it works wonderfully for this one.

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SPEAKER-ENCLOSURE SCREWS

By Robert J. Spear and Alexander F. Thornhill

Boards come in a bewildering number of types—fiberboard in low, medium, and high densities, particleboard, chipboard, oriented-strand board, wafer board, hard board, and flake board, to name just a few. Particleboard and fiberboard are the types most commonly used for speaker enclosures, and each has its own type of screw.

When constructing prototypes of our TL designs Alex and I often use an inexpensive shelving board, which permits us to build one enclosure, including baffles, braces, and dividers, for less than four dollars' worth of boards. Their mushy and inconsistent quality makes these boards an excellent worst-case test for fasteners. Our experiments require repeated removal of various panels, and in the process we have gained quite a bit of experience with screws.

WOOD SCREWS

The common soft-steel zinc chromate wood screw is a poor choice for particleboard; not because it's a bad fastener, but because it's the *wrong* one. The screw body tapers toward the tip, which means the bit used to bore the screw hole must have the same taper to ensure a proper fit; but tapered drill bits have all but disappeared from hardware stores. A few specialty shops that cater to the dwindling number of craftsman woodworkers who still use wood screws carry the tapered bits, but for our purposes finding them is hardly worth the effort. Better screws are available.

The common twist bit sold in most hardware stores is actually a metal-drilling bit. A similar bit for wood, called a brad-point or centering bit, is a great improvement, but like the twist bit it drills a hole with straight sides. If you put a tapered screw into an untapered hole, the threads at the bottom of the screw don't grip the wood. The fit feels snug at the top, but since there are no threads at the top of a wood screw, the snug fit doesn't equate with a tight grip.

The wood screw has other drawbacks. The slotted head doesn't work well for powered screw driving, as the driver blade can easily slip out under pressure and damage the cabinet or puncture a speaker cone. In mushy artificial boards, burst or swollen walls and spun-out screws are the norm. Holes for wood screws are also a pain to drill using common straight bits. First you need to bore the screw hole, then counterbore for the thicker, threadless part of the shaft, then countersink the hole to receive the screw head. Special bits that do all three at once exist, but each size and length of screw demands a different one.

DRYWALL SCREWS

Some years ago, a new screw appeared on the market. It had a straight body of hardened steel, a Phillips slot, a thin, pointed tip, and a bugle head. Called by many trade names, this screw is commonly known as a drywall or sheet-rock screw. It has a tenacious grip in wood. Driven hard, it can pull itself almost completely through a 2 × 4. Building supply stores carry these screws in lengths up to 6″, so they may be your only choice when you need a long screw.

Drywall screws are normally sold with a fine thread, which, like the wood screw, is rather closely spaced and shallow. Fine-thread screws will strip out of a soft board if overdriven. Coarse-thread sheet-rock screws have a strong grip in artificial boards and can be used interchangeably with the particleboard types described below, because the threads are identical.

The Phillips slot makes the screw much easier to drive with power tools, and since the shank is straight, a bored hole needs only to be countersunk. Most screws of this type are treated with a black finish to prevent the screw from rusting in the drywall compound. Rust isn't normally a problem for us, but black screws present a nice, finished appearance in places where the screw head may be exposed.

EXTERIOR DECK SCREW

The deck screw, available from Osmose, VSI, and others, has a hardened steel shank and a bugle head with a Phillips slot. Its thread is even coarser than that of a particleboard type, so the two are not interchangeable. However, the coarse thread lets the screw be driven very fast, and the rough texture imparted by the galvanized zinc coating (though not needed for interior use) produces a fantastic grip. The deck screw is usually pale to medium gray, depending on the galvanizing process, with a dull to a semibright finish, so you might not want to use it where the head will be visible.

A nice feature of the Osmose screw is a thinner shank in proportion to length. I rarely see a particleboard screw thinner than a 1¾″ #8, but the Osmose screw is available in a 2″ #6. (A lower number indicates a thinner shank). The greater shaft length lets you get a deep grip in the butt edge of a soft board, and the smaller diameter reduces the likelihood of bursting the board. The screws from VSI can sometimes be purchased in quantities of 500 in a small plastic pail with a snap lid and carrying handle. This is handy, and the pail has many uses in the workshop when the screws are gone.

PARTICLEBOARD SCREWS

Like a drywall screw, a particleboard type is made of hardened steel and has a Phillips head and a shank of constant diameter. It has a coarse thread and a V head taper. It has no protective chemical blackening, since it normally doesn't have to contend with moisture from green wood or drywall compounds. Some brands feature a fluted tip, which improves chip clearing and provides a cleaner bore as a self-drilling screw.

Perhaps the best of the particleboard screws is the Super Sinker 17, from Equality Screw Company. This screw has just about every characteristic you could want in a fastener. Like any good particleboard screw, it has a deep, aggressive thread for a fast drive and strong grip. A long portion of the upper shank is not threaded, reducing the chance that the boards will end up screwed apart.

Equality calls the tip of the Super Sinker a Type 17. It has a single-flute "auger" for boring and chip clearing when used as a self-drilling screw. The underside of the head is the straight V type, which Alex and I prefer.

ABOUT THE AUTHORS

Robert J. Spear holds an MS in music from Ithaca (NY) College and began his musical career as a bass player and teacher. Since 1980, he and his wife have lived near Washington, DC, where they hand build violins, violas, and cellos for professional musicians. Bob is an active member of the Catgut Acoustical Society, an international organization devoted to researching the acoustics of violin family instruments.

Alexander F. Thornhill holds a degree in electrical engineering from the University of Maryland. He is semiretired from a career at the Naval Research Lab in Washington, DC. Alex designed the radio transmitter for the Vanguard satellite, and has also worked on radio navigation devices and AF filters, among other things.

The head is cleverly designed to accept both Phillips and square drives.

SQUARE-DRIVE SCREWS

The square-drive (or Robertson) screw is the most jump resistant of all. Although it has been used in commercial production for close to 90 years, it is only now gaining favor among home woodworkers. The screw gets its name from the recessed square in the head in place of the familiar slot in a wood screw or the cross-shaped slot of a Phillips head. (You'll need a #1 or #2 square bit for these screws. Bits are inexpensive and last almost forever.)

We tried a box of 1¾" #8 prelubricated flat heads with nibs from McFeely's, which quickly became our favorite fastener. The fit between the bit and the recess is so snug that you can load a screw on the bit and it won't fall off—a great feature when you must drive a screw in a place too small for two hands.

The McFeely screws are crooked, which causes them to wobble a bit as they're driven in. To our surprise, the misshapen shank, coupled with the deep thread, produces a nearly unbreakable grip. Using a drill with a clutch, we repeatedly drove and withdrew these screws dozens of times as we modified a large transmission-line enclosure. We didn't have a single "spinner." This was the only screw to turn in such a fine performance. Square-drive bits also lasted much longer than Phillips bits; in fact, we're still using our original one. The dark brown, dry lubricant finish has a nice appearance, and the square-drive head imparts a professional appearance to any project.

USING PARTICLEBOARD SCREWS

In particleboard, predrilling is highly recommended, even if a screw is advertised as self-drilling. You will wish to avoid splitting the material, especially if you are fastening near the ends or in the butt edges. It's also a good idea to slightly countersink the hole. Most available countersinks adhere to the old wood-screw standard of a conical bore. When a bugle-head screw is driven into such a hole, the rim is the first part of the screw head to make contact with the board. This concentrates pressure on a very narrow ring under the head, making the material beneath the rim splinter and lift, and the screw sinks much deeper into the hole than you had intended.

As the screw head sinks, it deforms the board material and pushes it away. After the head has passed by, the edges of the wall spring back and trap the screw. If the screw needs to be withdrawn, the embedded head will push the material out ahead of it and cause the area around the hole to rupture. This is annoying at best, and at worst can ruin the surface of a veneered plywood board. In any case it means patching the hole (or quite a few holes).

A V-shaped head with a flat taper makes full contact with the board, so the stress is distributed evenly. Screws from Equality and McFeely's boast four small nibs under the head that let the screw countersink itself. The nibs are offset so the hole is just a bit wider than the head. If the screw is withdrawn, the head exits the hole without causing damage. This greatly speeds the job, but some countersinking is still necessary. We also realized that designing a new screw is not as simple a task as it might first appear.

Being able to repeatedly drive and remove screws without damaging the surface of the panel is a great plus for our work. The only drawback to Equality's Super Sinkers is that they are at present available only in #8 and #9 diameters, but with 1"–3" lengths you should find one adequate for all but the thinnest boards. We use the 1⅝" flat head in ¾" MDF with excellent results. The selection of nibbed designs from McFeely's is even more limited; #8 comes only in four lengths, from 1¼"–2". We found that the 1¾" length is a great performer in ¾" particleboard, and there were only a few occasions when we really wished for a longer screw.

Osmose, VSI, and other screws are available at many hardware and lumber outlets, and Equality and McFeely's sell direct. Equality requires a minimum order of $35 and charges an extra $5 for shipping. To order from McFeely's, use the toll-free 800 number, or write. McFeely's service is unusually friendly and efficient, and the firm has no minimum order. The McFeely's catalog is worth having just for the explanation and drawings showing how a modern screw is made.

DRILLS AND DIMPLERS

Maybe you already own a drywall screw drill with an adjustable depth stop and clutch. The better units cost over $100, and most of us can't afford such a specialized tool for occasional use. On the other hand, a pair of speaker boxes can require up to 200 screws. Driving them all by hand is slow and tiring, and does wrists and elbows no good.

Coupled with a "dimpler," however, a power drill gives nearly the same convenience for about a tenth the cost. This handy little device, made in Germany for Disston, chucks into your drill and accepts common power-drill screwdriver bits. The descriptions below are generally applicable to similar accessories from Stanley, VSI, and Vermont American as well. The units cost between $10 and $15, and are well worth their price.

The Disston Dimpler and others won't give you the fine depth and clutch adjustments of a Makita screw gun, but the Dimpler's fixed release point, though a bit deep, has proven adequate for most of our work. If you use a variable-speed reversing drill with the Dimpler, you can get about 90% of the benefit of the dedicated screw gun. You can drive slotted, square, or Phillips drives by changing bits, which are available in most hardware stores for less than a dollar.

To make driving screws even easier, predrill the proper diameter hole, and just before use load the screw threads with paraffin. Lubricating the screw makes a difference; you can hear and feel how much easier it is to drive. A pound of paraffin is cheap and yields four bars of wax, which will last a long time. Pick a different location each time you draw the screw across the wax, to prevent wearing a deep groove in the bar.

Don't use soap—it absorbs moisture. The screw will eventually rust and may discolor the wood around it. You won't have this problem with paraffin.

To fill in the holes above a screw head, woodworkers have long resorted to a quick paste made of white glue and sawdust. Borden's now markets a fast-drying wood filler that we have used with considerable success. It's easy to sand and nontoxic, and we haven't had any problems of cracking or fallout so far. One application usually suffices, because the product has little "sag," but deep holes will require a second application.

SOURCES

Equality Screw Company
1850 John Towers Ave.
El Cajon, CA 92020
(800) 854-2886
Super Sinker 17 and others

McFeely's
712 12th St.
PO Box 3
Lynchburg, VA 24505-0003
(800) 443-7937 (voice)
FAX (804) 847-7136

Osmose Wood Preserving Co.
PO Drawer O
Griffin, GA 30224
Osmose deck screws

VSI Fasteners, Inc.
Stanton, CA 90680
Power Drive fasteners

SpeakerBuilder
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Wayland's Wood World

STICKING TOGETHER

By Bob Wayland

Before the 1900s, cabinetmakers and woodworkers relied upon joints to hold wood parts together. Joints in antique furniture often have a self-locking feature that doesn't rely upon glue for strength—the dovetail. If you do the gluing process correctly, modern glues will produce joints that are stronger than the wood itself. But even though gluing is one of the simplest steps in making an enclosure, all too often it is poorly done.

Just what is a glued joint? Normally we shape and prepare two surfaces so they are in intimate contact, spread some adhesive on each, clamp them together, and allow the glue to dry. The real strength comes from the molecular forces between the adhesive and the wood. It is the layer where the adhesive has penetrated the wood that is of greatest importance to us. Here the glue must *wet* the wood to establish the molecular closeness required.

PHOTO 1: Common glues from left to right: Garrett Wade 202GF gap-filling glue (PVA), a superglue, a hide glue (animal glue; poor for speaker enclosures), Elmer's Glue-All (PVA), and two varieties of Elmer's Carpenter's Wood Glue (aliphatic). Another common glue (not shown) is Titebond Wood Glue (aliphatic). The 202GF glue is available from Garrett Wade, 161 Ave. of the Americas, NY, NY 10013-1299, as stock #62J01.03.

The most likely reason for failure of a well-made joint is improper wetting of the wood by the glue. So here is another one of woodworking's simple secrets: **be sure all glue surfaces are in smooth contact and are well wetted by the best glue for the woods.** (You might want to consult J.J. Bikerman's *The Science of Adhesive Joints*, Academic Press, 1968.)

Softwoods are less dense than hardwoods, and generally more permeable. Cherry, oak, and walnut, though a little less forgiving, give good results under controlled conditions. While there is quite a bit of variance in gluing properties between particleboard or medium-density fiberboard (PB/MDF), you can usually treat them like oak or cherry. With very dense solid woods such as teak, which contain resins or oils, gluing really becomes difficult.

WET WOOD

One factor common to all gluing operations is the moisture content of the joined materials. Moisture is always present in wood, even kiln dried. Whether you use solid wood or PB/MDF, the goal is a moisture content of 5–8%. Without expensive moisture meters, the speaker builder is hard put to ascertain the moisture content. In *Understanding Wood* (Taunton Press, 1980), R. Bruce Hoadley gives this rule of thumb: "50% Relative Humidity (RH) gives an approximate 9% equilibrium moisture content (EMC) . . . and 25% RH gives about 5% EMC and 75% RH gives about 14% EMC."

So for best results, try to keep your workroom at about 30–40% RH and give the wood a few weeks to come to EMC before using it. If, like most of us, you can't maintain this tight control of the RH, at least be aware that with the more demanding gluing operations, you may have problems.

WHICH GLUE?

Photo 1 shows some commonly available glues. Three easy-to-use types are readily available: aliphatic, polyvinyl acetate (PVA), and urea-formaldehyde. For special purposes, such as veneering and gap filling,

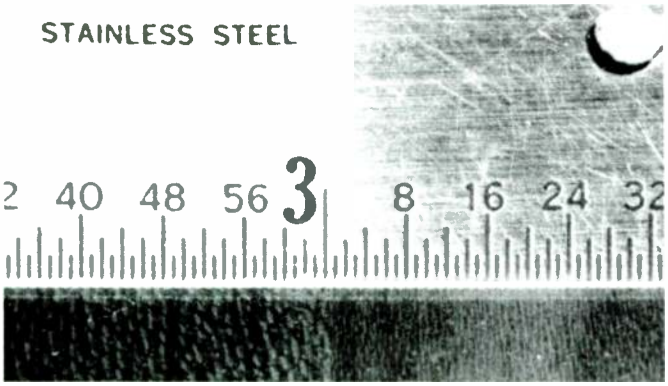

PHOTO 2: Glue line for two pieces of cherry edge glued together at the 3-inch mark. The scale divisions are 1/64".

