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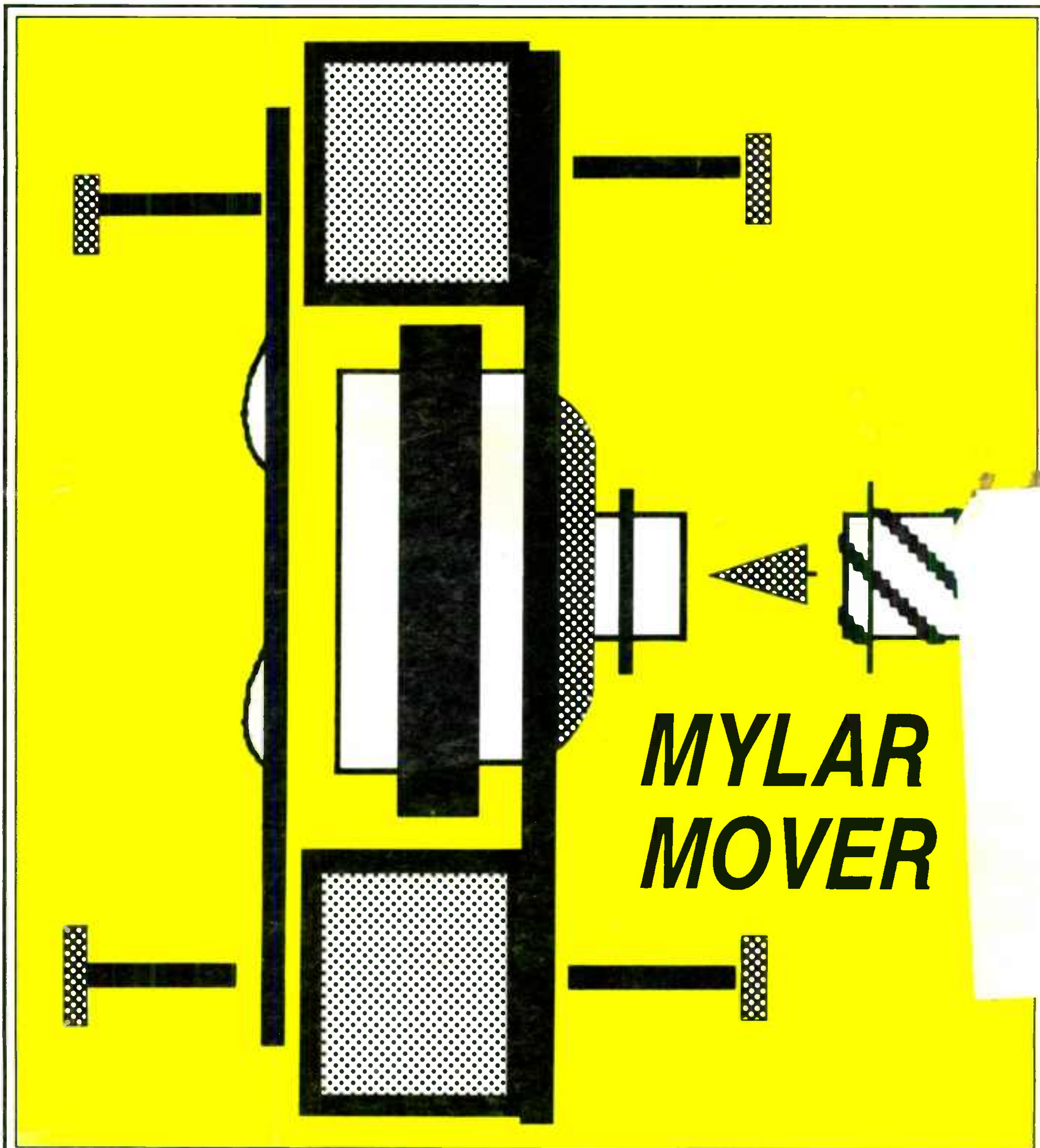
THE LOUDSPEAKER JOURNAL

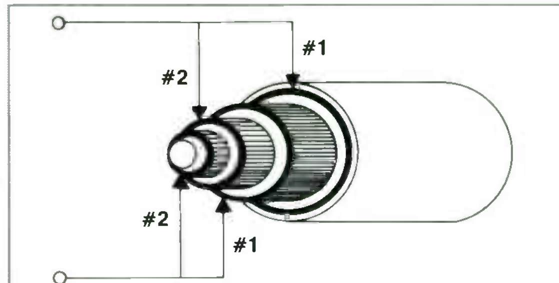


World Radio History

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

The MIT MultiCap

Why? FIRST – because it improves the sonic performance of their products. Audio manufacturers around the world are increasingly aware that when they need the best performance, MIT's unique, patented self-bypassed MultiCap delivers what other capacitor manufacturers claim but cannot offer: the highest level of *sonic* performance.



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

SECOND – MIT offers more: We can help you get the best results from our capacitors in your designs. MIT has over a half-million dollars in advanced test equipment. We know what it means when a capacitor has "phase deviations," "high ESR," and "high series inductance." We know how important it is – to the final sound of your products – to reduce these and other parasitics.

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MIT Introduces the New Metallized MultiCap
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The MIT Film & Foil MultiCap: Installation & Applications
Questions & Answers About Capacitors

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For International Inquiries:
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760 Pacific Road. Unit 19
Oakville, ONT Canada L6L 6M5
(416) 847-3277 FAX (416) 847-5471

World Radio History

Good News

AUDIO CONCEPTS has released its 36th mail order catalog. Although ACI's thrust has previously been speaker kits, the new catalog offers some speakers in assembled form only. Home theater packages are also now available.

Contact Audio Concepts, Inc. at 901 S. Fourth St., La Crosse, WI 54601, (608) 784-4570, FAX (608) 784-6367.

Reader Service #51

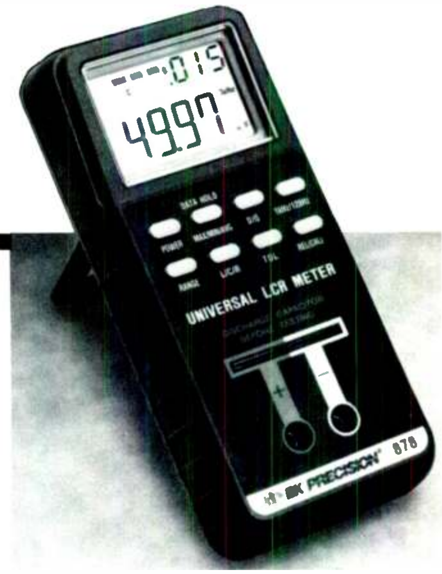
Flat driver loudspeakers are now available from **TC SOUNDS** in a floor-standing three-way system and two self-amplified subwoofers.

The TC-1 features a flat coaxial tweeter/midrange assembly with a 4″ flat piston diaphragm, and a 1″ soft dome tweeter mounted within the 1.5″ Kapton voice coil of the midrange, which is combined with two flat, high-excursion 8″ woofers.

The subwoofer uses one 12″ flat piston driver in conjunction with a 150W amplifier, and built-in active or optional external active crossover. The system is sixth-order vented with switchable damping to accommodate different environments. A larger system with two 12″ flat drivers and a 300W amp is also available.

Prices range from $4,495 for a pair of floor-standing TC-1s to $1,095 for a single 12″ woofer system with built-in 150W amplifier. For further information, contact TC Sounds at 6199 Cornerstone Ct., E. 105, San Diego, CA 92121, (619) 622-1212, FAX (619) 622-9293.

Reader Service #56



B+K PRECISION has introduced a hand-held LCR bridge with dual digital readouts. Designed for field service or general industrial applications, the Model 878 offers the functions of bench units and measures inductance, capacitance and resistance at an accuracy of 0.7%. A data hold function is also available to freeze any displayed reading; a minimum/maximum/average function keeps track of the running average of readings and records the highest and lowest running values.

The Model 878 retails for $275. For additional information, contact B+K Precision, 6470 W. Cortland St., Chicago, IL 60635, (312) 889-9087, FAX (312) 794-9740.

Reader Service #68

AUDIO TEKNOLOGY, INC. has released new LEAP manuals and Version 4.5, which features reduced key strokes and easier operation. The upgrade will be offered for a limited time to Version 4 users for $95.

The two-volume set includes a *Reference Manual* containing 19 chapters describing all graphs, menus and commands. A 300-page *Application Manual* includes information on loudspeaker measurements, design tips, filter calculations, and complete crossover system development.

For more information, contact Audio Teknology, Inc., 7556 SW Bridgeport Rd., Portland, OR, (503) 624-0405, FAX (503) 624-0194.

Reader Service #64

SCANTEK, INC. has produced a new Windows version of ENM (Environmental Noise Control) for DOS. Users may input sound level data (in octave or ⅓-octave bands), three-dimensional source and receiver coordinates, and directivity for several source types, as well as read data directly from a spectrum analyzer, create graphics in a spreadsheet format, and print displays in color or black and white. All input and output data are in ASCII format and can be read easily by other programs.

To learn more, contact Scantek, Inc., 916 Gist Ave., Silver Spring, MD 20910, (301) 495-7738, FAX (301) 495-7739.

Reader Service #67

CELESTION's Trinity compact loudspeaker system combines Celestion 1 two-way speakers with the CS-135 subwoofer. The diminutive Celestion 1 (10″ × 6″ × 7″) employs a 1″ titanium-dome tweeter; a 4″ felted-fiber-cone woofer delivers −3dB at 68Hz. A second-order high/low-pass crossover at 6.4kHz helps support pinpoint imaging and soundstage depth. The 20.5″ × 13.4″ × 7.5″ CS 135 subwoofer extends the low-frequency response nearly a full octave (−6dB at 38Hz) in a package optimized for mid-power systems in the 20–90W/channel range.

The Trinity system, finished in simulated black-ash veneer, retails for $399. To learn more, contact Celestion Industries, 89 Doug Brown Way, Holliston, MA 01746, (508) 429-6706, FAX 429-2426.

Reader Service #69

World Radio History

Now on the market is **TECHRON**'s Sound Lab-PC Version 1.3, which provides three-dimensional waterfall displays and an improved Noise Level Analysis (NLA) module. The software enables TEF-20 users to produce log or linear waterfall displays ranging from 2–36 curves which can be viewed from left or right as well as from the front or back. The new version displays continuous L_{EQ} information as well as fractional percentile (L_N) and L_{MEAN} values, even if a measurement is interrupted before completion. Other new features include NLA cursors, an AutoRepeat mode, a Combine Files feature, and muting.

Suggested price for the Sound Lab PC Version 1.3 is $50. To learn more, contact Techron, PO Box 1000, Elkhart, IN 46515-1000, (219) 294-8300, FAX (219) 294-8300.

Reader Service #66

NETWELL NOISE CONTROL has added acoustical foam baffles to its line of noise absorption products. The three-inch thick baffles, measuring 24″ × 48″, are made ready-to-hang from ceilings, and were designed to absorb 85% of reflective noise.

For more information or a free catalog, contact NetWell Noise Control, 6125 Blue Circle Dr., Minnetonka, MN 55343, (612) 939-9845 or (800) 638-9355, FAX (612) 933-9089.

Reader Service #65

AUDIOSOURCE has announced the release of its LLC-3, a three-in-one utility disc (Patent-pending) which cleans and tests audio systems. It combines a laser lens cleaner with test material for any CD player and audio system configuration.

The LLC-3 contains a special test section for Dolby Pro Logic surround sound setups. A set of test tones has been designed to provide users with an objective evaluation and adjustment of their home systems. Tests include; channel identification, polarity check, localization, sweep tones, dynamic impact/transient response check, and digital silence. The LLC-3 also contains a section of five music tracks representing a mix of digital recordings.

The unit is packaged in a 6″ × 12″ environmentally-safe EcoBox. Suggested retail price is $29.95. AudioSource is located at 1327 N. Carolan Ave., Burlingame, CA 94010, (415) 348-8114, FAX (415) 348-8083.

Reader Service #54

PEERLESS has announced the release of a new tweeter with an integrated cone, surround and center dome, vacuum-formed from a single piece of polypropylene.

Basket size is 62 × 62 mm; voice coil diameter is 13 mm; the 40 mm magnet has ferrofluid in the airgap. A ring inserted into the basket makes it possible to fit a smaller cone, resulting in an enlargement of the volume behind the cone and securing the low resonance. The ferrofluid ensures a flat response and no impedance peak. Power handling is enhanced by the aluminum voice coil former, the heat-conducting ferrofluid, and the ceramic magnet. Code for the new tweeter is 62 CT 13 40 PPB FF.