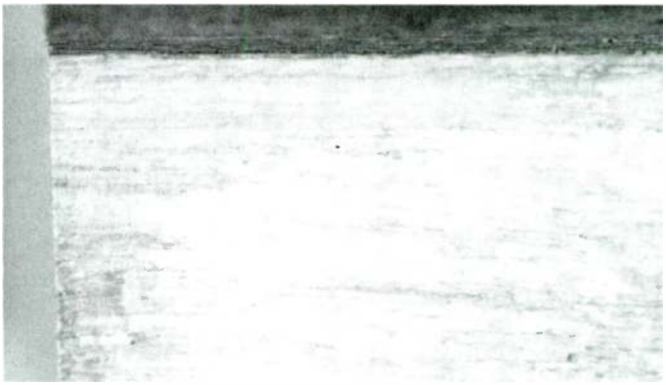

PHOTO 3: Glue-starved joint. Note the failure and separation along the glue line and the small amount of wood failure.

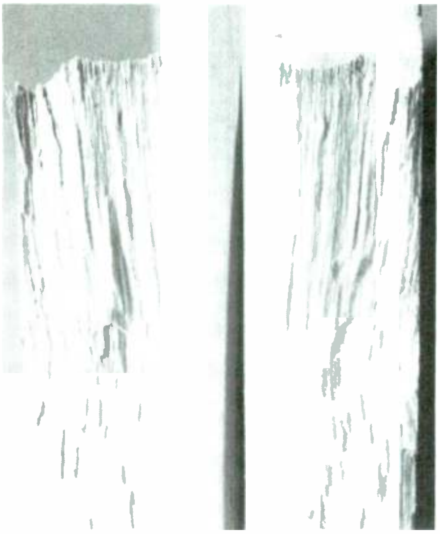

PHOTO 4: A very successful glue joint. Note the total wood failure.

PHOTO 5: Wood scrapers. From left to right: Stanley #80, hand scraper, and a new single-edge razor-blade scraper (Garrett Wade stock #52K08.01).

PHOTO 6: Wetting of wood by water: on an untreated surface, planed one week earlier (right); on a scraped area (middle); and on a sanded area (left).

speaker builders also sometimes use contact cement and cyanoacrylates (superglues). All of these will form very strong joints, and for solid wood we have little reason to choose one over another. For PB/MDF, in most applications, PVA adhesive with a high solids content (60%) gives the best results. My personal choice is Garrett Wade's gap-filling PVA 202GF.

Two caveats: Adding water to reduce the glue's viscosity can cause unwanted changes in its properties. Also, if you put your glue into a container for ease of application, avoid metal cans containing iron; the absorbed iron can cause a black stain on some woods.

GLUE LINES AND JOINTS

The glue between your two surfaces—the glue line—should be no more than a few thousands of an inch in thickness. Normally, as shown in *Photo 2*, the glue line will be almost invisible. You can, however, have too

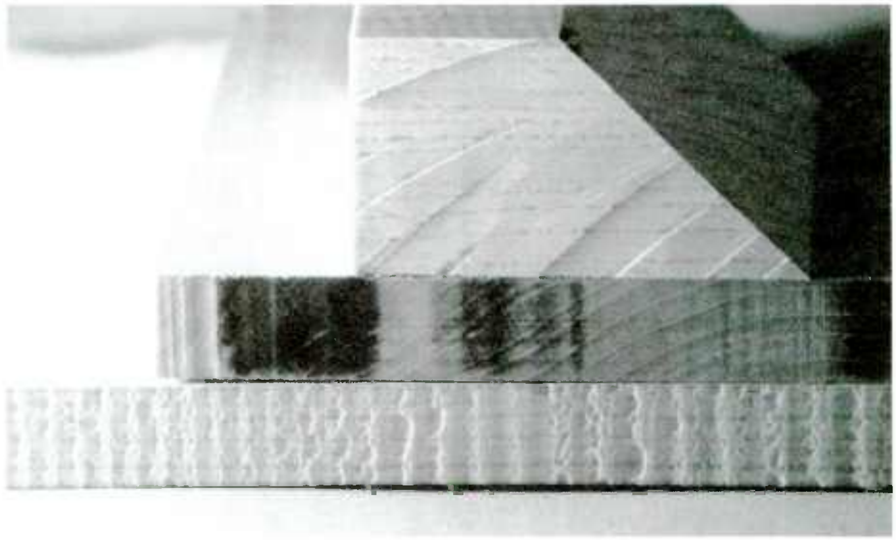

PHOTO 7: Unacceptable surface conditions for gluing.

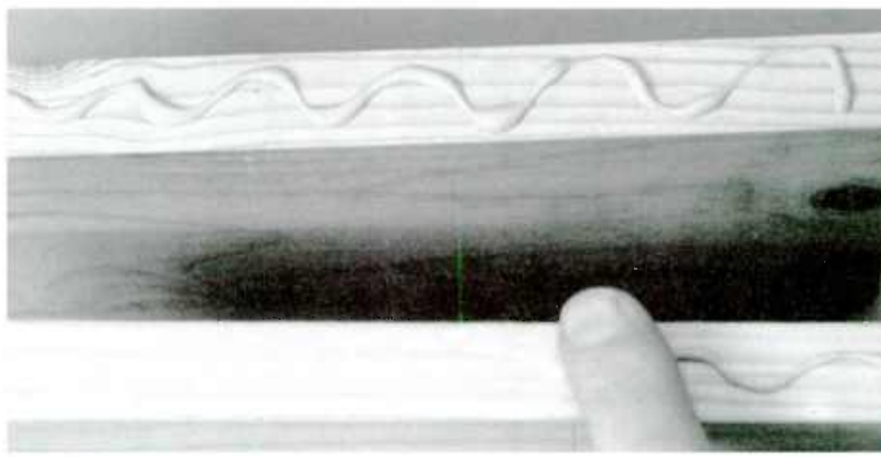

PHOTO 8: Glue application and spreading.

little in the glue line, producing a glue-starved joint. If you break such a joint apart (*Photo 3*), failure or separation will be along the glue line, where only a small amount of wood failure occurred. Compare this to *Photo 4*, where total wood failure occurred when I tried to break the joint.

NICE FACES

In making a good glue joint be sure that the glue wets the wood. Simple as this sounds, a number of mistakes are possible.

With fine sandpaper sand a sample of the wood you are using for your enclosure. Use a cabinet scraper on another area (*Photo 5*). Put

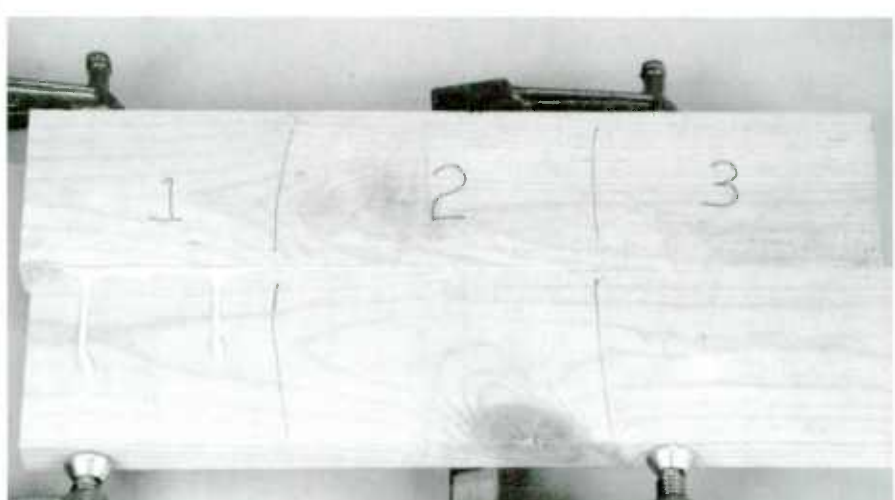

PHOTO 9: Squeezeout: too much or too soon (left); just right (middle); not enough (right).

a drop of water on each prepared area and one on a third, unprepared section. *Photo 6* clearly shows what happens if you prepare joint surfaces and let them sit around for a week. With most solid woods the results will be similar. (With PB/MDF, however, scraping is generally not effective.)

You can produce the same good wetting by planing the surfaces lightly just before you apply glue, but be careful—planing and scraping can destroy a close-fitting joint. Prepare the surfaces and glue as a single process. Also, if you use sanding for surface preparation, be sure to clean away the sanding dust. Dust particles may prevent the glue from wetting the wood properly.

Avoid two common mistakes: roughing a surface with coarse sandpaper and "cleaning" the surfaces with a solvent. Paint thinners and other solvents introduce a contaminant that interferes with glue action. Roughing a surface is part of a larger problem.

To keep the glue line thin, the surfaces must fit together very snugly. **Any distortion of the glue surface that prevents smooth, close contact will produce a poor joint**; and the condition of the surface is often destroyed by the very act of preparation. In *Photo 7*, the top block was gouged by improper sawing; a dull saw roughed up the

TABLE 1

DRYING TIMES OF VARIOUS GLUES

ADHESIVE	INITIAL GRAB	SETTING TIME	CURING TIME	DRY COLOR	
Aliphatic (A or yellow, e.g., Titebond, Elmer's Wood Glue)	10–60 sec	10–30 min	24 hours	translucent, amber	
Polyvinyl acetate (PVA or white glue, e.g., Elmer's Glue-All, Garrett Wade 202GF)	0.5–2 min	10-30 min	24 hours	clear to pale amber	
Urea-formaldehyde (U or plastic resin, e.g., Weldwood Plastic Resin)	Very slow; 4 hours pot life		4 hours	12–16 hours	light tan

Except for the aliphatic, which can be used at lower temperatures, these glues should be applied at temperatures above 70°F. Initial grab is also called "wet tack." Setting time refers to the time an adhesive needs to solidify before removing clamps or other pressure.

Curing time, a relative figure, indicates how soon the enclosure can safely be worked on. Most adhesives, however, attain only about 75% of full strength during this period and continue curing for days, taking about one week to reach 100%. Shelf life indicated on the package is relative. If you cap them tightly immediately after use and store them in a cool, dry place, glues can last a lot longer.

Most of the time you should wait for the period given in the above table as initial grab before assembling your joints. This allows the glue to develop needed viscosity. If you assemble too quickly you can produce a glue-starved joint.

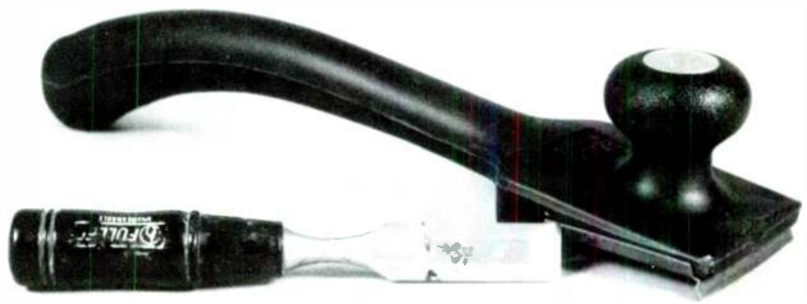

PHOTO 10: Glue chisel and scraper.

middle board; and the bottom board was fed to the jointer cutter head too fast, resulting in a ripple. One school of thought holds that using a sharp plane or jointer just before you glue is best surface preparation.

GLUE APPLICATION

The right amount of glue is crucial to a good glue line and a good joint. You can spend a good deal of money for glue spreaders, and I suspect you will find them a great bother. (An obvious exception is when you are gluing up plate joinery.) Put down a thin bead in a snakelike pattern and smooth it with your finger (*Photo 8*). Do this a few times—staying as much as possible with the same glue—and you'll soon develop a sense of just how thick a coat you need. Keep a damp paper towel handy to clean off your fingers.

If, after you have properly clamped the joint, you see a thin line of glue or a very few little bubbles along the joint (*Photo 9*), you probably used the right amount. If there is too much "squeezeout," as on the left of the joint in *Photo 9*, you may have used too much or started clamping before the glue had time to develop sufficient viscosity. Little or no squeezeout, as on the right of the joint in *Photo 9*, occurs when not enough glue is applied. Some woodworkers say that if you apply just the right amount of glue there will be no squeezeout; but in that case you wouldn't know whether the joint was glue starved.

The instructions for many adhesives advise you to apply the glue to only one surface, then rub the surfaces together to provide a good spreading of the glue. Well, OK. But what happens if you put glue on one surface and you have a lot to do and don't get back to assembling until after the adhesive has partially hardened? The glue won't properly wet the surface that didn't have the adhesive applied directly to it. To play it safe, always coat both surfaces.

GETTING RID OF THE MESS

One way to get rid of the squeezeout is to remove any surface glue contamination with a cheap chisel, held perpendicular to the joint, a little after the setting time. Clean the chisel frequently with a damp paper towel, and avoid removing any of the wood. The wood along the glue line will have swollen temporarily. If you remove any, you'll have a sunken area when the joint cures.

Another way to remove the squeezeout is to wait until the glue is cured and then use a scraper. Special scrapers are available, but an ordinary, inexpensive paint scraper (*Photo 10*) works fine.

You'll do just fine if you remember: **be sure all glue surfaces are in smooth contact and are well wetted by the best glue for the woods.**

NEW CALSOD 3.0 PROFESSIONAL SOFTWARE

This great package from Australia is the brand new upgrade to the CALSOD 2.50 Professional software from which smaller, CALSOD Standard versions such as 1.20 and 1.30 were originally extracted. Although CALSOD Standard 1.30 is an excellent and popular package which more than does the job for most people, Professional CALSOD 3.0 differs in that it is more extensive and aimed (as CALSOD was originally intended) at professional engineers, as shown below. By Witold Waldman/Audiosoft.

FEATURE DESCRIPTION	CALSOD 1.30	3.0
Modeling of sound pressure and impedance responses of vented-box closed-box, passive-radiator, and filter-assisted systems	Y	Y
Closed rear chamber and vented front chamber bandpass enclosure models for sound pressure and impedance response calculations	Y	Y
Driver impedance models with frequency dependent voice-coil inductance	Y	Y
Calculations incorporate effects of geometric placement of drivers on the loudspeaker baffle to account for time offsets	Y	Y
Simple manual curve fitting procedure for creating accurate driver sound pressure and impedance models	Y	Y
All calculations embody both the magnitude and phase response, and the driver models include minimum-phase equalizers for introducing peaks and dips in the response to accurately model actual driver behavior	Y	Y
Fast passive crossover network simulation and optimization using up to 60 components, with arbitrary component and loudspeaker connections	Y	Y
Standard filter target functions for Linkwitz-Riley, Butterworth, Bessel, constant voltage, and user-defined filter functions	Y	Y
Extensive graphics, including loudspeaker impedance and sound pressure response, crossover network filter transfer function, system input impedance, SPL on-axis and off-axis response, and SPL power response	Y	Y
Utility program for designing air-cored inductors	Y	Y
Simulation of baffle diffraction step	Y	Y
Simulation of effects of floor reflections on low-frequency response	Y	Y
Ability to provide simple analytical simulations for design studies	Y	Y
Support for HP LaserJet and DeskJet printers, as well as popular 9-pin and 24-pin dot matrix printers from IBM, Epson, NEC, and Toshiba	Y	Y
Screen plots can be saved as PCX files for importing into desktop publishing and word processing software	Y	Y
Full user's manual supplied on disk, complete with tutorial examples and formulas for initial filter network design	Y	Y
Double ported bandpass enclosure models for sound pressure and impedance response calculations	N	Y
Vented-box, closed-box, and passive-radiator simulations include the effects of enclosure leakage, absorption, and port/passive-radiator losses	N	Y
Active crossover network simulation and optimization	N	Y
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Powerful curve-fitting optimizer for determining sound pressure and impedance models of loudspeaker drivers	N	Y
Importing of SPL and impedance data from MLSSA, SYSid, System One, LMS, IMP loudspeaker test systems, incl. SPL optimization using up to 5 observation points to include off-axis radiation behavior	N	Y
Optimizing Thiele/Small parameter estimator utilizing impedance data from added mass, differential box volume, and vented-box impedance measurements, including frequency-dependent voice coil inductance	N	Y
Piston approximation for driver models to simulate driver off-axis radiation characteristics	N	Y
Specify orientation of principal radiation axis of each individual driver model used in the loudspeaker system	N	Y
Simulation of the effects of room gain on low-frequency response to help the tuning of low-frequency alignments	N	Y

Purchasing options available:

SOF-CAL3B3G	CALSOD 3.0 PROFESSIONAL Software, 3½" IBM	**$269.00**
SOF-CAL3B5G	CALSOD 3.0 PROFESSIONAL Software, 5¼" IBM	**269.00**
SOF-CALSODUP3	Upgrade from CALSOD 1.20 or 1.30 STANDARD to CALSOD 3.0 PROFESSIONAL. Please give CALSOD 1.20 or 1.30 registration number and specify new disk size.	**199.00**

NEW THIS ISSUE

ROOM DESIGN POWERSHEET SOFTWARE

Marc Bacon

A companion to the famous LOUDSPEAKER DESIGN POWERSHEET, this program covers a wide range of knowledge in easy-to-use spreadsheet format. Working from a main menu, the user can access programs dealing with room resonances, reverberation, boundary augmentation, wall diffuser design, resonance traps, and so forth. Since architectural acoustics can have more effect on final sound than anything else in the audio chain except the speakers themselves, the ease of being able to work through countless options without spending a dime on remodeling or moving furniture is very appealing. As with LDP, the RDP is priced extremely low in relation to the amount of programming effort, in order to make computer-aided architectural design available to everyone.

An unprotected source code allows the user to customize and build upon individual spreadsheets for his own use. Context-sensitive HELP and an introductory README.1ST file are also included. Requires an IBM PC or compatible with 640K of memory, hard disk, and Lotus 1-2-3, Quattro-Pro, Excel, or any other spreadsheet which can use Lotus *.WK1 files. PLEASE NOTE THAT SPREADSHEET SOFTWARE IS NOT INCLUDED.

ROOM DESIGN POWERSHEET MENU TREE

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		Help
	Room reverberation above 250Hz	
	Loudspeaker room boundary effects	
		Help
	Diffuser design	
	Steady-state value of sound pressure	
	Helmholtz resonator design	

Purchasing options available:

SOF-RDP1B5	ROOM DESIGN POWERSHEET for IBM, 2 x 5¼" DS/HD	**$59.95**
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> $200.00	6.00	30.00	25.00	30.00	40.00	50.00

NEW THIS ISSUE

STEREO DESIGN FOR THE HOME — BKAU1 — $7.95

Ray K. Dehn

Still in its original dust jacket, this is the first book ever published about the design of home stereo systems. Actual installations are shown in great detail through the use of 108 illustrations and photographs. Topics covered include how to save money and floor space; choosing your stereo components; the qualified dealer; how much you should spend; the effects of room environment and what to do about it; FM multiplex broadcasting; proper volume level; how much amplifier power you really need; operating your equipment; and (!) future developments and obsolescence. Chapters are: The Exciting Stereo Idea; Drapery—An Ideal Stage; Stereo Systems in Bookshelves; Speaker Staging with Cabinets; Speaker Systems—Their Design and Selection; Selection of Stereo Components; Operating Your Equipment; and You and Your Dealer. A collector's classic that belongs on every audiophile's bookshelf! 1962, 203pp., 6¼" x 9¼", hardbound.

THE THEORY AND DESIGN OF LOUDSPEAKER ENCLOSURES — BKSA1 — $24.95

J. Ernest Benson

This recent reprinting highlights the work of the man who was Richard Small's mentor and indeed has been called the Australian (Harry F.) Olson. The work was originally published in three parts in the *Amalgamated Wireless Australia Technical Review* in 1968 ("Electro-Acoustical Relations and Generalized Analysis"), 1971 ("Response Relationships for Infinite-Baffle and Closed-Box Systems"), and 1972 ("Introduction to Synthesis of Vented Systems"). Don Keele has said of this book: "It is a classic, and even more comprehensive and detailed than Thiele and Small's loudspeaker papers as published in the *AES Journal* (if you can believe that!). He goes into an exhaustive analysis of the infinite-baffle, closed-box, damped vented-box, passive-radiator vented-box, and acoustic-resistance controlled systems. The papers are very instructive and a must-read for anyone seriously interested in low-frequency cabinet design. It contains the only complete mathematical model and formula that includes all the previously mentioned systems that I know of... It's very mathematical, but written in an easy-to-understand manner. I highly recommend it!" We recommend it as well, with the understanding that it is indeed very technical and is certainly not for beginners. 1993, 244pp., 6" x 9", softbound.

AUDIO TEST & MEASUREMENT: CONFERENCE PROCEEDINGS — BKAS9 — $34.95

These thirty-two papers from the Portland, Oregon, Eleventh International Audio Engineering Society Conference of 29-31 May 1992 cover both the engineering and production aspects of testing, including state-of- the-art techniques. Authors examine electronic, digital, and acoustical measurements, bridging the gap between subjective and objective measurement to advance the science of audio testing. 1992, 359pp., 8¼" x 11¼", softbound.

305 CIRCUITS — BKAA28 — $27.70

Elektor Electronics Magazine

This recent addition to the famous "Circuits" collection demonstrates the practical aspects of electronics through projects that can be built at home, in a small workshop, or in the physics or science departments of schools and colleges. The volume includes projects for everyone, covering audio and hi-fi; computers and microprocessors; music and electrophonics; radio, television, and communications; and test and measurement equipment. United Kingdom, 1993.

HIGH-QUALITY ALPS 10K POTENTIOMETERS — VR10KB — $35.00

Alps Electric Company, Ltd.

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PLEASE NOTE THAT OLD COLONY NO LONGER CARRIES SOF-CAP1B5G, THE SHAREWARE VERSION OF PC-ECAP WHICH SOLD FOR $9.95.

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Richard Maddox

DAT recorders are already in use in 75% of the recording studios in the US, but there is a critical lack of reliable information on service and repair. This reference fills that need, supplying a wealth of technical detail and practical advice for engineers and technicians. Included are step-by-step instructions for regular maintenance and repair; detailed techniques for maintaining and adjusting tape transport and head alignment; complete how-to instructions for replacing the record/play head drum; a complete engineer's checklist for DAT troubleshooting; and specific service notes, by make and model. 1993, 256pp., 6" x 9".

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Kit Report

VMPS LARGER SUBWOOFER

By John F. Bundy

VMPS LARGER SUBWOOFER, Itone Audio/VMPS Audio Products, 3429 Morningside Dr., El Sobrante, CA 94803, (510) 222-4276, FAX (510) 232-3837.

SPECIFICATIONS: Frequency response: +0, –3dB 17–250Hz; THD: 0.4% max 22–250Hz with 1W drive; Sensitivity: 95dB/1W/1m; Max. undistorted output: 128dB/1m for 5% THD; Drive complement: 12″ & 15″ PPL active, 15″ slot-loaded PR; Recommended crossover range: 60–150Hz; Impedance: 4Ω; Power requirements: 20W min, 350W max; Dimensions (HxWxD): 39″ × 21.5″ × 17″; Shipping weight: 160 lbs; Finishes: Genuine oak or oil walnut veneer; black grille; Internal wiring: Powerline 11a.

PRICE: Kit $529, assembled $649; kit without cabinet $349. Prices include shipping in 48 states.

The following account is a predominantly subjective, only moderately technical report of my experience in assembling a VMPS Larger Subwoofer. After years of avidly pursuing the elusive goal of audible lowest-octave bass, primarily through the design and construction of home-made woofers, I decided to try this intriguing commercial unit, which claimed response of –3dB at 17Hz.

The VMPS Larger Subwoofer consists of two front-mounted drivers (12″ and 15″) and a downward-firing, slot-loaded 15″ passive radiator. The two active drivers can be driven in parallel, as one channel, or separately, so that a single unit can handle both right and left bass channels. The cabinet measures 39″ (H) × 21.5″ (W) × 17″ (D) and is available in oak or walnut veneer. The price is $479.00, including shipping.

The kit arrived in two well-cushioned boxes: one large, heavy unit consisting of the main cabinet with the passive radiator temporarily pre-mounted, and the other box containing the two drivers and miscellaneous parts. These dual drivers are of average quality, with stamped frames, polypropylene cones, and 2″ vented voice coils, with a rubber surround on the 12″ and a foam surround on the 15″. No Thiele/Small parameters are supplied. The f_S of each speaker is 25Hz. A phone call to the company revealed that the 15″, slot-loaded passive-radiator is factory tuned to 10Hz.

Without the grille and the grille frame, the 8.25 $ft.^3$ cabinet weighs around 75 lbs—a far cry from the VMPS brochure boast of "160 lb oak- or walnut-veneered enclosure." Even adding the weight of the grille frame (11 lbs) and that of the active speakers, the total weight would only be around 100 lbs. Even so, this is a heavy speaker. If you plan to move it around much, I recommend adding some heavy-duty casters.

SHODDY PREPARATION

The instruction manual, a computer printout, is fairly well written. Most of my minor assembly problems stemmed from a shortage of parts and shoddy factory preparation. Only enough gasketing was supplied to take care of the 15″ passive radiator and the 15″ active woofer, for example; I used my own gasketing for the 12″ speaker and the two speaker-terminal mounting plates. The kit contained only one set of speaker terminals, although I suspect most people will use this speaker for both right and left channels, by making separate (left and right) connections to the two active drivers. Internal wiring is Monster Special cable. The upper terminal mounting-plate opening had a substantial gouge in the routed inset, which I had to fill before installing the plate.

The instructions for adjusting the mass of the passive radiator (by using Mortite on the cone) ran out in mid-sentence: "You can also remove putty from the factory amount: this will make the...," leaving me in suspense as to the effect of this modification. The temporarily premounted passive radiator was oriented in such a way that it was impossible to add the eighth fastening screw, as the cabinet frame was in the way; rotating the radiator 10° would make inserting screws easier.

VMPS has been making this unit for years. Such little flaws and annoyances should have been corrected long ago.

Assembly took only a few hours, and the finished speaker has a pleasing, if massive, appearance, with an oak (in this case) veneered top, top edge, and bottom edge. The remainder, front and both sides—a major expanse—is black cloth. The measured maximum impedance, with the drivers paralleled, occurred at approximately 50Hz, with the lower minimum impedance at 25Hz, suggesting that this is the tuning frequency of the box.

QUALITY

The bottom line is, of course, sound quality. Testing the VMPS with low-frequency material from some of my favorite CDs proved beyond doubt that this woofer has authority, and is one of the few moderately priced units on the market that can produce accurate and impressive response in the lowest musical octave.[1] Add a couple of quality satellite speakers and a well-designed crossover, and for less than $1,000 you can enjoy a speaker system of exceptional quality, capable of clean, room-shaking bass.

MANUFACTURER RESPONSE

I am puzzled by Mr. Bundy's remarks concerning weight. Our standard subwoofer, which is one-third smaller than the Larger model with one fewer active driver, weighs 105 lbs in its shipping carton. It takes nearly a whole sheet of ¾″ MDF to make the cabinet of the Larger Subwoofer. We have never been able to ship this unit via anything but truck due to its size and weight. Usually we strap it to a small pallet and ship it as 150 lbs. We do not pay for shipping weight a product doesn't have. Mr. Bundy should check his shipping waybill.

I am also puzzled by Mr. Bundy's failure to mention one of the unit's most remarkable features: the adjustable bass damping. The mention of a 25Hz "tuning frequency" is irrelevant in a unit which has such a wide range of adjustable Q. Tuning the system to listening environment and associated equipment is the first job of the kit builder or new owner of factory assembled. I'm glad the reviewer liked the sound.

There is substantial slot output in the near-field below 17Hz; we select this as the nominal –3dB for convenience. The active drivers measure ±2dB from resonance to about 400Hz.

Brian Cheney
Itone Audio

FOOTNOTE

1. Particularly the end of Hindemith's Organ Sonata no. 1 (track 5, London 417 159), which will shake your house with an almost subaudible pedal-point somewhere in the region of 20Hz; and the huge drum strokes on Al Di Meola's "Kiss My Axe" (track 2, Tomato 79751).

Tools, Tips & Techniques

DANGER FROM NOISY DRILLS

Clearly, if the speaker builder's goal is to create great sounding speaker systems, he or she cherishes a keen sense of hearing. Alex and I have always worn hearing protectors when using power saws or routers. When using power drills, however, their small motors led us to believe they weren't as loud as other power tools. My wife, Deena, noticed that I lean over the drill, bringing my ears close to the motor. She suggested we run a few tests on our collection of drills with a sound-level meter. She thought the results might surprise us. They did.

The nastiest surprise in this survey was that the sound-level meter picked up decibels we didn't hear. In other words, we couldn't tell by listening which drills posed the greatest threat from noise. This should give you pause before pulling the switch of any power tool. We also found that the slower a drill, the quieter it measured. The slowest drill in our test was the quietest, in fact, but then we got another surprise: the fastest wasn't the noisiest. The Sears 315-2578 was slightly quieter than the Makita 6510LVR, even though it runs at twice the speed. The variation in noise levels between modern and older motor designs was often quite small. In our admittedly small sample (*Photo 1*), one of the newest drills was the loudest. *Table 1* shows the results of our tests on six drills ranging in age from one year old to over forty.

We also noticed a significant increase in noise when the drill bit was boring through a board, doubtless due to vibrations in the work piece. A partially completed enclosure acted as a reflector, amplifying the noise from the drill plus its own resonances. From a box with five sides we measured a doubling of acoustic power at a distance of one foot, pushing up all the readings by 3dB. The Makita drill plus the reflected noise from the enclosure produced an SPL of 106dBa at the ear—louder than a riveter and well above the highest safe level, according to the US Department of Labor's noise regulations.[1]

Exposure to this noise level for more than about 45 minutes a day can cause permanent damage to your hearing. And as your ear gets closer to the drill, the SPLs will rise dramatically.