For more information, contact Peerless of America, Inc., 800 W. Central Rd., Mt. Prospect, IL 60056, (708) 394-9678, FAX (708) 394-5952.

Reader Service #52

AUDIOSTATIC, producer of electrostatic loudspeaker systems for 25 years, has appointed SOTA Industries as its North American manufacturer and distributor. Audiostatic products have previously been manufactured in Holland and sold primarily in Europe and Asia.

Available models include the new ES 100 Full Range System with a frequency response of 35Hz–22kHz and sensitivity of 86dB. The SW-100 electrostatic subwoofer (frequency response 35–300Hz) can be added for use in large room environments.

Prices range from $2,495 to $14,995 per pair. For complete specifications, contact SOTA Industries at 1318-B Marquette Dr., Romeoville, IL 60441, (708) 759-8737, FAX (708) 759-8730.

Reader Service #57

NORTH CREEK supplies loudspeaker components and pre-engineered systems to home builders. Loudspeaker kits are also offered through their catalogs.

Drivers, components and accessories available through North Creek include Ohmite resistors, Sprague capacitors, Tef-Flex AG crossover cable, Multicore and Alpha silver solder, Neoprene gasket tape, Vifa tweeters, and Scan-Speak woofers. Loudspeaker kits from Celeste, Okara, Thendara, and Sabael are also available.

For a current catalog, contact North Creek Music Systems, Rte. 8, PO Box 500, Speculator, NY 12164, (518) 548-3623.

Reader Service #53

Reader Service #35

Reader Service #21

World Radio History

HEAR, HERE!

Our 1993 product line just arrived and there's lots to celebrate. A comprehensive array of nearly 100 drivers. Innovative technologies. Leading edge materials. Engineered to provide flexibility in your design process and clear cut sonic quality advantages at every level of performance.

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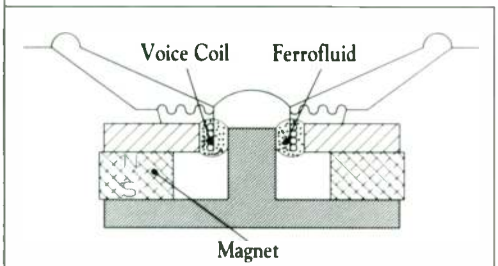
For hot voice coils, the cool solution.



Introducing the APG 900 Series — ferrofluids designed specifically to safely withstand 200 degree centigrade temperatures in speaker voice coils while maintaining long-term thermal stability. Offered in the low to medium viscosity range, APG 900 ferrofluids are ideal for all high efficiency speaker systems. This Series complements our existing product line of high viscosity ferrofluids widely used in tweeter and mid-range drivers. Call or fax us today. And, our in-house audio lab will help you with the speakers you have designs on.

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Reader Service #6

About This Issue

Radical surgery and thinking is the only way to describe **Mike Allen**'s interesting project for realizing an unusual transducer. Briefly, chop off the driver's cone and frame, glue it to a stretched mylar panel, and see what comes out. His adventure begins on page 10.

Contributing Editor **John Cockroft** is back with a ridiculously tiny new transmission line. A smaller one just might be possible, but imagination balks at the suggestion. "The Simpline," beginning on page 14, is not only a new design, but a step-by-step tutorial for any speaker building beginners. And don't be fooled by the simplicity, every detail conceals some remarkable sophistication.

Hand-to-hand combat is how **Manning Redhill** characterizes the pursuit of the correct paramenters for vented boxes. The elusive f_3 cutoff frequency is the key, according to this author, new to our pages this time. Dust off your calculators or sharpen your pencils. The discussion starts on page 24.

Bill Waslo continues his presentation of his new analyzer system which not only is a low cost speaker-in-the-room measurement tool, but has many other uses as well. He begins discussion of further capabilities of the IMP on page 30.

Joe Saluzzi concludes his years-long saga of building the perfect listening room. Although most of us can only dream of such a golden opportunity, Joe shows that the results are worth all the planning and months of hard work (p. 42).

The cover art this time is a little piece of Mike Allen's mounting scheme for what's left of his driver.

Speaker Builder

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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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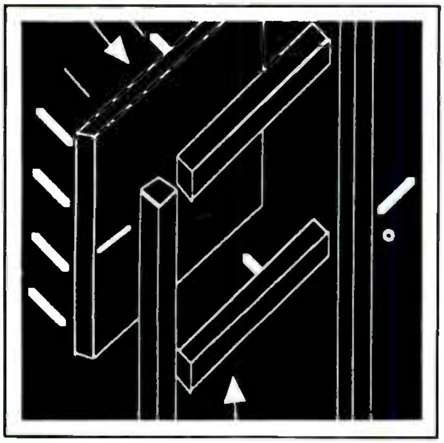

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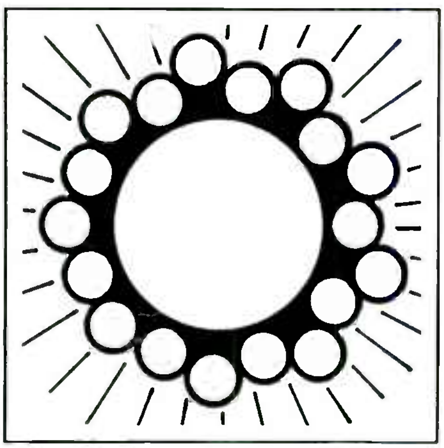

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FEATURES

DEPARTMENTS

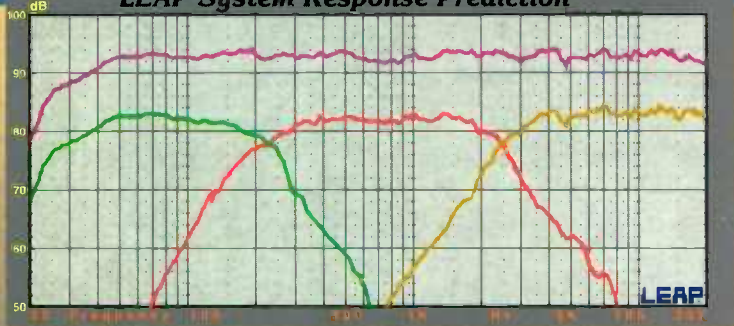
World Radio History

New! LEAP Version 4.5

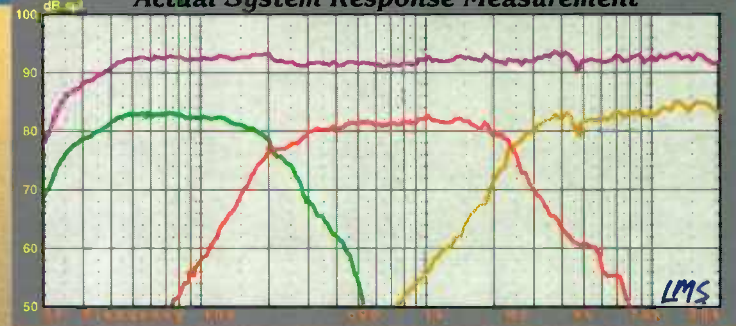
LEAP

Precision Development Tools for Precision Loudspeaker Designs

LEAP System Response Prediction



Actual System Response Measurement



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.

Extensive Documentation

The two volume manual set comprises almost 1 000 pages of documentation which thoroughly covers the operation of the program and provides numerous examples of how to maximize your use and understanding of the program's many features. The Reference Manual describes all graphs, menus, commands, and their operation. This manual explains the unique and special non-linear speaker and port models, as well as proper use of the optimizers, importing data, and the many other utilities. The Application Manual provides many exciting examples showing how to use the powerful features of the system in a combined manner to perform both simple and complex design tasks. Both novice and experienced users alike will find this information invaluable for exploiting the full power of the system. Additional information is also provided on loudspeaker measurements, design tips, filter calculations, and complete crossover system development for both passive and active based systems.

✔ 502 Page Reference Manual ✔ 436 Page Application Manual

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LEAP (Loudspeaker Enclosure Analysis Program) is a complete full range analysis package which provides virtually *all* of the tools necessary to develop precision loudspeaker systems, for today's demanding audio markets. Whether your applications are consumer audio, car stereo, professional audio, or custom esoteric marvels, LEAP provides the power, flexibility, and accuracy to investigate every possible design permutation. The open architecture and broad spectrum of features provided will dramatically reduce your development time, while improving the quality of the final result... and demonstrates why LEAP has become the #1 choice of professional loudspeaker designers world-wide!

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- ✔ Spkr Parameter Measurement
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- ✔ Motor Constants Calculator
- ✔ Export Data to ASCII Files

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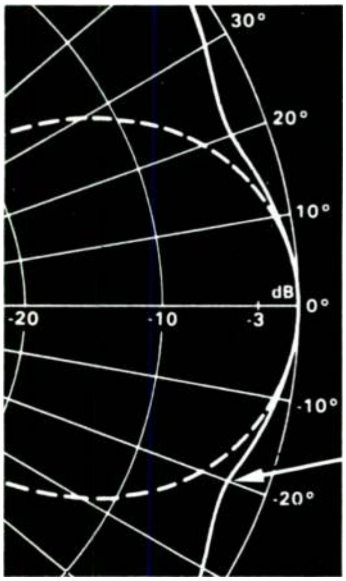

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World Radio History

Guest Editorial

THE WAY WE WERE AND THE WAY WE AREN'T

by Fred Janosky

As a child, I often "took things apart" to see how they worked. Even before I started school, I was disassembling small household items, such as my dad's electric razor, out of curiosity. In my second year of school, I recall working (playing?) with my father on assembling an educational toy that resulted in a working battery-powered electric motor.

By 1967, in the 4th grade, I had saved enough money to fulfill my dream of owning a tape recorder. After investigating all my choices, I purchased a Voice of Music quarter-track, reel-to-reel machine for the then huge sum of $84.00! (Voice of Music of Benton Harbor, Michigan, was reasonably popular in those days for making lower cost audio equipment.) I had countless hours of enjoyment and experimentation with my monophonic tape recorder. That began my fascination with audio and electronics. Knowing nothing of Thiele/Small equations, I built an extension speaker for my tape recorder one year later—my first loudspeaker project.

Of course, my audio system grew into several components and, throughout my grade school years, many of my science projects were audio-related. Before I received any formal training, assembling electronic kits played an important part in forming my knowledge and providing a source of fun and encouragement.

I can truthfully say that my interest in audio led me to pursue a degree in electrical engineering. This interest led me into other areas, such as woodworking, music, acoustics, even a business selling audio equipment. Of course, audio still remains a source of enjoyment, a hobby, and a part-time business for me.

But now, some things have changed. Our youth are into Nintendo, MTV reigns as a major influence, drugs are a big problem, and the quality of education (or lack of it) for young people is a big issue. Our country is even said to be falling short in our efforts to remain a world leader.

Recently, I met with a group of educators as part of a program we are initiating at my company (a large electric utility). We are discussing things we may be able to do to assist educators in our community meet the educational needs of our youth.

The meeting with these educators was enlightening. We discussed problems modern educators are experiencing, possible sources of these problems, and possible solutions. The educators were in agreement over many problems that seem to have slipped into our schools in recent years. Many of us can easily guess the source of the problems such as declining family values, parents not taking an interest in their children, and so forth.

One problem mentioned caught me by surprise. "Kids seem to lack a natural curiosity to find out how things work. Not long ago, kids would take things apart, tinker with cars and the like, but this is very rare now. Kids now expect to be entertained and seem to have little motivation to learn." I could not help but reflect on my younger years where the excitement of building something and experimenting continually helped me learn and broaden my horizons. Learning was fun!

Is this problem unique to our country? Do we have too many of the wrong things to entertain us? On a recent trip to Germany, I was amazed at the items for sale at a hobby store. There were many fun, technical and educational items. Some were kits where the builder's efforts would be rewarded with a quality, working finished product.

In a recent mail came the latest Heath Catalog. On the front page was a note explaining Heath's decision to exit the kit business. Their explanation was "times have changed, consumer needs have changed...for a number of reasons, folks just aren't buying and building many kits anymore." When I first read this cover note, I thought that the major reason to leave the kit business was probably more attributable to a poor effort by Heath to meet customer needs. (In 1987, I wrote a letter to the President of Heath explaining that remarketing Harman/Kardon audio equipment as kits is not a strategy for success, especially when one can purchase the assembled versions at lower prices. I never received a reply from Heath.)