One of the quietest drills on the market is the Bosch 1022VSR, a 3/8" variable speed reversing drill, which we weren't able to test.[2] An interesting alternative to electric-line-powered drills is the newest designs in battery-powered cordless drills. We have experience with two, the Panasonic EY6281 and the Sears 315.111320. While they are generally somewhat higher in cost than corded drills, and a bit less powerful, these

TABLE 1

HAND-DRILL SPL LEVELS

Manufacturer	Year	Model	Top RPM	SPL
Sears	c. 1950	315-2578	1,600	101
Black & Decker	c. 1965	7104 Type 1	1,200	98
Sears	c. 1980	900-27199	2,500	98
Makita	c. 1985	6510LVR	1,050	103
Panasonic	c. 1990	EY6281	350(low)	80.5
			1,000 (high)	83
Sears	c. 1991	315.111320	400	79

SPLs in dBa of six electric hand drills, four portable and two cordless. The measurements were made with a Radio Shack sound-level meter, Catalog #33-2050, the unloaded drill running at full speed. The drill case was at right angles to the SPL meter, at a distance of 12".

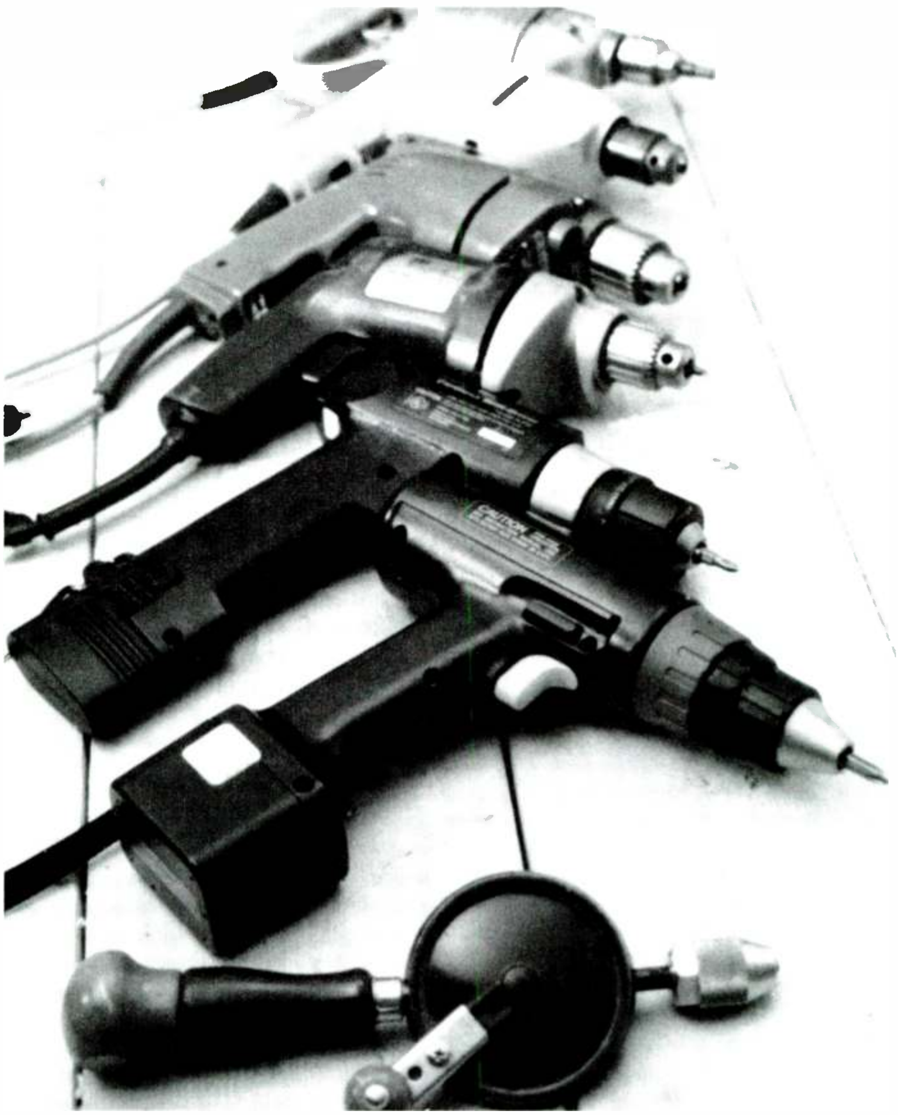

PHOTO 1: The drills used in this test (rear to front): Sears Craftsman (315-2578), Black & Decker (7104 Type 1), Sears Industrial (900-27199), Makita (6510LVR), Sears cordless (315.111320), and Panasonic cordless (EY6281). The quietest drill is in the foreground.

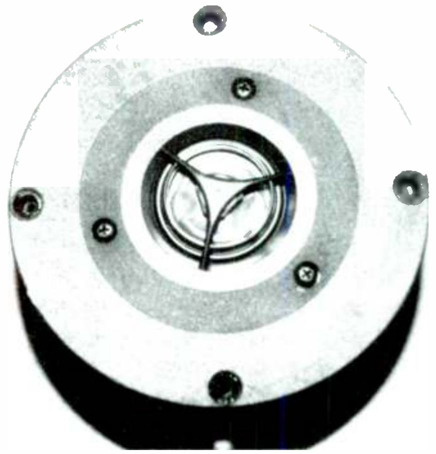

PHOTO 1: Dented Vifa aluminum dome tweeters (D25AG-35-06).

feature-laden tools run with significantly less noise.

Earmuff-style protectors are commonly available for ten dollars and up, and small rubber earplugs—which actually do a better job—cost just a few dollars. Stethoscope-type hearing protectors, which are light and

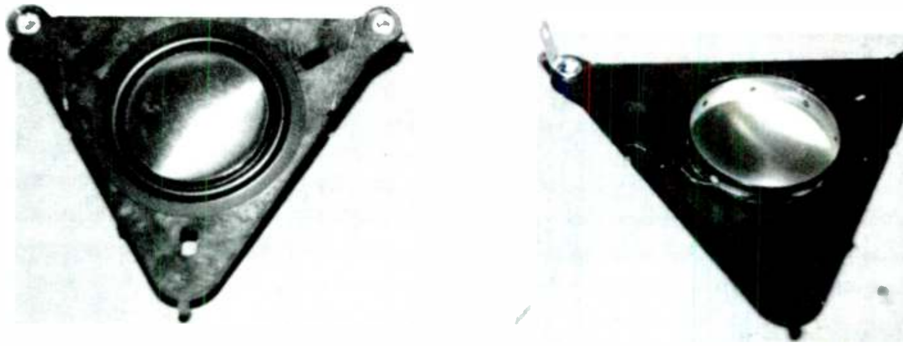

PHOTO 2: Replacement dome/voice coil (D/VC) assemblies.

hang comfortably around the neck when not in use, are popular in wood shops in our area.

We urge you to use a hearing protector whenever you use a power tool of any kind. If dealing with earmuffs or earplugs seems like a pain, remember this; ears don't toughen up the way muscles do. Once your hearing is damaged, it's damaged forever.

Robert J. Spear and Alex F. Thornhill
Accokeek, MD 20607-0212

REFERENCES

1. Tandy (Radio Shack) Sound Level Meter Owner's Manual, p. 15.
2. Thomas Klenck, "Electric Drills," *Popular Mechanics* 168 (June 1991): 59.

TWEETER REPAIR

Something didn't look right. A closer inspection revealed that my Vifa aluminum dome tweeters (D25AG-35-06) had been dented by small, probing fingers and even a pencil point (*Photo 1*). I was sure I would have to replace the tweeters, at $25 apiece, and needless to say I was a bit upset with certain children. Then I remembered—replacement dome/voice-coil (D/VC) assemblies were available for the tweeters. It was worth a try, and I ordered the parts from Audio Concepts.

The new D/VC assemblies came about a week later (*Photo 2*). I carefully removed the tweeters from the speaker enclosures and unsoldered the wires, then removed the three inner screws on the front of the faceplate and removed it (*Photo 3*). This revealed the triangular D/VC assemblies, held in place by small nubs on the magnet-assembly front plate. Between the D/VC assemblies and the

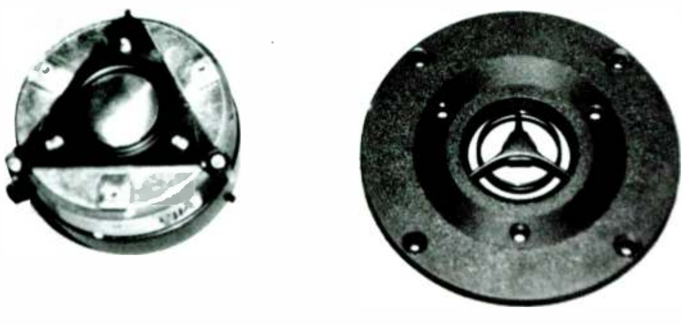

PHOTO 3: Faceplate removed, revealing D/VC assemblies.

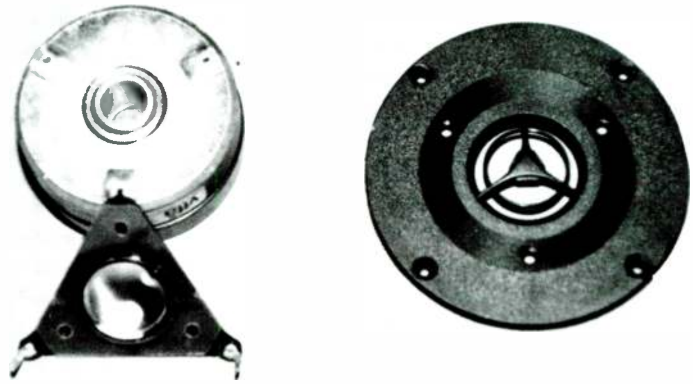

PHOTO 4: D/VC assemblies removed from magnet assembly.

magnet-assembly front plate was a thin sheet of insulating material to keep the voice-coil leads from shorting to the magnet assembly. I carefully lifted the old D/VC assemblies off the magnet assembly and removed the insulation sheet (*Photo 4*).

Installation of the new D/VC assemblies is the removal in reverse. Lay down the insulation sheet and carefully lower the voice coil into the circular gap in the magnet assembly. Align the nubs in the magnet-assembly front plate with the holes in the D/VC assembly. Replace the faceplate and secure the three screws. The whole process took me no more than half an hour, and the tweeters, reinstalled in the enclosures, sound fine.

Overall, this was a (fairly) painless, inexpensive way to repair damaged tweeters. I do have a couple of reservations: first, when I removed the old D/VC assemblies, a small amount of magnetic fluid clung to the voice coil. I don't know if the amount of fluid is critical, but there's slightly less after the replacement operation. Second, after I removed the old D/VC assemblies, I was able to push the dents out from the inside of the domes, and could barely tell they'd been damaged. So it might be worth trying to repair your domes before even spending the money on D/VC assemblies.

Stephen A. Crosby
APO AE 09470

SOURCE

Audio Concepts, Inc.
901 South 4th St.
La Crosse, WI 54601
(608) 784-4570
FAX (608) 784-6367

Software Report

LOUDSPEAKER 6.0

Reviewed by Dick Campbell

LOUDSPEAKER 6.0, Maximum Effort Software, 2701 Cedarwood Ave., Bellingham, WA 98225. Released November 1993. Kit includes 136-page user manual. Suggested price is $65.

Max Knittel knows what he is doing. Has he produced a useful piece of software to aid speaker-system designers? *Yes*—and at a reasonable price. Has he produced a manual to go with it that makes sense? It's magnificent—an example to all of what a software manual should be.

Many otherwise useful programs fall seriously short in the user-manual department. Mr. Knittel provides clear text, good screen captures, good illustrations, comprehensive references and index, and a nice consistent style.

The program runs under DOS and is painless to load. In 136 pages, its LS directory comprises 14 files totaling 873,230 bytes, and the LS\LIB directory's 14 files total 45,227. If you have a meg available on disk you're OK—thank goodness it's not "fatware." Your computer must have 512K of free RAM. The program will use a mouse, a coprocessor, and extended memory (bigger than 384K).

Mr. Knittel has changed the library format of earlier versions, so to convert old LIB files you'll have to run the PRINTLIB program. His configuration file LSCONFIG can change just about anything, from screen color to nine different printers. Since the program designs crossover coils, it asks whether you wish to use the American Wire Gauge (AWG) or the British Standard Gauge (SWG). How's that for a question?

It pays to work your way through the tutorial (Chapter XII). Like all software, LoudSpeaker 6.0 has quirks and keystroke sequences that are puzzling at first. If the contextual help screens fail, the manual has the answer. The main menu illustrates what you can do with the program:

- EDIT DRIVER PARAMETERS
- ILLUSTRATE BOX
- CHANGE BOX PARAMETERS
- DESIGN CIRCUIT
- WIND INDUCTOR
- VENT BOX
- MODEL LOUDSPEAKER
- GRAPH RESPONSES
- PRINT DESIGNS

FEATURES

Most Mind-Blowing Feature: Being able to type a number into a dialog box and follow it with units, like <c> for centimeters, <"> for inches, <l> for liters, <'> for feet and <m> for meters, no matter what units are default. If you follow one of these "switches" with an <a>, it means "area"; e.g., <"a> means "square inches."

Most Annoying Feature: There is no keyboard buffer flush when you auto-repeat-scroll the cursor to the edge of a dialog box, so you are beeped to death 15 times while the keyboard empties its guts. Not with an *ahhhh* but a *screeeech.*

Most Worrisome Feature: Going into VGA graphics mode on my 386-25 makes the Logitech bus mouse think it's at the bottom of the screen when the arrow is in the middle. In other words, the bottom half of the screen is off limits to the poor rodent. This problem has to do with a VGA video-card mode error. The same thing happens on my 486-33 with an E4000 VESA card and Microsoft mouse. A knowledgeable reader may shed some light on this. The Borland compiler should have handled it, *pas vrais*?

Most Frequented Feature: No matter what you're doing, Alt-M gets you a menu whence you can escape if you wish. If you start entering driver parameters and change your mind, however, the only true escape is Alt-M-Q-Y back to DOS, then restart the program. Kind of a waste.

Most Intelligent Feature: Being able to "stack" up to ten designs in memory is great, because you can compare them readily by printing or graphing. The development of a loudspeaker system is a trial-and-error process, zeroing in on a final design, and it's wonderful to have instant access to your other nine trials.

Cutest Feature: Getting a wire-form image of the box, driver hole, and vent tube up on the screen is comforting; it makes you think it's all going to fit after all. You can locate the vent tube and the speaker hole on different sides in different orientation, then print it out.

Most Comprehensive Feature: Designing crossovers. All configurations are available, from two-way first-order to three-way fourth-order. A subtle engineering compromise to inputting the entire driver-impedance data is to put in the driver impedances at the crossover frequencies only, preferably after designing the driver-impedance-correcting networks.

Potentially Most Useful Feature: Need an inductor? Open a window, type in the millihenries, pick a wire size or a coil-form diameter, and bingo! OK, Mac, where do I buy the plastic coil forms?

Most Aggravating Feature: Has some supernatural power ordained that there be a rigid envelope containing the acceptable "alignments" and all territory outside is forbidden? From an acoustical-engineering viewpoint nothing is forbidden, even if it's stupid and unrealizable. I want to be able to bolt any driver into any box and see the results. If my computer tries to divide by zero as a result of my stupidity, beep and slap my hand. LoudSpeaker 6.0 limits the user to only those alignments known to produce good results.

On second thought, that's not such a bad idea for most users who are just looking for excellent sonic results for minimal hassle. Keeps the tech-support line quiet as well, I suppose. And speaking of tech support, the documentation that accompanies the program provides no phone or FAX numbers for anyone seeking help. Nor does it list error messages with explanations.

BANG FOR THE BUCK

For $65 the user gets an engineering design tool that is thorough, accurate, well explained, and eminently useful. The upgrade announcement calls LoudSpeaker 6.0 the "'Swiss Army Knife' of speaker-design programs." It is—nothing else is required to succeed in a speaker-design project.

For mice that can't get to the bottom of the screen alternate keystrokes are available that work just fine. And unless you have a serious computer hardware or memory glitch, your operational tech support comes from the loudspeaker-design literature.

LoudSpeaker 6.0 delivers a big bang for the buck. I recommend it.

Continued on page 70

Works In Progress

A REEVALUATION OF TL THEORY AND PRACTICE

By Kevin Blair

My compliments to Robert Spear and Alex Thornhill on their contribution to the understanding of what goes on inside a transmission line's labyrinth ("Fibrous Tangle Effects on Acoustical TLs," *SB* 5/91, p. 7). I agree with their conclusion that, for most practical purposes, "transmission line theory has not progressed much since the time of Bailey's original article." One of the reasons for this lack of progress is the neglect of the work and scant writings of John Wright.

For those of you unfamiliar with him, Mr. Wright was the chief engineer for a British loudspeaker company originally known as IMF, later as IMF International, then as IMF Electronics. In the early 1980s, the company went belly up. This string of names is not to be confused, as it often has been, with the I.M. Fried Company, although Mr. Fried was the original contributor of the initials. In the mid-1980s, Wright and his designs reappeared with a new company: TDL Electronics.

By the 1970s, Wright had abandoned Bailey's original 1965 quarter-wavelength TL design and had marketed a series of loudspeakers based on the theory of a single unified filter. Over the last 15 years, I have tested and listened to Wright's designs, as well as those from many others. I have not found another design to date—save my own—which implements this kind of revision. In fact, I have been unable to determine whether any other manufacturer follows a consistent filter theory approach throughout its series of TLs.

The aforementioned lack of progress is easily understood, because most people have never questioned the validity of Bailey's original assumptions and interpretations. According to his theory, the overriding justification for why we still pursue this technique is that "the only safe method of removing the rear cone sound energy is by transmitting it down an infinite transmission line."[1]

We wish to control and reduce colorations while extending low-frequency response; however, we are to achieve this low-frequency extension only in a controlled and limited manner, as revealed by his experiments. He states that "the bass improvement was due to the line length being such that the delayed bass wave from the line was in phase with that radiated by the front of the cone."[2] And later, "it is therefore possible to use the radiation from the open end of the pipe to reinforce that from the front of the loudspeaker cone at low frequencies."[3] Although they have been the basis of many TL design projects, these statements are neither completely correct nor indicative of the actual driver-line interactions.

ROGER SANDERS RESPONDS

Mr. Blair's ideas are fascinating, yet so radical—redefining as they do the entire theory of transmission line design—that I find them difficult to accept without proof. To determine whether his theory is true, we need solid scientific data. His article contains interesting quotations and opinions, rather than the results of well-designed experiments and studies. Therefore, I can draw no conclusions from it.

For a theory to become a "rule," it must be an accurate *predictor* of performance. Ohm's law is such a rule: you can reliably predict the current in an electrical circuit by dividing the voltage by the resistance.

Bailey's original transmission-line theory also fulfills this basic criterion. You can undoubtedly design a speaker system with superb performance following his outline, as many independent designers have proven over time. His theories demonstrate *reproducibility*, and they have *withstood the test of time*—two features of a valid scientific law. We have yet to subject Mr. Blair's ideas to these tests.

A rule need not be true to be valid and useful, however, only accurately *predict* an outcome. For example, some people work with electrical circuits using the idea that current flows from positive to negative, which is not true. Although technically the rule is incorrect, it is valid because you can use it to design (predict) electrical circuitry. The fact that Mr. Bailey's rules are predictive does not preclude Mr. Blair's theory from being true.

A significant difference exists in the way the two authors build their enclosures, so that the two speaker systems may operate in entirely different ways. Specifically, a classical Bailey line is completely stuffed with damping material; the air is not free-flowing. Wright recommends a different approach: "...the line should *not be stuffed* [emphasis added]...the damping material must allow a free flow of air." Blair adds: "the line is not stuffed...I prefer to "weave" a matrix from strips of...foam...the nonrestrictive nature of this..."

In summary, I don't dismiss Mr. Blair's theory, rather I am inclined to believe that his design works well. Is it a transmission line, though, or a combination of "infinite baffle, labyrinth, and reflex loading" as he suggests? If so, then I suspect his theory is a variation of, rather than a new theory to explain, the classical transmission-line enclosure.

I know that Bailey's rules work; I suspect that Blair's do as well. I don't think that finding one valid precludes the other from being so. I cautiously await some convincing evidence in support of Mr. Blair's theory.

ROBERT SPEAR RESPONDS

One of the biggest obstacles Alex Thornhill and I faced with transmission lines is that they lack the rigorous definition available for vented boxes. We based our understanding on Dr. Bailey's description of them as nonresonant systems.

While we agree with Blair that it's sometimes a good idea to question basic assumptions, we are concerned with his assertion that a TL at low frequencies acts as a Helmholtz resonator. If a device displays twin impedance peaks, it's resonant, and, therefore, not a TL. Furthermore, the action of a Helmholtz resonator and the resonant responses of a quarter-wave line are markedly different.

Blair uses the twin "impedance maxima" to prove that the TL is an "over-damped reflex enclosure." In testing, we regularly record lines with three, four, and even five peaks. This condition varies considerably depending upon line design, length, woofer Q_{TS}, and stuffing density. The lowest of these peaks occasionally is eliminated as stuffing increases, although sometimes a peak is created where none had existed. We do not yet understand why this happens.

Blair uses short lines with a length less than a quarter-wavelength at low-frequency cut-off. He also uses purely resistive damping methods, which do not permit regulation of the phase relationship at "resonance" (for lack of a better term). We think his systems belong in that area of hybrids John Cockroft sometimes writes about. As Blair points out, there are ways to create a good-sounding speaker by borrowing vented-box practices and adapting them to line-like enclosures, but we would like to see more concrete support of his assertions.

Finally, it's a pleasure to learn of John Wright's work in the TL field. We had not known of his contributions before, and would like to obtain copies of his writings if possible.

TL MODELS

As most commonly implemented, the TL is actually an over-damped reflex enclosure. Examine the impedance curves of the various designs found in *TAA*, *SB*, and the many "how-to" books, as well as those for commercial systems. They consistently show an impedance maxima in the range of 35–50Hz, but unfortunately are not taken below 20Hz; the curves usually begin to rise again with decreasing frequency before this cutoff. Bailey reports a maxima below 15Hz (the most common frequency range for this second, lower maxima), but does not comment on its presence at higher frequencies.[4] An impedance curve with two maxima is one hallmark of a reflexive (i.e., Helmholtz) enclosure.[5] If your impedance curves do not extend down to around 5Hz, you will be unable to discern what is happening in your TL.

Several sporadic, phenomenological descriptions also support my conclusion:

1. "Opening the port had two effects. The bass...and the cone excursion was greatly reduced between 30 and 50 c/s."[6]

2. "A further effect at low frequencies is produced by the air mass in the line moving with the driver, and this component is additive to the driver's own moving mass."[7]

3. Wright suggests that the line should not, in fact, be stuffed, but rather damped in such a manner as to dissipate the unwanted mid-bass backwave and damp-line resonances. The geometry of the damping material must allow a free flow of air.[8]

Again, these are hallmarks of reflexive interactions. The line is not merely a second low-frequency source: it participates as a Helmholtz resonator. The driver is thus more controlled, and the bass is augmented when the vent is open. Below the upper resonance the line does not augment the woofer—it is the dominant sound source.

Of the two basic TL designs, one is the overstuffed. It exhibits one impedance maxima and behaves as a second-order high-pass filter. If the line is designed to be quarter-wavelength of F_{SB}, and the system Q is between 0.6–0.8, then the line will contribute low-frequency energy to the system's output. Thus, the critical factors in tuning this line are F_{SB} and its Q_T, not just the driver's free air resonance. The other TL model is the reflexive, which exhibits two impedance maxima (F_H and F_L) and behaves as a fourth-order high-pass filter. So how do you arrive at this design?

"At upper-bass frequencies the driver looks into a chamber where the mass of the cone reacts with the mass of the air and responds as under infinite baffle conditions. This chamber is coupled to a tapered filtered passageway which acts as an unrestricted quarter-wavelength transmission line, thus furthering the bass response down to frequencies where the line acts as a port for the system to behave as [a] nonresistive reflex enclosure, thus extending the response down to subsonic frequencies. By employing...it becomes possible to reap much of the advantages of the infinite baffle, labyrinth and reflex loading."[9] "For the lower range the solution is found in a line based on one-eighth of the free-air resonance of a high-Q bass driver."[10]

TRANSLATION AND REVISION

Select a rigid-cone woofer with an F_S below 30Hz, a Q_T between 0.35 and 0.45, and Q_M >3.5. Using T/S equations, calculate F_B.[11] If your driver selection, calculations, and construction techniques are adequate, the line length will be one-eighth-wavelength for F_B (with the appropriate loss corrections added) and one-quarter-wavelength for F_H. The line is not stuffed but damped acoustically. I prefer to "weave" a matrix from strips of selected open-cell polyurethane foam. This damps the TL better than simply lining it, and the foam is much more reproducible and stable than wool.

Due to this TL's nonresistive nature ($A_{VENT} \geq A_{DRIVER}$), its volume contributes to V_{BOX}. When executed correctly, the system will extend smoothly down to very low frequencies. In addition, it will respond to room positioning in a more favorable manner than will the stuffed or overdamped-reflexive TL, the T/S reflex, or the infinite baffle for a given driver.[12]

ACKNOWLEDGEMENTS

I would like to thank Mark Sayer of Meniscus for being a stable supplier of quality raw-drive units, and for his critical evaluation of prototypes. Thanks also to many other individuals throughout Michigan for their critical comments.

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Vintage Design

EXPONENTIAL BASS HORN (AMBASSADOR RADIO)

Portions supplied by Contributing Editor Bruce Edgar

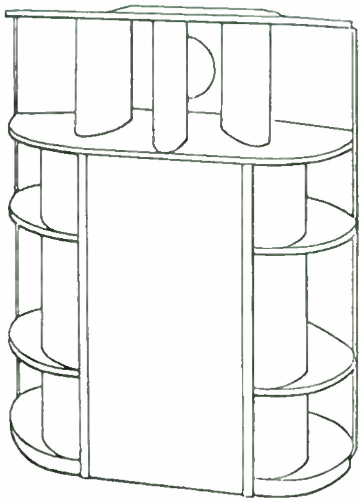
From: G.A. Briggs, Loudspeakers: The Why & How of Good Reproduction, *Vols. 4 & 5 (Audio Amateur Press, 1990).*

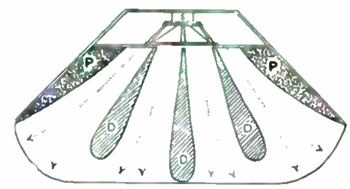
An interesting example of a folded exponential horn for bass, with four short virtual horns for treble.

The bass flare has a nominal cutoff at 65 cycles, but this is extended downward by the walls of the room to an extent determined by the physical characteristics of the room itself. The pressure at the back of the cone is relieved by a small aperture at the apex of the inner chamber.

The crossover network is carried out at high impedance and occurs at 375Hz.

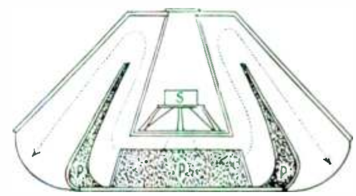
The complete unit handles an average input of 15W without breakup as a result of structural rigidity, all nonconductive cavities being packed with sand. A 12" unit for bass, and 8" with large magnet for treble, are fitted, both with cloth suspension.



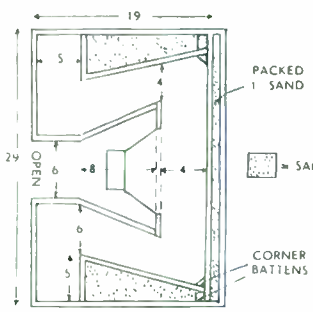


TREBLE REPRODUCER

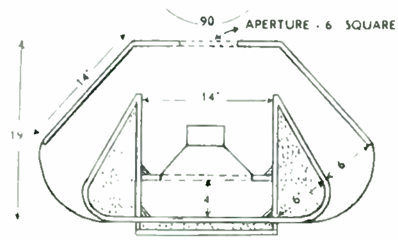
S - SPEAKER UNITS
D - SOLID DIFFUSERS
P - PACKED SAND



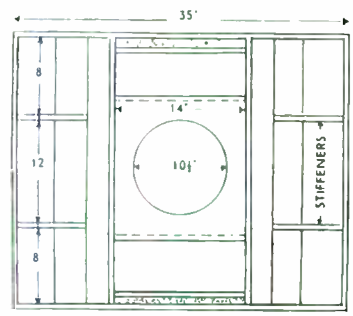
BASS REPRODUCER



SIDE SECTION THROUGH CENTRE



PLAN VIEW THROUGH CENTRE



FRONT SECTION (FRONT PANEL REMOVED)

SB *Mailbox*

MISSING LINK

In "Modular Active Crossovers" by Erno Borbely and Jean-Claude Gaertner (*SB* 1/94, p. 20), a line was omitted from the fifth paragraph. The complete sentence should read "The Butterworth offers a good compromise between bandpass flatness, bandstop slope, and transient response." Our apologies for any confusion this may have caused.

GREMLINS

I was pleased to see my Simplex speakers featured in *SB* 6/93 ("The Simplex," p. 32). Unfortunately typographic gremlins changed all given volumetric values from cubic feet to square feet ($ft.^2$). However, I'm sure that my fellow readers were not misled, just as they know that bells don't twinkle, but tinkle.

PHOTO 1: Adding foam around the drivers improved these speakers' sound.

Photo 1 shows how I have since modified these speakers by adding foam around the drivers. This has further improved their sound, which I attribute to a smoothing of the upper midrange and somewhat enhanced imaging.