After thinking about what I heard yesterday from the group of educators and remembering my own youthful experience, I must wonder, have times changed to the point where young people can't be concerned with finding out how something works? Will most of America's high-technology products be manufactured overseas? Can America maintain a lead in any field of technology? How can we builders/experimenters become involved with our youth to share our experiences and enthusiasm?

Fred Janosky works as an Electrical Engineer for General Public Utilities in the System Operations/System Control Department in Reading, PA. He also runs Audio Arts, a part-time business involved with home audio equipment and architectural sound systems.

Reader Service #3

World Radio History

THE FLEXIBLE DIPOLE WOOFER

BY MICHAEL ALLEN

We recently have seen some attention given to cone dipole speakers. The Amazing Loudspeaker by Carver and the Centaur by Apogee Acoustics both use dynamic cone woofers mounted on a panel to reproduce low frequencies without the box resonances of a sealed or ported cabinet. These 6–12″ cone woofers are characterized by very high Q_{TS} of 2.0 and up. They recreate the open nonresonant bass sound of fullrange electrostatic and magneplanar speakers.

Speaker builders trying to construct a baffleless woofer system find it very hard to locate cone woofers with a sufficiently high Q_E. In my high school introductory physics class, my students constructed a dipole woofer that uses a flexible cone. Actually, it is not a cone at all, but a double-laminated foam pad driven by a conventional magnet/coil driver. Remember the NAD 4150 floppy tonearm? It used a flexible tonearm to eliminate or absorb spurious tonearm resonances. Cone woofers also resonate somewhat at certain frequencies. The floppy woofer increases the Q_{TS} of the driver and helps eliminate any cone resonances for incredibly tight, clear, and open bass.

ABOUT THE AUTHOR

Michael Allen is a chemistry and physics instructor at Rancho Verde High School in southern California. He obtained a BS in geology from Iowa State University and then completed his major in chemistry at Augustana College in Rock Island, IL. He has been designing dipolar and bipolar speakers since 1986 when he was working his way through college at Stereo Sound Studios in Ames, IA. He also enjoys building amplifiers and preamps. Currently, he is busy building a reference bipolar point source speaker system.

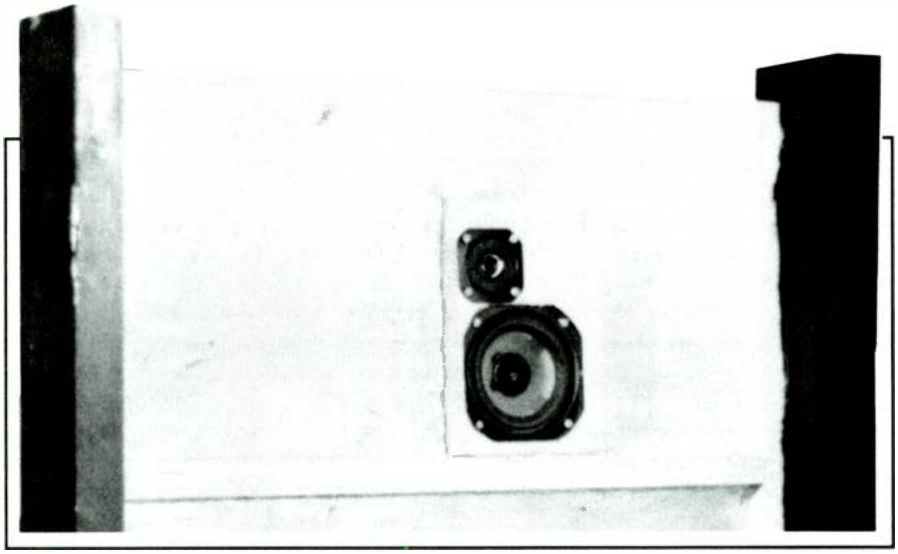

PHOTO 1: Front left speaker. Note tweeter offset to left of midrange. Rearward firing tweeter is mounted right of center.

In this unique project a 22″ × 33″ planar woofer (725 in.²) is constructed by using a drive assembly easily obtainable from a Radio Shack 10″ woofer (40-1331b). The Thiele/Small parameters for this "unmodified" driver are a f_S of 40Hz, a Q_T of 0.93, ($Q_E > 1$), and an efficiency of 91dB/W (1 m). Ignore the V_{AS} and M_O. The cone driver mounted in a box is rated to handle 50W maximum. Before anyone in the peanut gallery begins to snicker, remember this: the surround is cut off, the cone is cut off, and the cheap stamped basket frame is also cut off and discarded. Retained are the magnet, spider, and voice coil—hardly a basis to judge a woofer as good or not.

The midrange units I used were a pair of Boston Acoustics C-741Ws mounted on a finite baffle. The Thiele/Small measurements for these were an f_S of 135Hz, and a Q_T of 0.73. An even better choice

FIGURE 1a: Cut off dust cap.

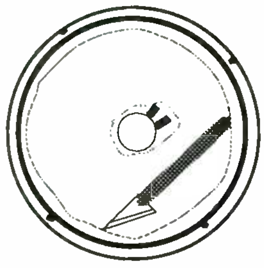

FIGURE 1b: Cut out cone.

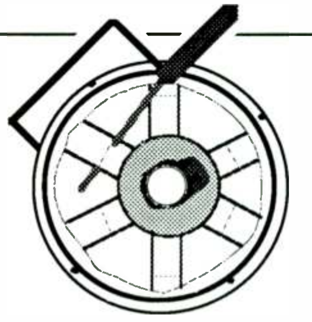

FIGURE 1c: Cut off basket.

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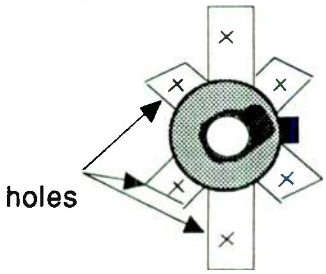

FIGURE 2a: Basket arms cut and drilled for mounting.

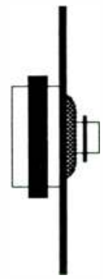

FIGURE 2b: Side view of stripped woofer.

may be the SEAS 11FM with a slightly higher Q_T and a smoother mid-bass and upper frequency range. For tweeters I used two pairs of Audax TW60ATi's with 10mm titanium domes wired in series. Series placement improves the damping factor on a tweeter that has been known to ring under high power. The other more obvious benefit is that the power handling has been quadrupled while the efficiency is only lowered 3dB, giving you an efficiency of 88.3dB/W (1 m).

In this design, we supply the midrange with a 3dB damping circuit switchable in or out for smoother frequency response or leaner (less) bass for the classic dipole sound. The cost of the drivers in this speaker is only about $170. The expense for the wood is minimal simply because there is little to buy.

But don't let the low cost fool you: this speaker will surprise you by how good it sounds. First of all, it is open. The image will be very impressive. Then you will notice the absence of the colorations in the bass and midrange which you have always disliked before. It is truly an innovative speaker with exceptional sound. The woofer section is remarkably tight yet full, and the relatively low cost and thinness would seem to make combination subwoofer/projection screens for television very practical.

CONSTRUCTION. After a reasonable amount of break-in, disassemble the woofer. First, cut out the cone and dust cap with an X-Acto® knife or razor blade (*Figs. 1a* and *1b*). Take care not to slice the voice coil leads.

Once you remove the cone, cut the arms of the basket (*Fig. 1c*). I used a nibbler. Caution: avoid dropping metal filings into the pole gap. Cut two of the arms longer, the upper and lower, for mounting. The side four are cut shorter, but allow room for a ⅛″ screw beyond the magnet for adjustments. Drill six 3⁄16″ holes as shown in *Fig. 2a.*

Note: The design's uniqueness is such that I will be attempting to patent it. If I am successful, I grant the right to anyone to try this design for *personal nonprofit use.*

The frame consists of square 1″ × 1″ pieces and a 24″ × 14″ × ¾″ MDF particleboard assembled with finishing nails and a good wood glue. Use clamps if possible (*Fig. 3*).

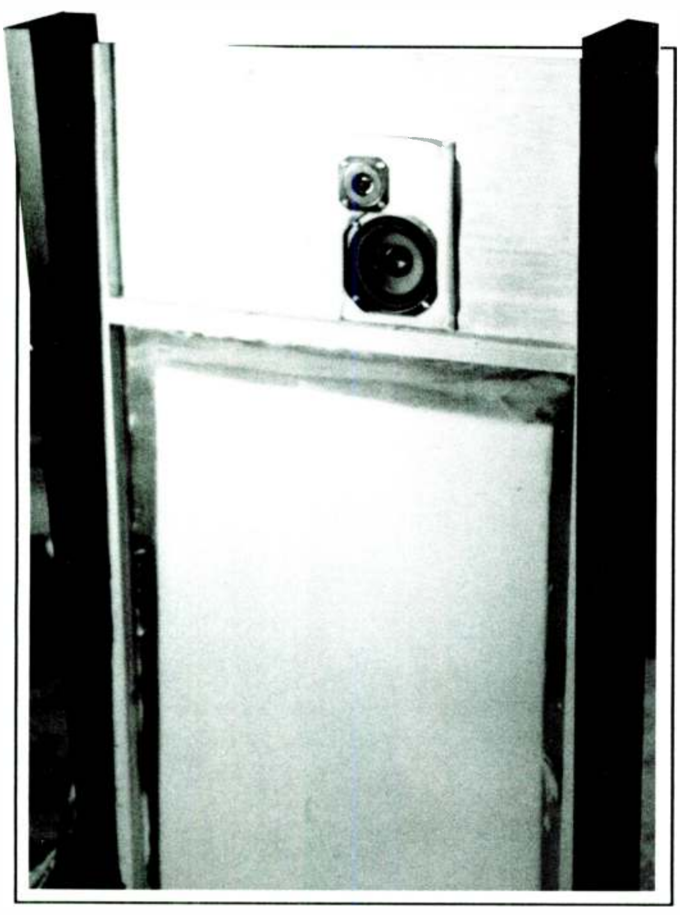

PHOTO 2: Mounted drivers on frame. Prototype used only a small anti-diffraction pad. Twin Mylar membranes, when shrunk, compress the foam diaphragm of the dipole woofer.

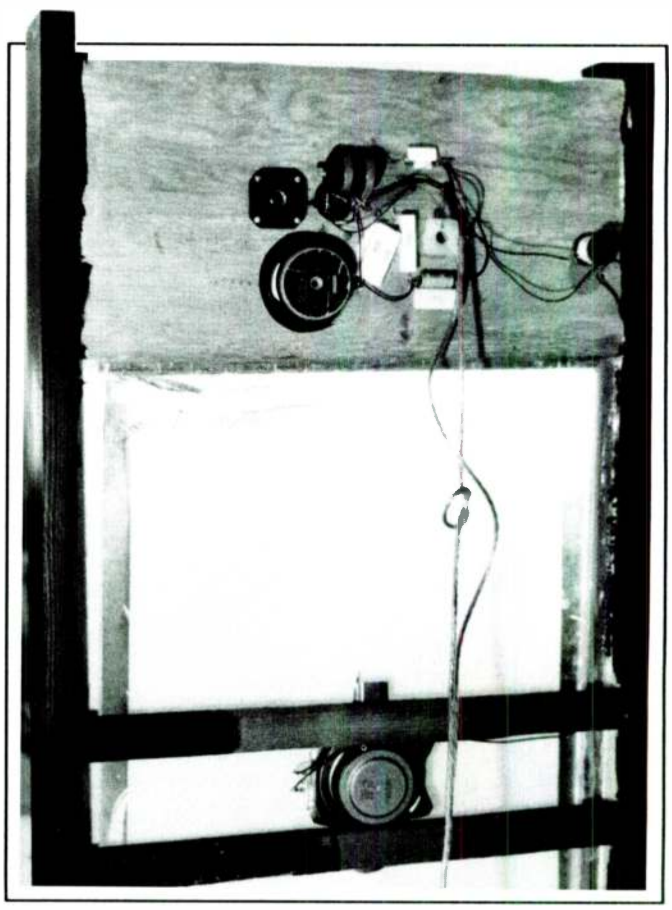

PHOTO 3: Rear view, showing crossover glued directly to baffle board. The 4Ω resistor for the midrange is a 50W wirewound (see crossover *Fig. 10* and *11*).