I cut the black tweeter ring from 3/16″ wet-suit material. The outer and inner diameters are 4 1/8″ and 2 3/4″ respectively. A gray foam silence-cloth table underlay, 8″ O.D. and 5 5/8″ I.D., about 1/8″ thick, was used around the woofer.

Don Stauffer
Roxbury Crossing, MA 02120

POLYDAX UPDATE

I applaud both Mr. Janni and Mr. Hunt for their dedication to their speaker design ("A Full-Range Open-Baffle System," *SB* 1/94, p. 30). It is quite obvious they have spent a considerable amount of time and energy finetuning their system. We are pleased they chose to work with two of our models (HD13D34H and HD30P45TSM).

As a loudspeaker components manufacturer, Audax also is dedicated to the research and development of new materials, processes, and the like, to further advance sound quality performance. To this end, we introduced over 90 new products in January of 1993.

The two models discussed in that article, HD13D34H (1 1/4″ dome tweeter) and HD30P45TSM (12″ paper cone woofer) have been part of our new rationalization program. The following improvements have been made:

TW034X0: the new model number designation replaces the HD13D34H designation. By flush-mounting the faceplate screws, we have managed to reduce the faceplate diffraction to provide a smoother overall response.

PR300M0: replaces the HD30P45TSM model. A new die-cast Zamak basket was developed to provide a strong, rigid base. In addition, a Kapton former and flat copper wire were designed to ensure increased power handling and heat transfer.

For complete specification data on these drivers, as well as the entire Audax line,

Continued on page 65

THE PRIVATE FILES OF G.R. KOONCE

G.R. Koonce

At long last, we have persuaded Mr. Koonce—one of America's great computer/loudspeaker gurus—to make available to the public this 1.7Mb, five-disk set containing 19 unique programs from his own personal library. As wide-ranging in purpose as they are fun to use, these handy IBM files developed over the years for Koonce's personal use can now benefit you!

Disk #1: Vented Box Design

VBPLOT2.EXE—Designed to work with 2 drivers of the same type. You can enter a single driver name and unit identifiers for each driver. The program will allow adding resistance to the driver circuit if Qes, Qms and Re are entered. Data entry may be by keyboard or from data files prepared by the other programs on this disk. The program will then design optimum (QB3 for low driver Qts, C4 for high Qts), non-optimum (you enter Vb, program supplies tuning), jammed B4 and Be4 (see *On Alignment Jamming* below) and specified (you give Vb and fb) vented boxes. Program will output designs as tabulated results, plot the small signal frequency response and the overshoot function (described below). The program also provides for vent design. One feature especially useful is that while displaying frequency response plots for a non-optimum or specified design you can change the Vb and fb (for specified design only) right from the graph to see the effects.

On Alignment Jamming: (See "Alignment Jamming," *Speaker Builder* magazine, 4/92, p. 14ff.; article reprint included with disk.) It is mathematically possible to force low Qts drivers into system alignments closely resembling the classic fourth-order Butterworth (B4), fourth-order Bessel (Be4) and Inter-Order Butterworth (IB4) alignments. I refer to such alignments as "jammed" alignments.

On the Overshoot Function: This is an indication of the transient response of the system, using approximation equations developed by R.O. Wright, Jr. The vertical axis is labeled displacement, but the function is similar to the system response to a unit step input as shown by Benson (see *The Theory and Design of Loudspeaker Enclosures*, available from Old Colony as BKSA1 for $24.95 plus shipping). When you hit the system with a step, the output jumps up and you would like it to return quickly to zero in a straight line, forming a triangle. A real speaker system does not do this—it overshoots zero and tends to ring to a final zero value. You would like to use a system that has minimum overshoot and settles with the least ringing. Unfortunately, the VB is not good in this respect. The Qtce value shown for VB designs is the Qtc of a CB that would have the same peak overshoot as the VB system. Use overshoot function as an indication of transient performance noting that you can make little change in it for a VB system. Changes in Qtc for a CB system will have significant effect on the system overshoot function.

TSPARAMF.EXE—This program runs the standard T/S parameter tests. The program supports the baffle (free air) test, the CB test for Vas, and two versions of the VB test for Vas (one where fm is measured and a second where port is covered and fc measured). The program simply takes in the data, computes Rx and Rxc, and then shows the resultant fs, Qes, Qms, Qts, Vas, EBP, and Reference Efficiency in dB/W/M. The program will output the results to a data file which VBPlot2 can read for VB design, but you must do this before you start to test another driver.

DTAFIL4.EXE—This program takes in information on a driver from catalog data or previous test results and writes a data file that VBPlot2 can input for VB design. It would only be useful for drivers you want to use regularly in the VB design program, as for one time use it is just as easy to enter the data directly into VBPlot2. This program also allows viewing and editing data files written by itself or TSPARAMF.

JAMPLOT1.EXE—Designs VB systems using the Alignment Jamming equations (see above). After you enter a real value (a number with decimal place) for Qb and a driver Qts, it then designs approximate QB3 or C4 (depends on driver Qts) and jammed B4, Be4, and IB4 vented boxes. It will plot the small signal frequency response normalized to fs and the overshoot function (see above). This program thus allows the investigation of changing Qb or providing a final touchup of a design after you have measured box Q.

Disk #2: Closed Box Design/Testing

CBPLOTVB.EXE—This program accepts Qtc and fc for a CB system and plots the frequency response. It is intended for use on finished CB systems. You run the baffle T/S parameter test on the finished system, crossover included, and instead of fs and Qts, you get values of fc and Qtc. Feeding those values to this program will plot the anechoic response. This will also print out the frequency response in a tabular format.

MCBDES87.EXE—This is a very old program, starting life about 10 years ago on a non-IBM-compatible computer. It has a tedious three-layer menu system that drives Koonce nuts, but it's the CB design program that he uses because it presents the CB in a way he likes. It produces a design graph for the entered driver that relates how F3, fc, Qtc, peak dB, and frequency of the peak vary with box size. When you print this graph, you have all you need for future CB designs with that driver. The program will support added resistance in the driver circuit, will plot small signal frequency response, will compare a pair of drivers, and has some large signal displays based on Small's work. Runtime file.

Disk #3: Crossover/Padding Design

TWWYCOG.EXE—This program designs two-way COs of 1st to 3rd order. It will also plot the CO response curves: magnitude, phase, on-axis summation, power summation, and input impedance phase and magnitude. Both text and graphic (except in CGA graphics mode) schematics are provided. You can plot the response of an actual CO by selecting a type with the same schematic and entering your component values. This is great for seeing the effects of not having the exact component values produced by the design. The following parallel CO types are covered: 1st order—Butterworth; 2nd order—Butterworth, M-derived, all pass, Bullock Equal Compromise; 3rd order—Butterworth, M-derived. Series COs: 1st order—Butterworth; 2nd order—Butterworth, M-derived; 3rd order—Butterworth, M-derived.

NEW THIS ISSUE

PADCOMP.EXE—This program works with resistive loads and will design simple series pads and L-pads. The program provides simple "text" schematics. Once a design is complete, the program allows "scans" to show performance variations with slight component value changes. The designs also show what portion of the input power is dissipated by each resistor and what is delivered to the load. The program will also calculate the equivalent resistance of two parallel resistors and evaluate the performance of existing series-shunt pads.

TRWYCO87.EXE—This program will design the following CO types/topologies, all in the parallel configuration (C means with cascaded midrange and T means with transposed midrange section): 1st order—Butterworth, all pass; 2nd order— cascaded 1st order Butterworth, constant power (C and T), Butterworth (C, T, and special cascaded), Linkwitz (C, T, and special cascaded), all pass (C and T); 3rd order—all pass (C and T), Butterworth (C), constant power (C and T).

Disk #4: Miscellaneous Box Design/Testing

ODDBOX.EXE—This program designs a box with a vertical back and horizontal top, but with the front panel tipped back and the bottom tipped to stay at a right angle to the front. A figure description sheet is included with the disk. The box is basically used to implement a "diffusor port," as discussed by Koonce in *Speaker Builder* 2/91, pp.45-46 (reprint also included with disk). The box has only parallel sides—the front/back and top/bottom are not parallel. This design has worked well for Koonce with CB systems, where he has filled in the front and mounted the CO parts in the captured volume. The outputs are the internal dimensions for the box.

SLOPEBOX.EXE—This program designs a box that has a horizontal top and bottom and vertical back, with the front tipped back at the top and both sides tipped in equally at the top. A hard copy of this figure is also included with this disk. You enter the front panel slope height, front panel width at the bottom, gross box volume, side and front tip angles. The only parallel faces are the top (rather small) and the bottom, making this box just about immune to standing wave problems. Although these boxes are sometimes difficult to build because they require cutting boards on compound angles, the sound of systems using it have shown it to be worth the trouble. The outputs are the internal dimensions for the box.

SLOPEANG.EXE—This is a simple program that takes in the height of the listener's ears and then prints a chart of the tip angle needed for a driver located 1 to 50 inches off the ground and located 5 to 15 feet from the listener to put the listener on the driver main axis. It is used to determine the front panel tip angle needed to put a narrow vertical directivity driver (such as a ribbon tweeter) on the correct axis for a listener.

DIPFREQ.EXE—This straightforward program takes in a horizontal distance between driver and microphone and prints out a chart of what frequency will show a "dip" due to floor bounce interference with the direct path. The chart covers driver and microphone heights from 2 to 40 inches. The program is intended for use by those testing via pink noise or warble tones. The results have no meaning with transient testing such as via IMP.

DRIVRDIR.EXE—This program displays the approximate directivity of a circular piston in an infinite baffle somewhat differently than the typical polar plots. The program prompts for the entry of the piston diameter and then displays a graph of angle (0 to 90 degrees) versus frequency. On this graph are three curves showing the off-axis angle versus frequency for the response down 3, 6, and 10 dB. This aids you in determining just how "high" in frequency you dare push a driver. The piston diameter for woofers is normally estimated at 80% of the nominal diameter.

SPKRVOL.EXE—The function of this program is to estimate the volume taken by a woofer in testing or a finished cabinet. The frame, surround, cone, rear suspension and magnet assembly are handled independently via simple models. The program will handle the volume of the driver mounted inside the box against the inside of the front baffle (rear-mounted), mounted in a hole (hole volume is computed), from the front of the front baffle (front-mounted), and simply held against the front of a test box facing the box. The program describes the models used and defines the various driver mountings. Koonce uses this program regularly to estimate the driver volume change for test boxes and construction.

MATRIX.EXE—Developed to estimate the size increase you must allow in box volume if you use matrix bracing. Matrix bracing, in this program, is an egg crate bracing with thin wood standing vertical and horizontal in the cabinet. The wood is cut out to allow air flow. The program is intended for small- to medium-sized cabinets and restricts the matrix spacing to 3 to 6 inches. You enter the net box volume, then optionally the volume lost to drivers, ports, etc., then the size of the front panel board, and then the thickness of the matrix bracing wood. The program then returns the approximate internal gross volume needed and the number of braces and their spacing in both directions. Treat the output as an aid in doing your final design.

Continued ☞

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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

Disk #5: Driver Evaluation/Overshoot Function

QKLOOKVB.EXE—The purpose of this program is to give a quick estimate of the performance of a driver in CB or VB systems. You enter an optional system/driver name and the T/S parameters (fs, Qts, and Vs) for a driver. The program then will output, to the screen or printer, valid CB designs at four Qtc values and the standard C4, QB3, and BB4 optimum VB designs. If the driver Qts is below 0.38, the program will also output the "jammed" B4, Be4, and IB4 VB designs. If you enter a net box volume, the program will also provide the CB and non-optimum VB designs for that volume. Added circuit resistance is not supported, as the program is mainly intended to evaluate catalog data for determining a driver's usefulness.

OSPLOT6U.EXE—A developmental program used to examine the overshoot function for VB systems. You enter a driver Qts (0.1 to 0.8), and then the program designs realizable optimum VB alignments (QB3 for low driver Qts, else C4) along with the "jammed" B4, Be4, and IB4 alignments, all for a box Q of 7. The program can plot the overshoot function or the small signal frequency response of the systems you select. The frequency response plots are normalized to fs and the normal alignment chart coefficients (alpha, h, and f3/fs) are given for each design.

OSPLOT2.EXE—This is also developmental program used to examine the overshoot function of a CB system. The program accepts 1 to 4 values of CB system Q (Qtc) and then plots the overshoot function for these systems.

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KOONCE PROGRAM CHARACTERISTICS

Name	Displays Color	Supports Mono	Mouse Support	Graphics Required
VBPLOT2	Yes	No	No	EGA Color
TSPARAMF	Yes	Yes	No	None
DTAFIL4	Yes	Yes	No	None
JAMPLOT1	Yes	No	No	EGA Color
CBPLOTVB	Yes	No	Yes	EGA Color
MCBDES87	Yes	No	No	EGA Color
TWWYCOG	Yes	Yes	No	EGA Color VGA Color CGA Hi-Res Hercules
PADCOMP	Yes	Yes	No	None
TRWYCO87	Yes	Yes	No	None
ODDBOX	Yes	Yes	No	None
SLOPEBOX	Yes	Yes	No	None
SLOPEANG	Yes	Yes	No	None
DIPFREQ	Yes	Yes	No	None
DRIVRDIR	Yes	Yes	No	EGA Color Hercules
SPKRVOL	Yes	Yes	No	None
MATRIX	Yes	Yes	No	None
QKLOOKVB	Yes	No	Yes	None
OSPLOT6U	Yes	No	No	EGA Color
OSPLOT2	Yes	No	No	EGA Color

THE LISTENING ROOM FOR MAC — SOF-TLR3M3G

Ralph Gonzalez **$47.50**

Like the popular PC version, this program for the Macintosh allows you to interactively position listener and speakers in your listening room, although this is now accomplished using the Macintosh "dragging" graphical technique. The program actively displays the magnitudes of standing waves, as well as the effects of (now up to 124) early reflections on the direct response. Several features have been added, notably local optimization of listener and/or speaker positions to maximize, minimize, or smooth the standing wave patterns. This Mac version also enables you to model the woofer low frequency limit and slope, and produces high-resolution output including multiple graph overlays. Requires 512K RAM.

A HISTORY OF MARSHALL VALVE GUITAR AMPLIFIERS, 1962-1992 — BKHL2

Michael Doyle **$32.95**

Marshall amps have defined the sound of rock for a generation. This book explores the British company responsible for that sweet overdrive sound, tracing the impressive lineage of its tube guitar amps. Doyle is the acknowledged authority on the subject, and here he combines detailed chronologies of the various model and serial numbers, straightforward explanations of their features and construction, and aesthetic evaluations of the results. Includes hundreds of black-and-white photos, plus a 32-page color section, plus another 32-page color appendix that reproduces parts of the Marshall catalogs of the '60s.

THE COMPLETE SOUND BLASTER — BKAM3

Howard Massey **$12.95**

Whether you already own a Sound Blaster—the most popular computer peripheral ever invented—or are considering buying one, this is the only book you will ever need. Covers installation, an introduction to the basics of sound and MIDI, software products, and much more.