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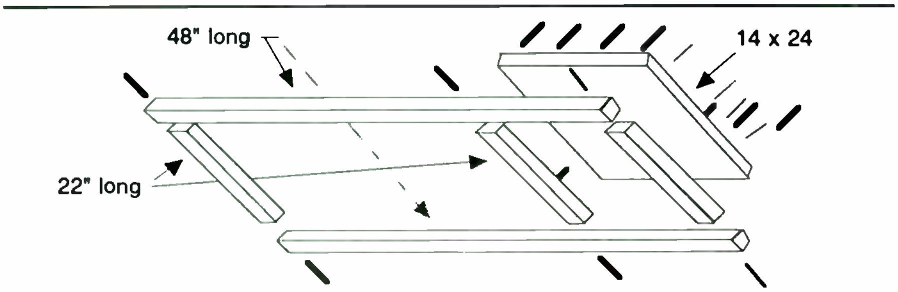

FIGURE 3: Nail and frame assembly.

FIGURE 4: Side view showing plate mounting. Arrow indicates ½″ space left for Mylar.

When attaching the MDF particleboard plate, be sure to leave ½″ of the lateral 1 × 1 for the Mylar® film attachment (*Fig. 4*).

After the frame is dry, the holes for the Audax TW60ATi tweeters and the 4½″ SEAS 11FM midrange may be cut. Place the bottom of the midrange 2″ above the middle lateral 1 × 1, and 4″ from the inside vertical 1 × 1. The two tweeters are mounted 1″ directly above the midrange, centered side by side. The outer tweeters fire forward and the inside tweeters fire rearward. Please note that the speakers must be assembled in mirrored pairs (*Fig. 5*).

To help remove any resonances in the mounting panel, use silicone to attach a 13″ × 22″ piece of ½″ polyurethane foam to the front panel. I wired the tweeters in series and crossed them over at 4kHz. Usually, this is too low for this type of tweeter, but in series wiring the power handling is quadrupled while the efficiency is only halved to 88.3dB/1W (1 m). I deliberately kept the crossover components as simple as possible.

Our flexible diaphragm uses two sheets of heatshrinkable Mylar made by 3M for weatherproofing patio doors and windows. It is, however, quite possible that any close-weave, lightweight, elastic fabric will work—hence the nickname "Spandex® woofer." (The possibility of a portable subwoofer which could be rolled up like a tent boggles my mind.)

Construction begins with a sheet of the Mylar glued to the frame using silicone caulk adhesive. Stretch the Mylar to remove any wrinkles and roll down the glue bead to remove any excess. After it dries, cut out an 18″ × 29″ piece of ½-inch thick polyurethane foam, round the corners (2″ radius), and spray on a thick coat of spray adhesive. (3M makes some stuff that is readily available, but it does stay in the air and sticks to everything!) Carefully center it on the Mylar and affix. Next, covering all exposed Mylar, spray adhesive on the now top side of the foam. Remove the Mylar protectant and squeeze a bead of silicone caulk adhesive on the Mylar on top of the frame pieces. Then, carefully stretch the top piece of Mylar film on top of the sticky foam and frame. Try to eliminate a large bubble of trapped air by applying pressure from the center outward. Again, roll down the glue bead to achieve a good bond (*Fig. 6*).

Allow the glues to dry overnight. You are now ready to attach the side pieces of 1″ × 6″ × 48″ oak, walnut, or whatever. The frame should be canted back to aim the tweeter upward. Use two screws per side piece and place a bead of silicone on the frame to halt any vibration, as shown in *Fig. 7*.

While the Mylar is drying, you can mount the driver assembly on the crosspieces. Two 2″ × 2″ × 24″ lengths are set at the top and bottom of the magnetic driver. With the driver centered on 12″, put 1½″ number 8 screws through the holes of the long basket arms into the 2 × 2s. Next, attach two short pieces of steel or aluminum to the back side of the 2 × 2s such that 2½″ driver adjustment screws can be put through the holes of the short basket arms and then into ones

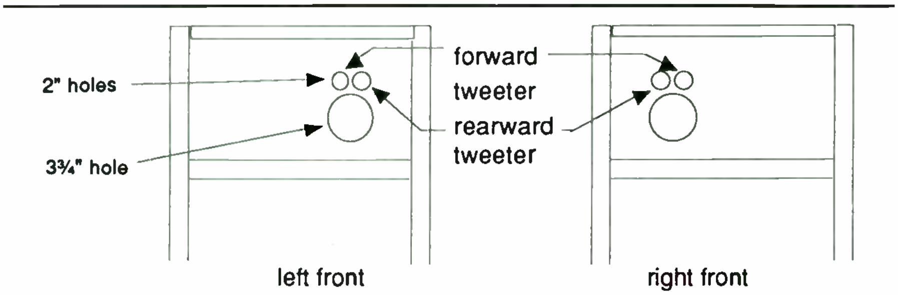

FIGURE 5: Tweeter and midrange placement.

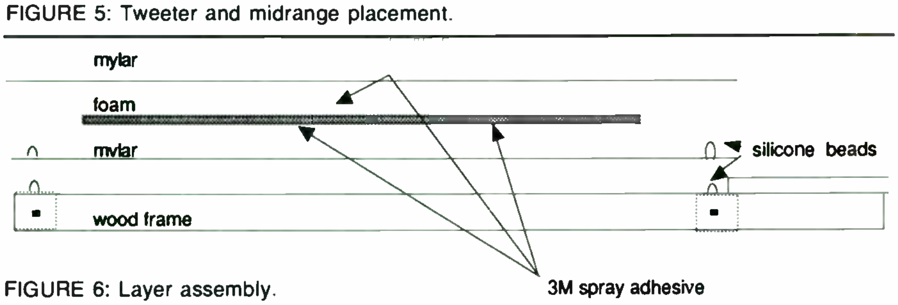

FIGURE 6: Layer assembly.

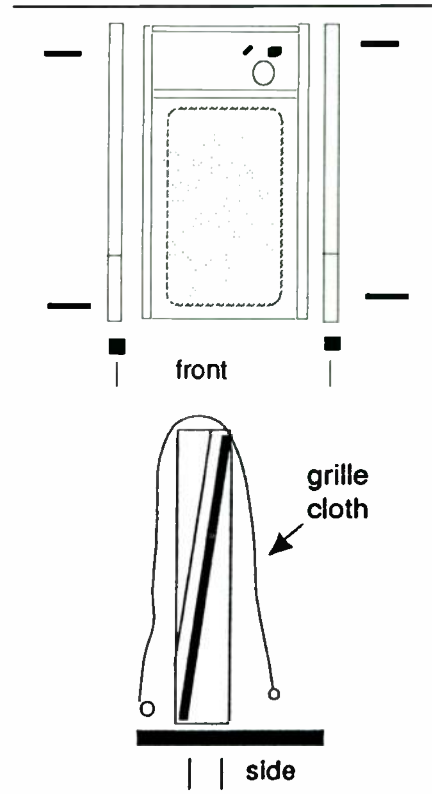

FIGURE 7: Side and grille placement.

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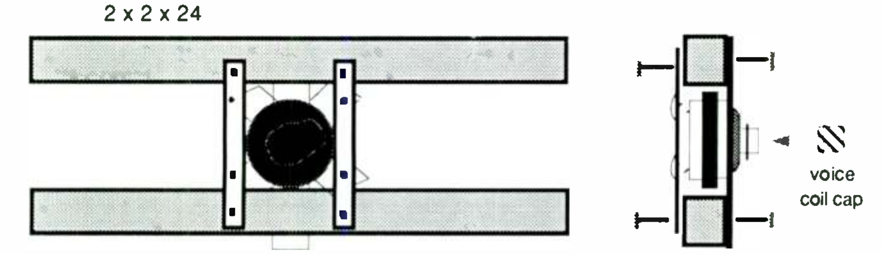

FIGURE 8: Woofer crosspiece assembly.

drilled in the short metal pieces (*Fig. 8*). The adjustment screws allow the voice coil to travel unhindered, allowing bass response at low volume levels.

A cap must be placed on the voice coil to attach it to the woofer diaphragm. An easy-to-find piece that works marvelously is the top ¾″ of a 2 ltr. soda bottle. The cut-off neck fits snugly inside the 1″ voice coil and can be permanently fastened with a little bit of silicone caulk. Screw on the bottle cap with a little bit of glue on the threads and you are ready to fix it to the Mylar.

At this time you will want to use a blow dryer to shrink the Mylar sheets to a wrinkle-free, tightly stretched condition. This should be done one side at a time, a little bit at a time. Be sure to check your glue connections to avoid pulling the Mylar off the frame. Trim any excess Mylar from the frame at this time.

Turning the woofer frame on its side, gently ease the magnetic driver 2 × 2 assembly to the center of the woofer. The two 2 × 2s should fit snugly between the dress side pieces. Position the driver assembly so it is located in the exact center of the Mylar sheet and the driver is aligned parallel to the sheet. Spread a prodigious amount of silicone caulk around the Mylar, ease in the magnetic driver until it makes contact, and then permanently attach the 2 × 2s with silicone and two 3″ wood screws through the side pieces (*Figs. 9a* and *9b*).

While the silicone dries, finish mounting the Audax TW60ATi tweeters and SEAS 11FM midrange in the MDF particleboard. The crossover, shown in *Fig. 10*, is siliconed directly to the back of the MDF board.[1] The midrange has a DPDT switch included for those people who want even more bass by attenuating the midrange presence by 3dB. Attach the wires to the drivers, being careful to connect the tweeters in proper dipole phase. Mount a five-way binding post near the bottom of the side panels. To make the speaker stand up, screw 12-inch long square tubular pipe to the bottom of the side pieces, allowing you to mount Tiptoes® on the frame.

Hook up the speaker to your amplifier and play some material with some bass drums at low volume. Adjust the woofer alignment screws so that the Mylar moves with the largest displacement. After a 30–50 hour break-in period, the Mylar will flex just enough for some really nice bass.

Finally, attach the grille cloth, covering both the front and rear of the speaker. Fabric with some elasticity can be wrapped and glued to a wood dowel at the bottom of the speakerfront. Pull the fabric over the top, and attach to another dowel at the bottom of the back (*Fig. 7*).

REFERENCES

1. Dickason, Vance, *The Loudspeaker Design Cookbook*, 4th ed., pp. 87–123. Available from Old Colony Sound Lab, POB 243, Peterborough, NH 03458; $29.95 plus $3 s/h (USA).

2. Gonzalez, Ralph and Bill Fitzpatrick, LMPG Loudspeaker Modeling Program. Available from Old Colony; $49.95 (IBM) or $39.95 (MAC) plus $3 s/h (USA).

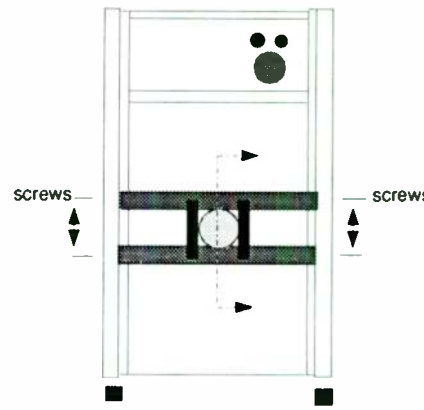

FIGURE 9a: Rear view.

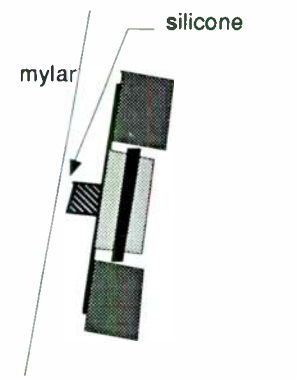

FIGURE 9b: Membrane attachment.

ADDENDUM. In using Ralph Gonzalez's LMPG program, I noticed a small dip in the frequency response of the midrange and tweeter crossover region in the program's graph.[2] According to the LMPG program, with a simple reversal of the tweeter leads (i.e., the forward firing tweeter out of phase with the midrange, the rearward firing tweeter in phase with the midrange), the response should smooth out to ±2dB from 40 to 20kHz! Try it both ways and listen from your own listening chair for the best image. Good luck!

The day after I sent my preliminary manuscript to *Speaker Builder* I received my new *SB* 2/92. To my horror, I found a design quite similar to mine incorrectly

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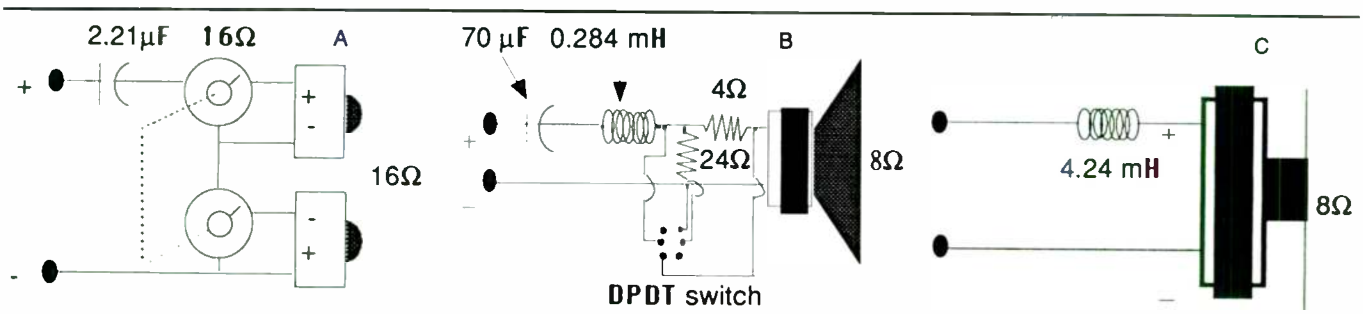

FIGURE 10: Crossover[1] a: Audax TW60Ti tweeters; b: SEAS 11fm midrange; c: Realistic 40-1331b woofer magnet assembly.

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THE SIMPLINE

BY JOHN COCKROFT
Contributing Editor

I designed the Simpline not only because I wanted a fine-sounding loudspeaker system, but to dispel the myth once and for all that a transmission line must be complex and expensive.

A few years ago, I wondered whether I could design a speaker system with only the bare essentials necessary to faithfully reproduce music. It all started when I found an old, physically abused sample FE-103 driver from the mid-60's, when the mini-speaker age began.

The first FE-103s were imported in 1965 through Olson Electronics (now defunct). Slightly later, Radio Shack imported the same driver with the same FE-103 designation. The Radio Shack 103s had red cloth half-roll (inverted) surrounds, while the Olson surrounds were cream-colored. The FE-103 was the first of the raw mini-speakers to hit the American market in the wake of the highly successful KLHFM radio, with its 4" mini-speaker and an equalized amplifier to boost the bass response.

This driver, with its rather light cone and 7 oz. magnet, was known as a "full range" driver. Surprisingly, the same unit is still sold today by Radio Shack as their model 40-1197, as an auto speaker for $10.95. In 1966 it cost $7.95, therefore I'm sure you'll agree that it is one of today's best bargains.

My original FE-103 required some first aid for a puncture near the base of the center dome. Even after the surgery, it pleased my sense of irony to note that the FE-103 still compared favorably with today's high-tech wonders.

SPEAKER DESIGN. The Simpline, for all its sonic merits, is ugly. Even so, it is quite a sophisticated little speaker. To make matters worse, it leans against the wall (*Fig. 1*) at a precarious angle.

In spite of its simple construction, the Simpline is based on many design concepts. First, it is a short, rather high-density transmission line speaker. It sports the close room coupling device of Roy Allison (having the speaker placed close to one wall of the room, and as far away as possible from the opposite wall) to help smooth the upper bass and lower midrange. In addition, it is tipped slightly back toward the wall, allowing the treble to spread out naturally, as opposed to beaming.

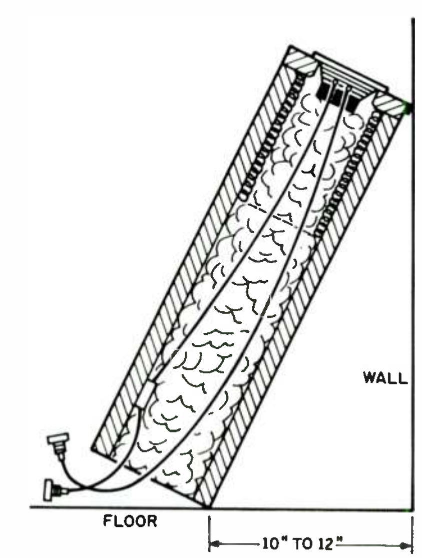

FIGURE 1: The Simpline speaker.

Tipping the enclosure provides an exit port, and allows a large hole for the lead-in wires. This may help the wires stay cooler than normal. Further, because the speaker is tilted, the sound exits from the port, striking the floor at an angle and allowing it to continue at an equal angle, and not back into the line. (Some sound does reflect back into the line due to the radiation resistance of the room air at the line's end.)

Since most floors are carpeted and padded, further damping is accomplished with this design. Diffraction is held to a minimum through the use of a small baffle, and the close proximity of the wall. The center of the woofer is only 3" from the rear wall. I think it is reasonable to believe that the bass—at least the bass radiating from the front of the driver—is radiating into a hemispherical space.

Because a single driver is used, phase should be intact. I didn't have to sweat over any crossovers, although I did have to work out a simple preemphasis filter to give the treble a hand. In the interests of simplicity and economy, it might be possible to tweak a treble control or adjust a graphic equalizer, if one is available in your system, to avoid using the filter. But the filter is so rudimentary, and the response so right, that I think it should be used.

One place not to use the filter might be in an ambient or surround-sound situation. In such a case, the treble isn't used, and an unfiltered Simpline might perform well, although it has never been used in this situation.

SPEAKER CHARACTERISTICS. The only obvious compromise with the Simpline is its power-handling ability. Efficiency is a direct trade-off for bass, and the Simpline has bass. When used in the type of rooms for which it was designed—bedrooms and small living rooms—it performs remarkably well. It is not, however, designed for high-decibel environments.

This speaker's advantages are natural timbre and clarity, but it has enough dynamics to make things work out well. It sounds quite wonderful with my little Adcom 535 60W amplifier. The original Simpline also sounded good on a 150W/channel Tandberg amp, and it delighted

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TABLE 1

SIMPLINE PARTS LIST

QTY.	DESCRIPTION
2	Radio Shack 40-1197 drivers (no substitute)
2	2µF Mylar® or polypropylene capacitors (may be made up of two 1µF capacitors in parallel)
2	10Ω, 10W resistors
3	particleboard shelves, 11½" × 4' (or one 4' and one 6' shelf)
8 oz.	polyester fiberfill or Acousta-Stuf
4'	cotton batting (surgical or household cotton in 8" or 10" widths)
13'	hook-up wire (16 gauge preferred; 18 gauge okay)
4	input jacks (banana jacks or your favorite alternative)
1 pkg.	lead BB-size sinkers, split
8	speaker mounting screws (#6 × ¾" Pan head sheet metal screws)
8 oz.	white glue (Elmer's Glue All, Wilhold, or similar)

Miscellaneous
60/40 tin/lead solder (or equivalent) rosin core (Don't use acid core solder.)
RTV silicone sealant (often sold as bathtub sealant in home supply stores)
Mortite or similar material
50–60 4d finishing nails
Finishing materials

Note: The items above are for a pair of Simplines.

friend and fellow speaker designer/builder Bob Baldwin when we lit up a few lights on his old Threshold amp.

At times, the Simpline has a smooth, seamless sound usually associated with headphones rather than speakers. If I stand between the Simplines with my back to the wall in just the right spot, I feel as though I am wearing headphones.

The Simpline produces a smooth, nonresonant bass which blends into a midrange of effortless clarity, and is topped with a natural high end. It has none of the shrillness or forwardness often associated with small speaker systems. The presentation is extremely well balanced and musical. Complex masses, both choral and orchestral, are nicely handled. That the Simpline can do all this at a basic cost of $20 per unit still amazes me.

GETTING STARTED. The Simpline might be an ideal project for a first-timer. It requires a little building, a little soldering, and speaker doctoring, but not too much. It is also inexpensive. Because you may be a newcomer to speaker building, I will go into a bit more detail than usual for such a relatively simple project.

Another advantage for a first-timer is that the dimensions are not critical. Sonically, ½" either way won't be noticeable. (Just don't make one side ½" narrower than its mate.)

The first step is to acquire all the materials required. (A good look at the parts list is in order.) Particleboard shelving is available at building supply stores. It comes in 4', 6', and 8' lengths, and is 11½" wide. It is usually ⅝" thick, but is sometimes ¾" thick. If you have some particleboard scraps at home, you can get by with just two 4' shelves to make a pair of Simplines. The problem is you will not have enough material with one shelf to make the speaker baffle. If you don't have any scraps, buy three 4' shelves, or one 4' and one 6' shelf.

CUTTING OUT THE PIECES. Cut both 4' boards in half to make four 2' pieces (*Fig. 2*). The pieces won't be quite 2' long because of the kerf (the width of the saw blade). Set your saw to 23¾", and run both pieces through it. That way they will be the same length.

Set your saw to 5", and cut a lengthwise slice from all four boards. Keep the 5" boards separate from the others. Two 5" boards and two of the other boards will make up the body of the enclosure. I haven't mentioned the width of the other board because I don't know the exact width of your saw blade or your boards (as they came from the store).

Cut two baffles, one for each Simpline. One dimension is the width of the 5" board plus twice the thickness of your shelves; the other dimension is the width of the other boards. Also, cut out the speaker hole. You must undercut the hole where the solder lugs are located to allow space for the driver lugs and input wires when it is installed in the enclosure (*Figs. 3, 4,* and *5*). For this reason, you should have the driver on hand when cutting the hole.

Use a saber saw with a wood blade to cut the hole. The best way to center it is to draw two diagonal lines connecting the corners of the baffle. Where the lines intersect is the center.

The hole should be 3⅝" in diameter. Make a mark 1¹³⁄₁₆" from the intersection of the two lines. Press the point of a pencil compass into the intersection, and open the compass to the mark. Scribe a circle. (Go around a couple of times so you can see it easily.) When you cut it out, there will be a lot of sawdust and vibration obscuring the line. Measure the diameter to make sure it is 3⅝".

Before you cut the hole, drill a starting hole so you can insert the saw blade into the wood. In most cases, a ⅜" drill bit will do the job. To be sure, measure the width of the blade from front to back, and make sure the hole is a little larger.

Pick a spot where one of the diagonal lines intersects the circumference of the circle. Measure in from that point a distance that is one-half the diameter of the drill bit you are using (*Fig. 3*). This will ensure that the hole will be at a spot where you want to start sawing.

For greater accuracy, especially with a hand drill, you might use a smaller drill bit first (such as a ¹⁄₁₆" or a ⅛" bit). This will help ensure that the larger bit won't slip off-target when you start to drill the holes. Use a center punch or a nail to make an indentation at the center mark.

Find a tin can that is larger in diameter than the hole, but not as large as the baffle. Set the baffle on the rim of the can with the starting hole over the can. This gives you a safe support for the baffle. It also protects you from the saw blade, and provides a place for some of the sawdust to go. Just make sure you don't cut into the can.

When sawing, stay just inside the line. Make short cuts (about half the distance between the diagonal lines), then move the baffle on the can to a comfortable position and continue.

UNDERCUTTING THE BAFFLE. The hardest part of this project is undercutting a space for the solder lugs and input wire. Place the driver in the hole

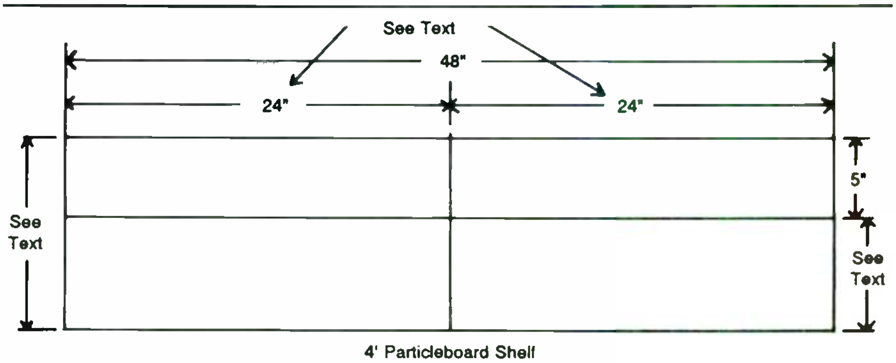

FIGURE 2: Cutting diagram for particleboard shelving.