THE VTL BOOK — BKVT1

David Manley **$19.95**

First published in 1988, *The VTL Book* quickly sold thousands of copies in two editions and was labeled "an audio classic" almost immediately. Now it's back, and bigger and better than ever. Besides containing all of Vacuum Tube Logic's circuit diagrams and other operational hints, *The VTL Book* also contains lots of hard-to-find tube information such as tube characteristics, base diagrams, substitutions, measuring setups, inverse RIAA network, tables and formulas for power conversion, ohms-per-foot resistance, oscillograms, output class definitions, and much, much more! In addition, there is a broad (and often contentious) discourse by the author on other interesting topics such as loudspeakers, cables, digital and analog, transformers, cartridges, and preamps. This volume is packed with information and is essential reading not just for those interested in tubes, but also for everyone interested in any aspect of audio at all. 1994, softbound.

DIGITAL AUDIO SIGNAL PROCESSING — BKAR4

John Strawn, editor **$21.95**

In this book, six top experts in the field take you step-by- step through the math, physics, and technological background needed to analyze and engineer digital audio systems. F. Richard Moore introduces the mathematics of digital signal processing. Julius O. Smith presents digital filter theory, while Tracy Peterson explains spiral synthesis. James Moorer surveys the interface between signal processing and computer music. And finally, John Gordon and John Strawn show how topics covered earlier in the book have been applied to the development of the vocoder. Described by G.W. McNally in the *Journal of the Audio Engineering Society* as "essential reading for anyone with an interest in computer music." 283pp., 6" x 9", softbound.

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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

Continued from page 62

please write or call Polydax Speaker Corp., 10 Upton Dr., Wilmington, MA 01887, (508) 658-0700.

Ralph P. Nichols
Sales & Marketing Manager
Polydax Speaker Corp.

FOAM

As a professional loudspeaker repairman and owner of a Waldom Reconing Center, I found Len Moskowitz's "Foam Surround Repair" (*SB* 5/93, p. 71) disturbing. The AR-3a woofer uses a 10½" cone, for which a replacement of heavy molded paper, with a correctly sized foam surround, is available from Waldom. It is the most expensive 10"–12" cone we sell, and unique to AR woofers. The required voice coil, spider, and dust cap are still available.

Mr. Moskowitz lives in NJ but ordered a refoaming kit from NC. Are there no reconing centers in NJ?

For $27.95 he received two 12" foam surrounds worth approximately $10 plus $1 worth of glue and syringes. His comment about the seam is justified. You cannot buy a 10½" surround. A cemented butt joint is preferable to an overlap. Methel Ethel Keytone (MEK) is the solvent to use for removing the old adhesive and foam.

To center a voice coil:

1. Remove the dust cap, either with MEK or by carefully cutting with a small utility knife, Ex-acto, or scalpel.

2. Remove any particles inside the voice coil with reversed masking tape.

3. Insert shims between the voice coil and pole piece (0.008"– 0.020"). With such a small gap centering should not be left to chance.

Here are some suggestions for readers who decide to replace rotten foam surrounds themselves. Contact the nearest Waldom Reconing Center and purchase the surrounds, 1–2 oz of solvent (bring your own bottle), the necessary shims, ½ oz of PVA adhesive, or latex contact cement. *Do not use solvent-based contact cement—it will distort the foam.* You will need a sharp knife, a small brush, and a large eyedropper (for use as a solvent applicator). You may need 3–5 cc of AA-40 to reglue the dust caps. Stick a piece of tape to the dust cap to provide a handle for replacement.

If you can't track down a reconer via the yellow pages, area music stores, professional sound companies, or hi-fi dealers, then contact Image Communications, 4301 W. 69th St., Chicago, IL 60629, (312) 585-1212, FAX (312) 585-7847. They do not sell to the public and should be able to refer you to the nearest reconing center.

David A. Young
Nova Scotia, Canada BOJ 1E0

Len Moskowitz responds:

Disregarding Mr. Young's plug for Waldom, he brings up some points that are worthy of discussion. As he comments, a replacement cone for the AR-3a woofer is expensive, even from a non-OEM source like Waldom. As I noted in my article, AR won't repair these woofers and doesn't sell repair kits to reconers. If I wanted original OEM performance I had the option of buying brand-new drivers or replacing just the surrounds. Luckily, in my case the cone was in perfect shape—all I needed was surrounds, which were available at a reasonable cost from Ken's (now Stepp Audio Technologies).

At the time I wrote the article, my local reconers didn't sell surround repair kits. Now they do, and at low prices. Maybe competition from mail-order suppliers is a good thing for the consumer?

The contact cement Ken's provided was not solvent based.

The centering procedure supplied with the kit works fine; I listen to the proof of its adequacy every day. I've also had reports from other folks via the Internet who have had similar successes. Keep in mind that the spiders in my drivers were intact and still controlled the cone's centering. The voice coils were in equally good shape and the dust caps were in place, so there was no need to clean the gap. This is normally the case when foam surrounds decay.

The method used to join the ends of the surround plays a completely negligible role in the AR woofer's performance parameters.

I welcome diversity in the audio marketplace. When materials for repair are unavailable or a repair is too complex, and when the local reconing center can offer identically performing components at lower cost than the original manufacturer, the center serves a valued and essential role. But when you can save money from a mail-order source and get a satisfying result, why not use that source? Stepp Audio and other mail-order vendors fill a valuable niche. If they can earn a good profit while providing reasonable value, I applaud them. If Mr. Young or other reconers can offer better value, more power to them! Why not put an ad in SB so we can all learn about it?

SB's readers should be aware that Waldom manufactures its own cones and voice coils. While we hope they approximate the original manufacturer's component specifications, the consumer can't be sure of this. I would therefore suggest that folks try to use OEM-provided kits when they are available at reasonable cost.

BUDGET BIAMP

In "Biamping the Sapphire II Sub-I System" (*SB* 3/92, p. 24), Gary Galo presents a wonderfully inexpensive way to biamp—just replace the input-coupling capacitor of your power amp. I've been wanting to do just that, except I didn't want to change the cap *inside.* (I didn't want to void my warranty on my GFA-555). I've been giving some thought to a similar but less daring approach, and would be interested to hear Mr. Galo's thoughts on it.

In my copy of *Allied Radio Data Handbook* (Nov. 1955 ed.) I learned that two (2) series capacitors total to

$$C_T = \frac{C_1C_2}{C_1 + C_2}$$

By using the formula C = 1/2πRF from Vance Dickason's *Loudspeaker Design Cookbook,* I figured out that my Adcom's input-coupling capacitor must be 0.0795μF (since cutoff is 20Hz and impedance is R = 100kΩ). Using the series formula, I calculated the figures in *Table 1* showing the new cutoff frequency, when I used an external capacitor in series between preamp and amp. Will this work?

Frank Campagna
Medford, NY 11763

Contributing Editor Gary Galo responds:

The formula you cite for capacitors in series is correct. Actually, there are two formulas for finding capacitance in series. The one you use depends on how many capacitors are in the series network. If you have only two, the formula is:

$$C_{EQ} = C_1 \times C_2 / C_1 + C_2$$

If you have three or more:

$$C_{EQ} = 1 / (1/C_1 + 1/C_2 + 1/C_3)$$

Note that the net capacitance in a series network is called equivalent capacitance, *not* total capacitance, *since the net capacitance of the series network will be lower than the smallest capacitor in the network. That's why we designate the result as C_{EQ}. When you're*

TABLE 1

Frequency-Setting Capacitors for Adcom Input

External Series C C_1	Internal Adcom C C_2	Resultant Effective C $C_T = C_1C_2/C_1 + C_2$	Cutoff Frequency (Hz) $F = 1/(2\pi RC)$
0.000	0.0795	SAME AS C2	20
0.020	0.0795	0.016	100
0.021	0.0795	0.017	96
0.022	0.0795	0.017	92
0.023	0.0795	0.018	89
0.024	0.0795	0.018	86
0.025	0.0795	0.019	84
0.026	0.0795	0.020	81
0.027	0.0795	0.020	79
0.028	0.0795	0.021	77
0.029	0.0795	0.021	75
0.030	0.0795	0.022	73
0.031	0.0795	0.022	71
0.032	0.0795	0.023	70
0.033	0.0795	0.023	68
0.034	0.0795	0.024	67
0.035	0.0795	0.024	65
0.036	0.0795	0.025	64
0.037	0.0795	0.025	63
0.038	0.0795	0.026	62
0.039	0.0795	0.026	61
0.040	0.0795	0.027	60
0.041	0.0795	0.027	59
0.042	0.0795	0.027	58
0.043	0.0795	0.028	57
0.044	0.0795	0.028	56
0.045	0.0795	0.029	55
0.046	0.0795	0.029	55
0.047	0.0795	0.030	54
0.048	0.0795	0.030	53
0.049	0.0795	0.030	53
0.050	0.0795	0.031	52
0.051	0.0795	0.031	51

computing capacitors in parallel, you simply add them up. In this case, the result is designated C_T. (Resistors are exactly the opposite—series adds, parallel divides).

The older Adcom GFA-555 is a direct-coupled amplifier, as are the 545 and 535. They don't have input-coupling capacitors. All three have input impedances of 23k, so you can easily compute the value of the external-series capacitor using the formula in the article:

$$C = 159{,}000 / RF$$

You noted that your amplifier is still under warranty, which leads me to believe that you may have the newer GFA-555II. All of the latest-generation Adcom power amps are true DC, servo-controlled designs, and all have input-coupling capacitors. These include the GFA-535II, 545II, 555II, 585 and 565. The 555II has a 1μF input-coupling cap and a 100k input impedance. The low-frequency cutoff resulting from this R/C combination (-3dB) is 1.5Hz.

I think you've misinterpreted Adcom's specifications. None of their amplifiers have low-frequency cutoffs anywhere near 20Hz (this would be totally unacceptable in a full-range high-fidelity amp). They are all less than 5Hz, and the newer amps are even lower.

You can't accurately determine the value of an input-coupling cap, if one is used at all, based on the manufacturer's frequency-response specification and input impedance. Adcom specified the -3dB point of the GFA-555 as 4Hz. This could lead you to believe that the amplifier has an input-coupling capacitor even though it does not.

Unless an amplifier is a true DC design (like the newer Adcom amps), some low-frequency bandwidth limiting will occur in the feedback loop. If an input-coupling capacitor is used, the combination of the amp's internal bandwidth and the input R/C time constant will determine the ultimate low-frequency cutoff point. The only way to accurately determine the value of the input-coupling cap, if one is used at all, is to look inside the amplifier or consult a schematic diagram.

Fortunately, the amp's internal bandwidth limiting is of no consequence when you're adding, or reconfiguring, an input-coupling cap for a biamped setup. The R/C network's new low-frequency cutoff point will be several octaves higher than the amp's internal rolloff point. In this case, the amp's internal bandwidth limiting will have no effect on the performance of the new input R/C filter.

If you own a 555II, you can certainly use an external capacitor in series with the internal one to achieve the desired low-frequency crossover point. Just use the series-capacitor *formula to determine the correct value for the external cap.*

Many power amplifiers have capacitors with poor audio performance as input-coupling caps. These include cheap electrolytics and less-than-optimum film types. In these cases, the cap used by the manufacturer will be the limiting factor in terms of sonic performance. If you put an MIT Multi-Cap or IAR Wonder Cap in series with a cheap electrolytic, the sonic performance of your amplifier will be limited to that of the electrolytic.

Fortunately, Adcom used high-quality film capacitors in its current generation of power amps. The 555II is supplied with either Roederstein MKC 1862 polypropylenes or Electronic Concepts 5MC22B105K polycarbonates. Both have excellent audio characteristics. If you have a high-resolution system, however, you may discern a subtle improvement when substituting an MIT Multi-Cap. In this case, I still recommend replacing the internal-coupling cap with the appropriate new value, rather than placing an external capacitor in series.

You could use an external-series capacitor as a temporary measure, until your warranty expires. At that point you could change the internal capacitor. If your amp is the original GFA-555, however, all you need is the external-series capacitor. Once your warranty has expired, I think it would be best to place the cap inside the amp, between the input jack and the PC board, as I noted in the article.

A CLEANER LOOK

For the past couple of years I have thoroughly enjoyed a subwoofer I built based on Craig Cushing's article "A More Compact Transmission Line Subwoofer" (*SB* 1/87, p. 9). I plan to build another, and am seeking opinions on some aesthetic considerations.

I believe the line terminus is on the front panel of the speaker to augment low-level output, but I wonder if moving the terminus "around the corner" to the side panel (panel A in *Fig. 1* of Mr. Cushing's article) would harm the response in any way. Configuring the terminus in this manner leaves the front panel with a cleaner look.

If moving the terminus to the side panel is *not* detrimental to the response, how about

PREVIEW
Glass Audio

Issue 1, 1994

- Single Ended Amp
- A Standalone DAC
- Dual 1 + 1 Cascade Amp

moving it to the bottom panel and venting through the base? My current subwoofer sits on a 2″ base that could be modified to allow air to escape. Venting to the bottom gives both front and side panels a clean look.

Venting to the bottom panel also opens the possibility of extending the length of the line a couple of feet into the base (depending on the height of the base). What do other readers see as advantages or disadvantages to extending the length of line into the base?

Darren C. Pennington
Independence, OR 97351

The Dynapleat

Continued from page 22

smooth and extended. The bass is powerful, requiring a subwoofer only for the very lowest frequencies. The bass seemed to go lower than the measured 60Hz, perhaps because of the large diaphragm area, which is approximately equal to a 15″ speaker for the six drivers. After listening to the speakers, in fact, I decided that they would be wasted as surround speakers, and I have used them to replace my main front speakers.

Anyone who likes the sound of large-area panel-type loudspeakers will find these to their taste, I am certain. And they are significantly lower in cost.

Danielle II

Continued from page 34

subwoofer system is available as well in a kit, which includes:

- 4 Vieta L120/F3 13″ subwoofers
- 2 Black Hole damping pads
- 2 pairs of ORCA binding posts
- A reprint of this article

I trust that the reader will gain as much enjoyment from listening to his or her finished systems as I did in developing them. Please feel free to write me with your comments via *SB*. (If you do, remember to enclose a self-addressed envelope and postal coupon for reply.) It is in our common interest to continuously improve the art and science of speaker building.

Software Report

Continued from page 57

MANUFACTURER RESPONSE

My thanks to SB *and Dick Campbell for the very satisfying review of LoudSpeaker 6.0. It is greatly rewarding to have my efforts appreciated and now, I hope, used by many speaker builders.*

I do have a few comments and explanations. First, the program can use 384K of expanded (not extended) memory to load program overlays that it would otherwise occasionally load from disk.

Second, I have not as yet been able to solve or even duplicate the mouse problem in VGA graphics mode that Dick Campbell experienced. Out of the nearly 100 testers and early purchasers, I am aware of only one other report of this problem. Since the movement of the mouse cursor arrow is handled by the Microsoft (or Logitech) driver, I suspect the Borland compiler does not correctly set all of the video card registers for some cards so that the mouse driver does not know the monitor's correct screen resolution.