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so the lugs are parallel to one edge of the baffle. Make two pencil marks on the baffle face, just at the edge of the hole, and a short distance outside the lugs. This will be the location of the undercut. Draw a line from each mark vertically through the hole, then make a mark on the underside of the baffle in the same spot.

the speaker flange and the baffle, so make sure there is plenty of clearance for the lugs. Finish things off by beveling the remainder of the speaker hole's inner edge to form a ¼″ face at a 45° angle. This will allow a smoother transition of sound from the rear of the speaker around the speaker hole. While you're at it, cut a $\frac{1}{16}$″ bevel around the

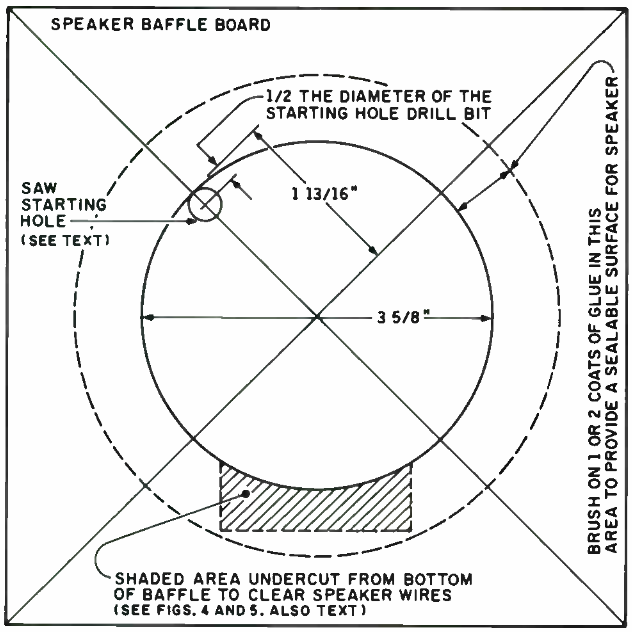

FIGURE 3: Speaker baffle layout.

The best tool for undercutting is a Stanley Surform #297. It looks like a rat-tail file that has metamorphosed into a cheese grater. Cloth-backed 36-grit or 50-grit aluminum oxide "sandpaper" also works well. Just tear a strip about 3″ wide, roll it into a rather tight tube, and use it like a rat-tail file. You can also use a coarse rat-tail file or a half-round file, but it might be rather slow going with either of these.

To undercut the baffle, insert the Surform into the speaker hole from the top, and begin to remove material from the lower face of the baffle between the two marks (*Fig. 5*). You can also turn the baffle over and work from the other side, or alternate back and forth. As you proceed, you will be able to insert the speaker deeper into the hole.

At this point, you may have to enlarge the speaker hole a bit to allow the flange to lie flat on the baffle. Work back and forth between these locations until the speaker fits in nicely, and there is about ⅛″ clearance around the lugs. This should allow enough space for the wires soldered to the driver when it is installed.

When the driver is mounted, some sealing material must be placed between upper corner of the hole and baffle top. The Surform tool will make these tasks quite easy.

ASSEMBLING THE ENCLOSURE. Place all the parts together to see if they fit. Mark where the glue will go along the edges of the boards. I always preglue all the parts when I assemble speaker enclosures to seal the porous edges. I simply brush a coat of glue on both edges of all the joint surfaces and let it dry. This makes the joints much stronger. I usually don't nail my enclosures together. Instead, I use weights and right-angle fixtures to hold the pieces in place while the glue dries.

For most builders, nails are more practical. Four-penny 1½″ finishing nails work well. Use about six per side, and start them about 1″ from the ends of the boards. The nails will go in the wider boards. On the outside edges of the boards, draw lines marking half their thickness. When you assemble the enclosure, drive the nails along this line. To help keep the nails from splitting the particleboard, blunt the points with a hammer before driving them.

Before assembly, drive the nails part-

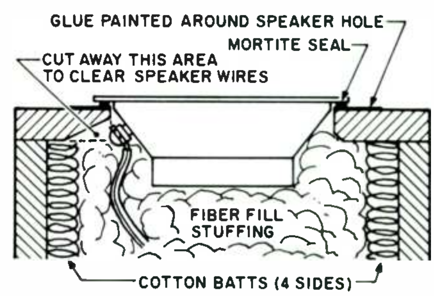

FIGURE 4: Preparation of the speaker enclosure.

Wipe any excess glue from the outside of the joint with a damp rag or paper towel. Using a paste brush, an acid brush, a cotton swab, or your finger, smooth out the excess glue at the seam. Let it dry enough so it won't run when the boards are turned over.

Attach the other 5″ board the same way. It is important that all the ends line way into the wood. It's a good idea to line up one of the other sides along the nail line. Hold the nail to be driven against the edge of this board to ensure that it will be driven vertically. Drive the nails at the ends of the boards so that their points are just showing. The other nails need not be driven quite that deep.

Take one of the 5″ boards which has been preglued, and place it on edge on a hard, flat surface such as the garage floor. Take another 5″ board and stand it on edge against the first one so it forms a "T". Run a healthy bead of white glue along the top edge of the first board. Then place one of the wider boards with the nails (also preglued) on top of the first board so their edges and ends align. The board should rest on the other leg of the "T" and be square in all directions.

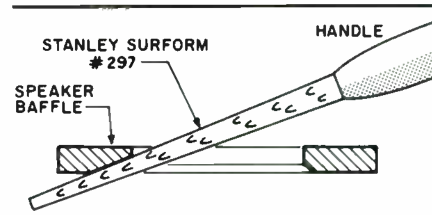

FIGURE 5: Using the Stanley Surform #297 tool to undercut the speaker baffle.

Carefully drive the end nail as straight as possible partway into the 5″ board. Then line up the boards along their entire lengths, and drive the nail at the other end all the way into the 5″ board, taking care that everything stays square. Finish driving the first nail, then drive the remaining ones.

Continued on page 18

World Radio History

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AIRBORNE Loudspeaker Driver Unit — **PRELIMINARY DATA**

20WP38/4 — **20 cm WOOFER MIDRANGE**

Features

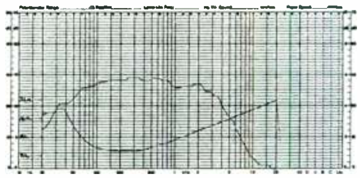
- Aluminium Voice Coil Former
- Vented Magnet System
- Polypropylene Cone
- Poly Dust Cap
- Coated Foam Surround
- Optimized for Vented Box

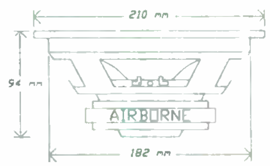
Parameters

Nominal Impedance		4 Ohms
Nominal Power		80 Watt
Music Power		120 Watt
Frequency Range		30-3.0 KHz
Sensitivity	1W/1m	89 dB
Magnet Weight	20 oz	566 g
Moving Mass		25.0 g
Effective Cone Area		212 cm2
Voice Coil Diameter		38 mm
Voice Coil Lenght		16 mm
Air Gap Height		6 mm
Voice Coil Resistance		3.3 Ohms
Voice Coil Inductance		.62 mH
Free Air Resonance		30 Hz
Vas		67.8 ltr
Qts		0.32
Qms		2.95
Qes		0.36

Impedance Compensation

Resistor	3.3 Ohms
Capacitor	51 mfd





Recommended Vented Box Size

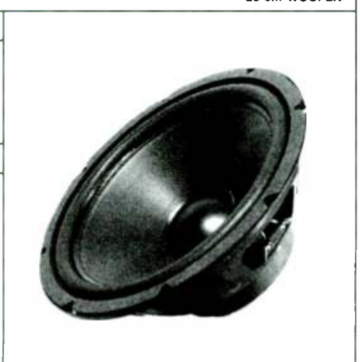
Type	Box Vol	Fb/Fc	F3	Peak	Vent Dia	Vent Lenght
B4	32 ltr	39 Hz	40 Hz	0 dB	5.0 cm	8.8 cm
SBB4	30 ltr	30 Hz	47 Hz	0 dB	5.0 cm	18.9 cm
SC4	28 ltr	33 Hz	45 Hz	0 dB	5.0 cm	16.1 cm
QB3	28 ltr	37 Hz	43 Hz	0 dB	5.0 cm	12.3 cm

AIRBORNE Loudspeaker Driver Unit — **PRELIMINARY DATA**

25WP38/4 — **25 cm WOOFER**

Features

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

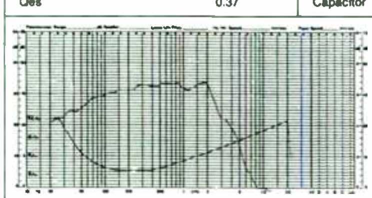


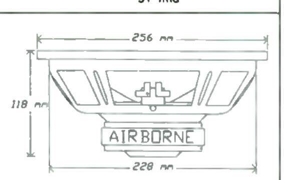
Parameters

Nominal Impedance		4 Ohms
Nominal Power		100 Watt
Music Power		150 Watt
Frequency Range		25-2.5 KHz
Sensitivity	1W/1m	91 dB
Magnet Weight	28 oz	792 g
Moving Mass		34.0 g
Effective Cone Area		344 cm2
Voice Coil Diameter		38 mm
Voice Coil Lenght		16 mm
Air Gap Height		6 mm
Voice Coil Resistance		3.3 Ohms
Voice Coil Inductance		62 mH
Free Air Resonance		26 Hz
Vas		176 ltr
Qts		0.32
Qms		2.54
Qes		0.37

Impedance Compensation

Resistor	3.3 Ohms
Capacitor	51 mfd





Recommended Vented Box Size

Type	Box Vol	Fb/Fc	F3	Peak	Vent Dia	Vent Lenght
B4	85 ltr	33 Hz	35 Hz	0 dB	7.5 cm	9.2 cm
SBB4	80 ltr	27 Hz	41 Hz	0 dB	7.5 cm	18.1 cm
SC4	75 ltr	30 Hz	39 Hz	0 dB	7.5 cm	15.0 cm
QB3	76 ltr	33 Hz	38 Hz	0 dB	7.5 cm	11.4 cm

AIRBORNE Loudspeaker Driver Unit — **PRELIMINARY DATA**

30WP50/4 — **30 cm WOOFER**

Features

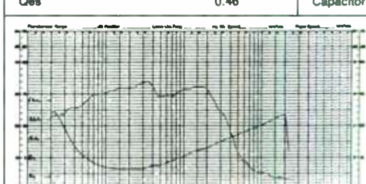
- Aluminium Voice Coil Former
- Vented Magnet System
- Polypropylene Cone
- Poly Dust Cap
- Coated Foam Surround
- Optimized for Vented Box

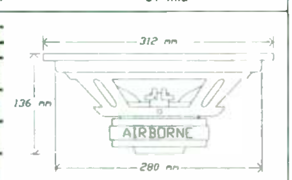
Parameters

Nominal Impedance		4 Ohms
Nominal Power		120 Watt
Music Power		180 Watt
Frequency Range		20-2.0 KHz
Sensitivity	1W/1m	93 dB
Magnet Weight	40 oz	1132 g
Moving Mass		56.0 g
Effective Cone Area		494 cm2
Voice Coil Diameter		50 mm
Voice Coil Lenght		20 mm
Air Gap Height		8 mm
Voice Coil Resistance		3.3 Ohms
Voice Coil Inductance		.62 mH
Free Air Resonance		22 Hz
Vas		232 ltr
Qts		0.33
Qms		3.46
Qes		0.46

Impedance Compensation

Resistor	3.3 Ohms
Capacitor	51 mfd





Recommended Vented Box Size

Type	Box Vol	Fb/Fc	F3	Peak	Vent Dia	Vent Lenght
B4	120 ltr	27 Hz	28 Hz	0 dB	10 cm	20.4 cm
SBB4	111 ltr	22 Hz	33 Hz	0 dB	10 cm	37.8 cm
SC4	105 ltr	24 Hz	32 Hz	0 dB	10 cm	31.5 cm
QB3	107 ltr	27 Hz	30 Hz	0 dB	10 cm	24.9 cm

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up so the baffle will have a level surface on which to rest.

When the glue is dry (if you are building two Simplines, you can be working on the second one while the first is drying), attach the baffle. Try to line up the baffles on both enclosures so the undercut section is in the same relative position, or perhaps in a mirror-image position. With that in mind, make some identifying mark on each baffle's face.

Near the center along each edge of the baffle, mark a short line. Drive the nail that will go into the wider board just through to the other side. You need not drive the other three nails quite so deep.

Stand the enclosure on end. Put a generous bead of glue along the top edges and line up the baffle, observing the location of the identifying mark on the baffle face. When the baffle is aligned, drive the first nail partway through the side. When lining up the other two sides, you may have to pry or push the outer edges of the enclosure out so they line up with the baffle edges. When the edges are aligned, nail the baffle in place and wipe off any glue.

When all the joints are dry, reglue them with glue thickened with a little cornstarch, talcum, or sawdust to fill any voids, and to form fillets along the seams. Thickened glue enables you to apply the glue on vertical surfaces without drips. Place generous amounts along all the joints. Set the enclosure aside to dry. (Doctored glue is not suitable for general use.)

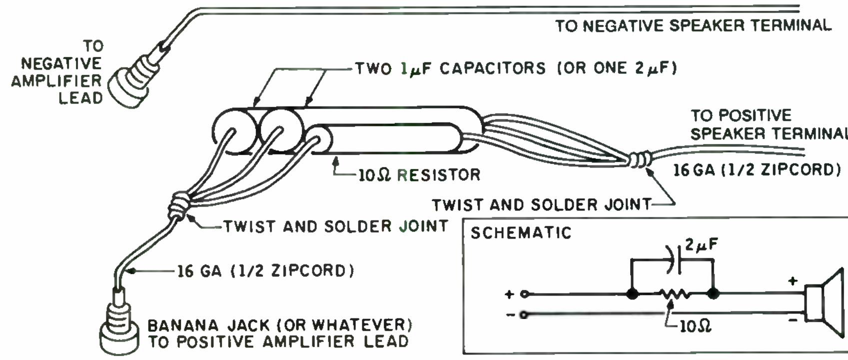

FIGURE 6: Simpline equalizing filter. The components should be glued to an inner wall.

ADDING THE FILTER. The filter consists of a 10Ω, 10W resistor paralleled with a 2μF Mylar capacitor. When I say paralleled, I mean the resistor and the capacitor are lying side by side, with the wires at each end intertwined (*Fig. 6*). This filter is connected in series with the positive terminal of the driver.

On the original Simpline, I let the lines from both speaker terminals dangle out of the bottom of the enclosure. I put banana jacks on the dangling ends, because I use banana plugs on my amplifier leads. Then I just placed a banana jack on one end of the filter and a banana plug on the other end and inserted the filter between the positive amplifier lead and the positive speaker lead. I justified this approach by telling myself I would probably be changing the filter often before I got it right.

I think it's a good idea to mount the filter on one of the enclosure walls, near the bottom opening, just in case you need to access it. You can glue the elements to the wall with a bead of RTV (room temperature vulcanizing) silicone sealant (bathtub sealant). It might be easier to glue the parts in place before wiring them together.

Radio Shack doesn't stock a 2μF Mylar capacitor. They do, however, have a 1μF capacitor. You can simply use a couple of them in parallel.

BATTING AND WIRING. While the glue on the filter parts is drying, cut the cotton batting for the enclosure from a roll of surgical or household cotton. You can use one long piece of batting for the entire enclosure or cut a piece for each wall. Be sure to allow enough length or cut a fourth piece for the side to be added later. Spot-glue the batting inside the three assembled walls where they meet the baffle.

Bonded polyester material used to fill comforters or pieces of old blankets probably could be used instead of cotton batting. It may even be possible to leave out the batting altogether.

When the cotton is in place and the glue on the filter parts is dry, wire the parts together. Twist together all the leads on one end and solder them. Do the same on the other end. I suggest using 16-gauge zipcord for the speaker wire. It's available at hardware stores by the foot or in 30′ and 100′ rolls at Radio Shack. Hardware stores refer to it as heater wire because it is heavier than common zipcord, which is usually 18 gauge.

One piece of zipcord should go from the wires at the bottom end of the filter, out the bottom of the enclosure, and about 1′ beyond. Use any kind of connectors you prefer.

It might help to pull the zipcord apart into two separate wires. Start at one end with a razor blade or wire cutters, then grasp the wire in both hands and pull the strands apart. Zipcord is coded for polarity. One strand usually has smooth insulation and the other longitudinal ridges along the outer edge. I usually make the ridged strand the positive lead and the smooth one the negative.

Another piece of zipcord should go from the upper end of the filter to about 6″ above the speaker baffle. Solder it to the upper end of the filter.

Cut a piece of zipcord that equals the combined length of the other pieces plus the filter. Use wire coded negative (the smooth strand). You will insert this wire later when the stuffing is installed.

STUFFING THE SIMPLINE. The stuffing consists of 4 oz. (114 grams) of polyester fiberfill or Acousta-Stuf for each speaker. Fiberfill is used in pillows and stuffed animals and is available in fabric stores, department stores, and probably in some hobby shops. I prefer the kind that comes in a bag to the kind that comes in sheets or rolls. Usually it is quite lumpy and must be pulled apart and smoothed out before using.

After teasing the stuffing so it is all pretty much the same density, place the enclosure on a table with the open side up. Lay the stuffing reasonably evenly throughout the line. Bring it up to within ½″ of the baffle.

Put some of the stuffing under the positive speaker wire to keep it away from the walls. At this time, lay in the negative wire. Try to arrange the leads roughly in the center of the line and not touching each other.

When all the stuffing is installed, put the fourth piece of cotton batting in place. Gently press down the stuffing along the edges of the line where the final side will be attached. Make sure all the appropriate surfaces have been preglued.

FINISHING THE ENCLOSURE. Start the nails in the final side as you did before with the other pieces. Move the

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enclosure to a more stable surface (such as the garage floor). Place newspapers under the enclosure to protect the floor, and have a damp cloth handy.

Place a ¼″ bead of white glue along the edges of the two attached sides. Hold the final side in a vertical position and place a similar bead on the edge where it will contact the back of the speaker baffle. With a sweeping motion, bring everything together so that the joint at the baffle is closed up before the glue runs off the end.

While keeping pressure on the baffle joint, line up one side edge. Partially drive the first nail on one end, then the second nail on the other end. Repeat this process on the other side. Then completely drive in all four nails.

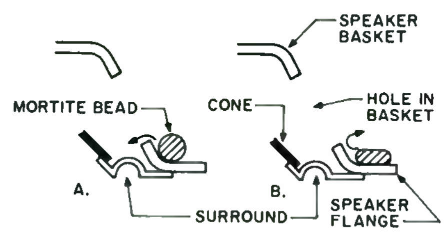

FIGURE 7: The position and disposition of the Mortite® bead on the back of the speaker flange. *A* shows the bead in position. *B* shows the bead flattened down to help it stay in place.

Stand up the Simpline so the baffle is on top. Drive in the nail on the baffle edge. Then put the enclosure back on its side and drive in all the rest of the nails. Clean up any excess glue with the damp cloth or paper towels.

Leave the Simpline in that position for several hours (overnight) to dry. When it's convenient, brush a coat of glue around the speaker hole to provide a better surface for the speaker sealant to adhere to.

If you plan to finish your Simplines, now is the time to do it. Using a nail set, drive the heads of the finishing nails about 1/16″ below the surface. Fill in the depressions with spackle or putty, then finish as desired.

INSTALL THE DRIVER. When your enclosures are finished, insert the driver, making sure it fits well, and there is enough space for the terminals and wires. Carefully drill the four pilot holes for the #6 Pan head sheet metal screws (¾″ long). Use a 1/16″ drill bit. If you're not used to drilling, it might be a good idea to mark the screw locations, then remove the speaker. If you don't have a center punch, a large nail will do. Just place it over the mark and hit it gently with a hammer. The indentation will keep the point of the drill from slipping.

Wrap a piece of tape around the drill bit, about ½″ from the tip, to serve as a depth gauge so you don't go all the way through the baffle. (If you do, it's no big deal. The only problem is that sometimes the drill will get tangled up in the stuffing. Pushing the stuffing down prior to drilling will help.) It's a good idea to drive the screws into the pilot holes before mounting the speaker, so there will be less resistance on the screwdriver. This will lessen the chance of the screwdriver slipping and damaging the speaker. Refluff the stuffing near the speaker hole after you are finished drilling, before you mount the speakers.

Pull the speaker leads out of the baffle hole. Position the driver face down and place a 3/16″ bead of Mortite® or similar material (such as Gardener Bender's G-B Duct Seal) around the back of the speaker mounting flange, where it joins the basket (*Fig. 7*). Knead the two ends of the Mortite together. Press the Mortite down all around so it stays in place. Make sure it is flat enough so the sealant won't go into the holes in the driver basket. (Just press it down below the lower edge of the basket holes.)

Trim about 3/8″ of the insulation from the leads protruding from the speaker. Twist the wires together with your fingers until they form a tight bunch. Tin these leads, making sure there is a generous amount of solder on the wires. Tin the two speaker lugs (the ones pointing down toward the magnet) the same way. Put a couple of layers of electrical tape on the magnet under the lugs, bending about ¼″ over the top, to avoid shorts.

Sit down on a chair within comfortable reach of your soldering pencil. Hold Simpline between your knees with the baffle facing up. The notch hole for the speaker lugs should be facing away from you. Place the speaker face down on the baffle, with the lugs facing you. The speaker will be covering the far side of the hole, and the speaker wires will be sticking up through the near side.

Using a pair of needle-nose pliers, grip the insulation on the positive wire (the one with the ridges) just below the bare wire. Bring the soldered end of the wire up to the positive lug. You may have to bend the lead a bit to get it to lie parallel to the lug and touching all along it. Hold the wire in place.

Place the point of your soldering pencil along the sides of the joined pair so both pieces are being heated. Hold the iron there until the solder on both the lug and the lead flows. Move the soldering pencil away, but hold the pliers steady until the joint has solidified. You should hold your breath during this process to avoid inhaling the potent fumes.

Solder the negative lug in the same manner. Don't keep the heat on the joint any longer than necessary. If you can manage to hold the pliers in place, try to touch the tip of the soldering pencil to the end of the solder on the roll so you can pick up a bit of fresh solder and flux, as you bring the soldering pencil to the joint. You can build up an excess of solder on the wires and lugs as you tin them so there will be enough solder to flow around the joints. If you move the pliers before the solder hardens, it will appear dull, in which case you must reheat and reflow the joint.

Make sure the Mortite ring is okay, then turn the speaker over by bringing the edge farthest away from you upward and toward you, pivoting around the terminals. Gently lower the driver into place, moving the speaker leads as necessary to clear the edge of the hole, and, to relieve stress on the speaker terminals. Press the speaker down on the baffle, making sure the screw holes line up.

When running in the screws, cup your hand around the screwdriver shaft with the back of your hand facing the cone. This will protect the cone if the screwdriver should slip off the screw head. Or place your left hand over the speaker cone and surround with your fingers spread out a bit. Place the screwdriver between your thumb and forefinger.

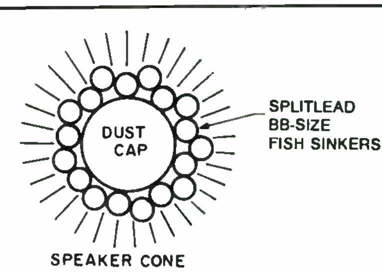

FIGURE 8: The location of the 18 split-lead BB-size sinkers glued to the speaker cone for added mass and increased mehcanical Q.

Drive all the screws down to the speaker flange. Then work a little on two screws that are opposite each other (say, one-half turn at a time). Tighten the other two screws the same way. Try to keep the flange parallel with the baffle. Stop when the screws feel pretty snug but not totally tight. There will proba-

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bly be a little space between the frame and the baffle because of the Mortite. If the Mortite squishes out around the edges of the speaker, cut it away with the screwdriver blade.

Glue a strip of dense foam or felt (or even weather stripping) along the back of the baffle where it will touch the rear wall. This will prevent buzzing as the Simpline vibrates. Alternatively, place a piece of foam between the speaker and the wall, and allow the weight of the speaker to hold it in place.

MODIFYING THE SPEAKER. You must modify the driver's cone and dust cap by adding mass and stiffening/damping material. I saved this step for last because it is easier to do the job when the speaker is installed.

Hold the Simpline between your knees. Brush two coats of polyvinyl acetate (PVA) glue (such as Elmer's Glue All) on the cone. A cheap brush, such as the type that comes in kids' water-color sets, will work well. Try about a size 6. In a pinch, you could probably use a paste brush. To make cleaning the brush easier, wet it with water before dipping it in the glue and pinch out any excess water.

Apply the glue full strength using a flowing motion. Keep it off the cloth surround. If you accidentally get some on the flexible part of the surround, stop everything and remove it with a damp tissue. Don't allow it to dry.