The only time that this mouse problem may hinder usage of LoudSpeaker is in the box illustration module. Here, positioning the mouse cursor on the front of the box and clicking the left or right button locates the center of the driver or vent. There are menu selections via the keyboard for positioning the driver and vent, but only a few standard choices. I will keep working on it.

Entering driver parameters for a new driver follows a specific course. If you change your desired driver partway through, you cannot immediately go back and start over. You can, however, merely enter the new driver parameters from the current entry on. When the last parameter is keyed in, you are back at the first parameter, and now you can edit any parameter in any order to find all the correct parameters for your new driver.

The inductor design module allows you to accurately wind an inductor by scramble winding the specified number of turns onto the correctly dimensioned coil form. I've always glued mine up from wooden dowels and hardboard flanges to get the correct dimensions. You can go back a step in the program after you've designed an inductor and specify the closest available wooden dowel radius and have LoudSpeaker recalculate the number of turns of wire now needed for the desired inductance value.

Technical support is provided by mail. Since LoudSpeaker is written and supported by myself alone in what spare time I try to have, I just cannot answer immediate telephone or fax requests for help. I would rather keep the cost of production, distribution, and support low and sell a product on which speaker builders would be willing to chance a modest amount of money. I believe LoudSpeaker 6.0 is a design tool that will satisfy 90% of the amateur speaker builders 90% of the time.

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Vieta L120F, 4 woofers $400. Jim, NYC, (718) 979-7555.

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Rane ME60 two channel ⅓ octave EQ $350; ARIA 3 with cabinets $800; B&K ST-202 $425; B&K EX-442 $625. All mint condition. Jerry, (601) 264-6971.

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Speakers: Sanders 4cell ESL, BIAS, XFMRS, crossovers, equalization, $700. Audiostatic ES240, $350. 10" Isobarik subwoofers $200/pr. Drivers: 6" × 12" Dynaudio, 4 OK, 2 need rebuilding, $225. Rebuildable carved maple F-hole guitar $75. Electric guitar part set: Schaller gold tuners, two humbuckers, bridge, ebony board, rod $100. Before 9 p.m. MST (505) 783-4551.

Revox B77 open reel recorder, $750; Denon DP-2550 turntable, SME 3990-III arm, Shure V15 cartridge, $300; Yamaha DSP-1 sound field processor, $495; dbx 124 4-channel dbx-II processor, $150; Nakamichi 700-II 3-head cassette recorder, $400. Audio, videotape, CDs, more—stamp gets list. Darroch, 1807 Elm Crest, Arlington, TX 76012.

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Seas 25 FEW/8 pair, perfect, $49 ($98); Magnavox CDB473 with B-Filter Crowndac, Burr Brown OP-amps, ultrafast diodes, sep. xformer for analog, mint, $299; Dynaco FM-5, mint, improved, $95. David W. Platt, 636 Marion Ave., Springdale, PA 15144, (412) 274-8149.

Kenwood 60 watt integrated amplifier $100; Technics SA-202 receiver 30 wpc $100. Commodore 64, disk drive, monitor, software, printer, accessories, $225. Tandy 600 laptop computer, case, printer including $100 of manuals, $350. Pete Groth, 384 Trestle Lane, Clinton Corners, NY 12514, (914) 266-4183, 6-10 p.m. EST.

WANTED

Info on Mods to Duntech Black Knights. Doak, (504) 738-1235. 6-10 p.m. CST.

Bogen MO-100A, Eico HF-22, Fisher 70A, Fisher 70AZ, Heath W-4M, Heath W-4AM, Lafayette LA-70, old theatre amps, equipment, output transformers. Sell/trade: vintage tube equipment, tubes, transformers, caps. Send $.75 SASE for list. Dennis Boyle, 1707 S. Ervay, Dallas, TX 75215, (214) 428-3901.

(4) Precision TA305F 12" Swan woofers or equivalent, (2) Acior woofers, (1) 10V516 Focal bass driver, Nad stereo basic amp #2155 or #4155. James Annal, 9216 S Harding, Evergreen Park, IL 60642, (708) 425-6719.

Dynaudio 30W-100 4Ω. Used and in good condition. Foam surround. Only one is needed. Peter, (207) 827-3293.

Four Accuton/Cermatec C2-11 tweeters, $75/ea. Adcom GFP 555 preamp, asking $250. All in top condition. Leigh, (904) 378-7485.

Assembly manual or schematic for the Heathkit model IG-72 audio frequency generator. I own one in need of repair. Kurt Lyons, 2118 Fleetwood, Grosse Pointe, MI 48236, (313) 884-8941.

Scan-speak and Dynaudio drivers as well as back issues of *Voice Coil*. Richard, (519) 687-2040.

I need replacement diaphragms for Western Electric 596, 597 field coil tweeters. V. Vogt, 330 SW 43rd St., #247, Renton, WA 98055.

CLUBS

WANTED: SPEAKER AND AUDIO AMATEURS IN THE BRADENTON/SARASOTA/ST. PETERSBURG/TAMPA, FLORIDA AREAS. Would like to form a club and develop a lab for testing speakers/amps/preamps and passive and active crossovers or just to discuss speaker projects and ideas. Angel Rivera, Bradenton, FL 34206, (813) 792-3870.

WANTED: PRO-SOUND HOBBYISTS OR CURRENT EMPLOYEES IN SOUND REINFORCEMENT FIELD to correspond with USAF serviceman in England. Looking for equipment sources and contact with anyone who has a passion for quality reproduction of live music. Rick Diaz, PSC 41, Box 6912, APO AE, 09464.

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

NORTHERN VIRGINIA BUSINESS CLUB. I am interested in turning my speaker-building interests into a profitable business. So I'm organizing this business club to attract other speaker builder entrepreneurs with the same interests. Call Frank Troy, (703) 912-8226, M-F, 7:30 a.m. to 4:30 p.m.

WEST VALLEY AUDIO SOCIETY. We are starting a group interested in all aspects of high perfomance audio. West San Fernando Valley, CA. Contact Barry, (818) 225-1341.

ELECTROSTATIC LOUDSPEAKER USERS GROUP is now a worldwide 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 SASE to: Barry Waldron, 1847 Country Club Dr., Placerville, CA 95667.

Reader Service #35

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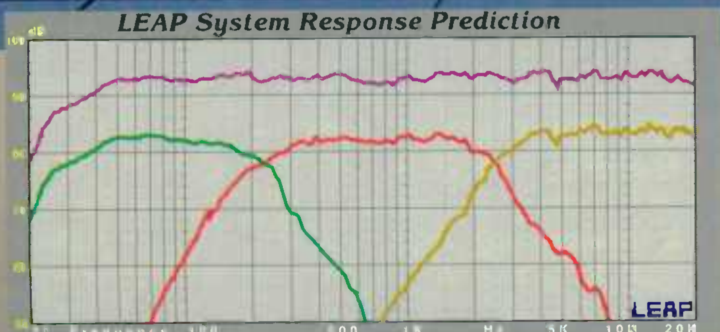

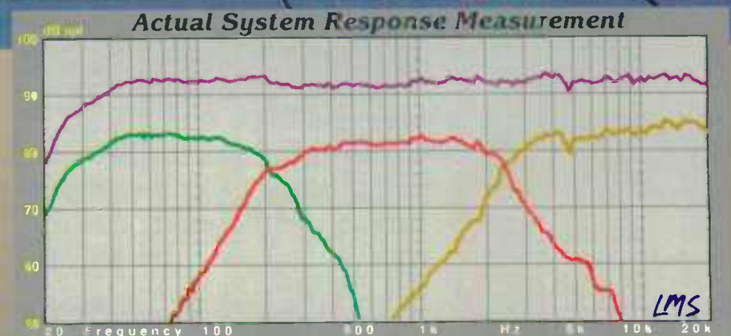

The Art and Science... of loudspeaker system development today has become more complex than ever before. Competition is tough, and to compete each design must perform to the best of its ability, and make the most out of every dollar's worth of transducer cost. The simple approach of choosing a combination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

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ALL PERSONS INTERESTED IN STARTING AN AUDIO/SPEAKER BUILDER CLUB IN THE SOUTHWEST MISSOURI-NORTHWEST ARKANSAS AREA, please send your name, address, phone number, and something about yourself to: Greg McKinney, 900 S. Roanoke, Apt. #2, Springfield, MO 65806.

MONTREAL SPEAKER BUILDER CLUB. Meets when it can, BYOB. Discussions range from speaker design and testing to equipment modification. All welcome, contact Jeanne Mance, Montreal, PQ H2V 4J5, (514) 281-7954.

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.

THE BOSTON AUDIO SOCIETY, the nation's oldest (founded 1972), seeks new members. Dues include the monthly meeting notice and our newsletter, the *BAS Speaker* (6/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.

NEW JERSEY AUDIO SOCIETY meets monthly. Emphasis is on construction and modification of electronics and speakers. Dues include 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 Bob Young, (908) 381-6269; or Bob Clark, (908) 647-0194.

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.

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! Tubes, 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.

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.

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.

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.

PACIFIC NORTHWEST 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. Write Box 435, Mercer Island, WA 98040 or call Bob McDonald, (206) 232-8130 or Nick Daniggelis, (206) 323-6196.

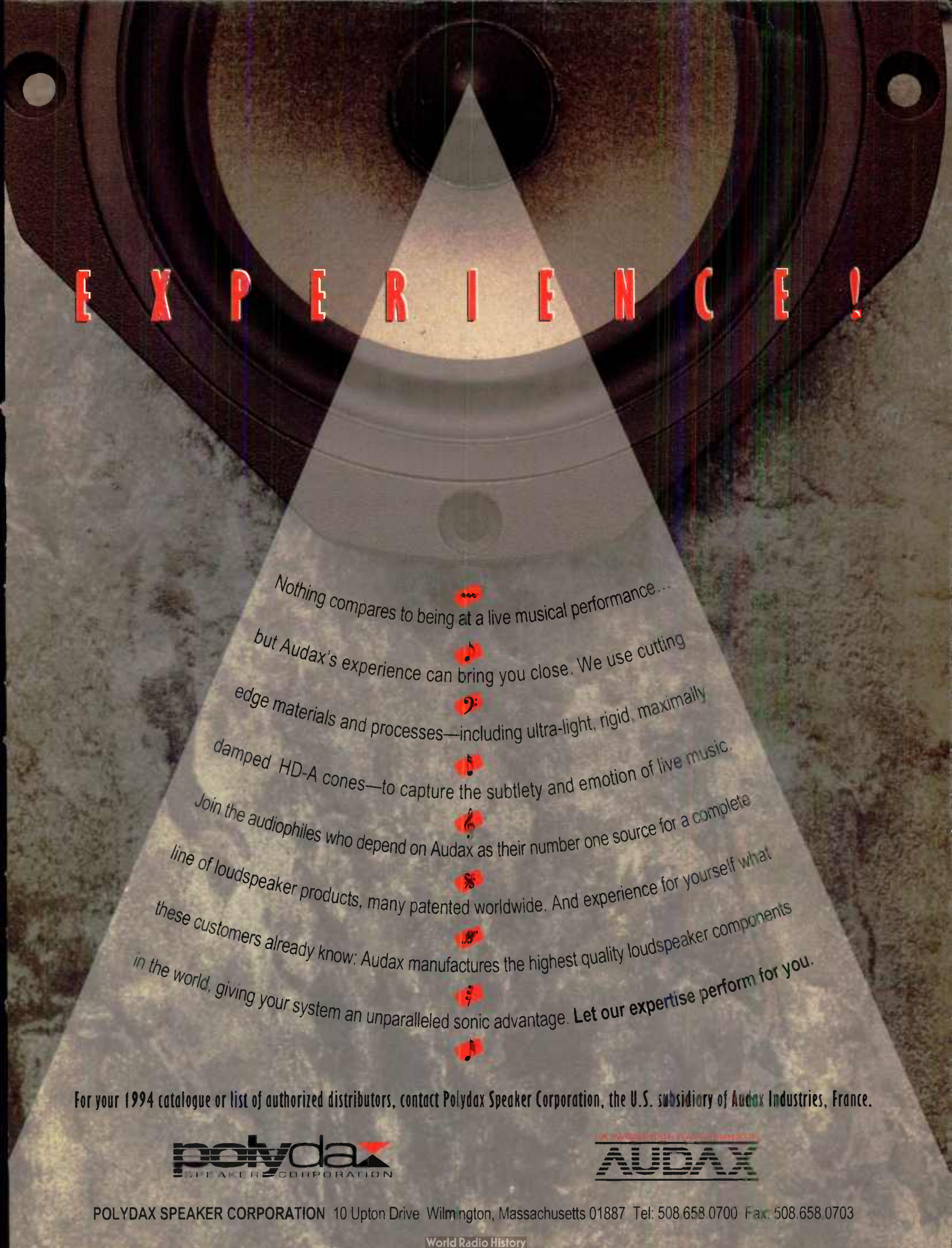
PIEDMONT AUDIO SOCIETY in the Raleigh/Durham and Chapel Hill area is meeting monthly to listen to music, demonstrate owner-built and modified equipment, and exchange views and ideas on electronics and speaker construction. Tube and solid-state electronics are of interest and all levels of experience 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, 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 E.A. Rawlings, 5411 Bocage St., Montreal, Canada H4J 1A2.

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 Alexandria, Va. Prospective members are welcome but must register in advance in order to be admitted to the meetings. No exceptions please. Call Horace Vignale, (703) 578-4929.

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 write to PO Box 18262, Wynberg 7824, South Africa. We'll be very pleased to hear from you.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HI-FI COLLECTOR/HOBBYIST seeks "living letters"/audio pen pals from other states to correspond via reel-to-reel tape. Noncommercial strictly; make up short monologues on subjects from vintage technology, with regional FM excerpts for background or equipment samples, from personal tales of yard-sale scavenging 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 (1/4" tape) will be cheerfully answered and tapes returned via parcel post. James Addison, 171 Hartford Rd., Apt. #7, New Britain, CT 06053.

DO YOU LIVE NEAR LAWRENCE, KA? I am a student at the Univ. of Kansas looking for other speaker builders within driving distance. I would like to exchange ideas and listen to other home-brew systems. Michael Marmor, 1520 Lynch Court #2, Lawrence, KS 66044, (913) 843-8993.

TUBE AUDIO ENTHUSIASTS. Northern California club meets every other month. For next meeting announcement send SASE #10 to Tim Eding, PO Box 611662, San Jose, CA 95161.

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 other's latest creations, give us a call. Geoffrey, (213) 965-0449; Edward, (310) 395-5196.

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 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. Write to WNY Audio Society, PO Box 312, N. Tonawanda, NY 14120.

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.

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 bimonthly newsletters, plus participation in meetings and lectures. For more information, send SASE to CAS, 11685 W. 22nd St., Lakewood, CO 80215, (303) 231-9978.

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, Bühlerstr. 21, 7030 Böblingen, Germany.

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