I usually start at the junction of the cone and the surround, using horizontal strokes covering an area of about 1½" at a time. I work down to the junction of the cone and the dust cap. Then I use light, vertical strokes from the bottom up to smooth out the glue. You will never get it perfectly smooth, so don't try. If you keep going back over the glue as it dries, you may lift the glue right off the cone. If this happens, put some fresh glue on the brush and stipple the glue onto that area. After the cone is covered, proceed to the dust cap. Apply a lighter coat of glue there.

Wait a few hours before applying the second coat of glue. Don't panic when coating the cone. The glue is opaque when wet, but dries completely transparent. When you're done, clean your brush with soap and cool water.

To lower the cone's resonant frequency and increase the mechanical Q, you must add about five grams of lead to the junction of the cone and the dust cap. I usually use ⅛-inch diameter solid solder wire for adding mass to my speakers, but you may not be able to find it.

As an alternative, use split-lead BB-size fish sinkers. Nine of these weigh five grams. They are split almost all the way through, so all you have to do is slip a single-edge razor blade into the split and slice down vertically through the remaining lead. Don't use the family cutting board for this, as lead is highly toxic.

Glue the split sinkers around the junction of the cone and dust cap (*Fig. 8*) like petals of a flower. Just brush a ring of glue around the cone where it meets the dust cap, then place the weights, flat side down, on the glue. Move them around until they look okay. Perhaps the sinkers should be glued to the cone before you apply the two coats of glue. That would reduce any problem with buzzing if the weights were not securely fastened.

Your Simplines are now complete. My apartment dictates a speaker spacing of about 6' which sounds fine, but please feel free to experiment. The space from the bottom of the Simplines to the rear wall should be 10–12".

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RMS Power:	60	60	60	100	150	150	150	100
System Power:	150	150	150	175	200	200	200	150
Sensitivity:	88	88	89	90	89	89.6	89	92
Voice coil:	25	25	25	40	50	50	50	50
Magnet mass:	240	344	240	794	1134	1700	1700	1134
SD meters:	.008	.008	.0143	.022	.0345	.0545	.0545	.0855
Dcr:	5.5	5.6	5.6	4.7	6.45	6.1	3.11	4.6
Inductance:	.62	.7	.68	.98	1.7	1.6	2.0	2.3
Xmax:	2	2	3	4	7.68	7.68	10.54	5
Mmd:	7.24	6.5	11.9	26.4	57	89	73	119
BL:	4.97	5.07	5.61	6.3	12.15	13.22	7.8	15.866
Qms:	1.659	1.81	3.052	6.74	3.978	5.458	5.1	6.677
Qes:	.628	.652	.636	.441	.420	.452	.481	.288
Qts:	.455	.479	.526	.414	.38	.418	.44	.276
Vas:	9	7	28	56	111	242	380	561
Range:	57-9k	67-9k	43-7k	32-4k	24-2k	20-1k	17-500	18-1k
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AC drivers feature vented pole pieces and rubber surrounds, (except AC7 and AC15 which have foam surrounds, the AC15 does not have a vented pole piece). AC5S, AC8, AC10 and AC12 have polypropylene cones, AC5, AC7 and AC15 have doped paper cones, DV12 has long-fiber cone.
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STALKING f_3

BY MANNING REDHILL

If you have chosen a vented box design for your next speaker project, you must prepare yourself for the inevitable tug-of-war contest with the laws of physics. Fortunately, much design work has already been done in this area. The work of A.N. Thiele and R.H. Small (and others), the basis for all vented designs, provides several key formulas.

In the following, I'll review some of the equations that go into linear Thiele/Small calculations and then discuss some additional computations you can use for box design. Instead of specifying the usual alignment parameters α and h, I investigate what happens when the cut-off frequency, f_3, is specified.

A SHORT REVIEW. At low frequencies, when a driver acts as a solid piston and wavelengths are long compared to box dimensions, a driver in a vented box can be regarded as a fourth-order electrical filter. While Leo Beranek was among the first to use lumped electrical circuit elements as analogs for loudspeaker parameters, Thiele was the first to use modern filter synthesis methods with such filters in the loudspeaker context.[1, 2] Later, Small showed how to take the effect of box losses into account making predictions of driver behavior in a vented enclosure more accurate.[3] Many computer packages are now available that make Thiele/Small calculations easy, but anyone interested in enclosure design should read at least the papers by Small; they are models of clarity.

The basis of Small's notation are now standard:

- f_S is the resonant frequency of the isolated driver.
- Q_{ES} is the electrical Q of the driver.
- Q_{MS} is the mechanical Q of the driver.
- Q_{TS} is the total driver Q and is given by $Q_{ES}\,Q_{MS}/(Q_{ES} + Q_{MS})$
- V_{AS} is the compliance of the driver given as the volume of air with the saved compliance. All of these quantities are supplied with drivers that have any pedigree at all, but speaker builders are urged to measure them as these values may vary. I recommend reading *The Loudspeaker Design Cookbook*[4], in this regard.

As for the box:

- D_V is the diameter of the vent.
- f_B is the resonant frequency of the vented box with no driver hole.
- L_V is the length of the vent.
- Q_L is the Q of the box. f_B is the box volume.

The box frequency f_B is completely determined by the volume of the box and the vent dimensions. On the other hand, Q_L is a wild card that depends principally upon box leaks, sound absorption, and the vent's breathing resistance. While nearly impossible to predict with accuracy, $Q_L = 7$ is regarded as a good place to start when calculating. Within *The Loudspeaker Design Cookbook* is a method for measuring Q_L once the box is built. I also recommend reading the empirical wisdom of G.L. Augsburger ("New Guidelines for Vented Box Construction," *SB* 2/91, pp. 12–17) on vented box construction.

Three other parameters are convenient combinations of the above and are in common use: $\alpha = V_{AS}/V_B$, the volume ratio, $h = f_B/f_S$, the tuning ratio, and $f_{SB} = (f_S f_B)^{1/2}$ or $f_S h^{1/2}$, the resonant frequency of the driver mounted in the box.

T/S EQUATIONS. When coupled, the driver and the vented box—both lossy spring-mass second-order systems—yield a fourth-order high-pass system. The magnitude of the response of such a system is given by:

$$R(x) = \frac{x^4}{\left[(x^4 - a_2x^2 + 1)^2 + (a_1x^3 - a_3x)^2\right]^{1/2}} \quad (1)$$

where the normalized frequency is:

$$x = f/(f_s h^{1/2}) \text{ or } f/f_{sb} \quad (2)$$

and where f is the frequency of the input signal. The identification of the coef ficients α_I with the driver and box parameters is as follows:

$$\alpha_1 = (Q_L + hQ_{ts})/d$$
$$\alpha_2 = [h + (a + 1 + h)^2]/(h^{1/2}d)$$
$$\alpha_3 = (hQ_L + Q_{TS})/d$$
$$d = Q_L Q_{TS} h^{1/2}$$

THE BOX FREQUENCY. The box resonates at what is known as the Helmholtz frequency (after the physicist who first made the analysis), which is determined by the compliance [compliance = 1/(spring constant)] of the air in the box and by the mass of air entrained by the vent. The relationship is:

$$f_b = \frac{cD_v}{\left(12 \cdot 16\pi L_{eff} V_b\right)^{1/2}} \quad (3)$$

where D_V is the vent diameter in inches, V_B is the volume of the box in cubic feet, c is the velocity of sound in ft/sec, and L_{EFF} is the effective length of the vent in inches.

Continued on page 26

ABOUT THE AUTHOR

Manning Redhill is a professor of mathematical physics at the University of California. She received her Ph.D. at MIT in theoretical nuclear physics and now teaches and does research in nonlinear mathematics. Her interest in loudspeaker and enclosure design arose from her investigations into interactive resonators. Her housemate, a professional cabinet maker, builds her designs.

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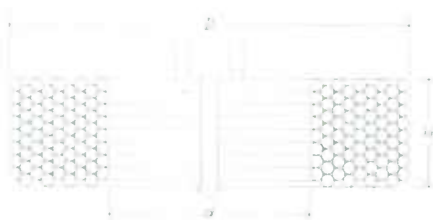

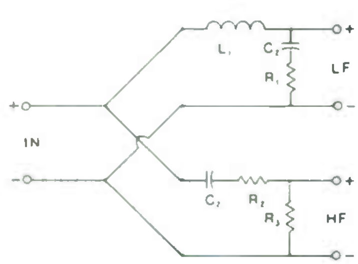

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Continued from page 24

$$L_{eff} = L_v + .83(\pi/4)^{1/2}D_v \qquad (4)$$

L_V is the length of the vent pipe. For metric units, drop the "12" in *Equation 3* and express the other quantities *all* in centimeters, square centimeters, etc., or *all* in meters, square meters, etc. The velocity of sound at room temperature is 1,129 ft/sec or 344 meters/sec or 34,000 cm/sec.

Damping material can change the effective volume of the box.[4] It is better to use the effective length L_{EFF} of the vent in calculations instead of the physical length L_V because when the box breathes, more than the air contained in the vent pipe moves. Exactly how much more depends upon how the pipe is terminated. The outside end is usually flush with a flat baffle and the inside end is usually left hanging. If the inside end is near a wall or the floor of the box, it will affect the actual amount of air in the moving mass. For this reason, the factor "0.83" in *Equation 4* is only approximate. You must trim the vent pipe to yield the desired box frequency for each box.

ALIGNMENTS. The way you tune the two resonant systems—the driver and the box—affects the response of the coupled system, just as the alignment (hence the term) of a sequence of RF circuits affects the total response. In *Equation 1*, there are four parameters, α_1, α_2, α_3 and the frequency normalization f_{SB}; however, five parameters are at our disposal: f_B, f_S, V_B, Q_L, and Q_{TS}. Other ways to express these parameters are f_{SB}, α, h, Q_L, and Q_{TX}. In other words, no unique way to achieve a desired response exists. Having chosen a driver, you may choose from a continuum of box sizes and vent parameters, for example, to attain a desired response.

You may have noticed that the cut-off frequency f_3 never comes into the picture although it is often of vital importance to designers. The wide field of parameter choices mentioned above allows you to first pick the cut-off frequency before determining which of the possible alignments helps you achieve it. This puts f_3 very much into the picture.

The cut-off is the frequency at which the response is at half of the power of what it is at high frequency. Mathematically, it is expressed as:

$$[R(x_3)]^2 = 1/2 \qquad (5)$$

where R (x_3) is the response at x_3 from *Equation 1* and where $x_3 = f_3/(f_S h^{1/2})$ is the normalized cut-off frequency. Solve *Equation 5* for α in terms of h,

$$\alpha = h[A_2 - (1/(Q_{st}Q_L)] - 1 - h^2 \qquad (6)$$

or, for the box volume from the definition of α:

$$V_b = \frac{V_{as}}{h[A_2 - 1/(Q_{ts}Q_L)] - 1 - h^2} \qquad (7)$$

In either form, A_2 carries the information about the cut-off frequency:

$$A_2 = \frac{1}{x_3^2}\left\{1 + x_3^4 + \left[2x_3^8 - (a_1x_3^3 - a_3x_3)^2\right]^{1/2}\right\} \qquad (8)$$

If the square root argument is negative, then it is not possible to realize the alignment. A_2 is more complicated than it appears because α_1, α_3, and x_3 are all functions of h. Given a driver and a desired cut-off f_3, *Equation 7* provides the box size V_6 in terms of box tunings h. You can express the box frequency in any terms you find convenient. For example, if the definition f_B/f_S replaces h, and *Equation 3* replaces f_B, then you obtain the box volumes and vent length combinations that will yield a constant cut-off frequency.

THE BASS IDEAL. I call curves such as V_B as a function of h at constant f_3 isosychnitic curves, (iso-sik-NIT-ic) from the Greek meaning "constant frequency." An isosychnitic such as *Equation 6* gives all the α-h combinations that are consistent with a chosen value of the cut-off frequency f_3.

The Swan 305 woofer (recently advertised in *SB* 2/92, p. 31) has the following specifications:

- f_S = 24.5Hz
- V_{AS} = 167 liters
- Q_{MS} = 3.66
- Q_{ES} = 0.344

The manufacturer recommends a box of 100 liters (3.53 ft³) tuned to 31Hz, thus yielding a system that puts f_3 at 31Hz. The 3.43" inch-long vent 3" in diameter translates into an h of 1.26 from *Equation 3*. The design point is shown as a black dot on the 31Hz isosychnitic curve in *Fig. 1*. The flatness of the curve shows that a little change in f_3 can save some volume, although the resulting alignment may not be what you wish.

Flatness can also work against you be-

Continued on page 28

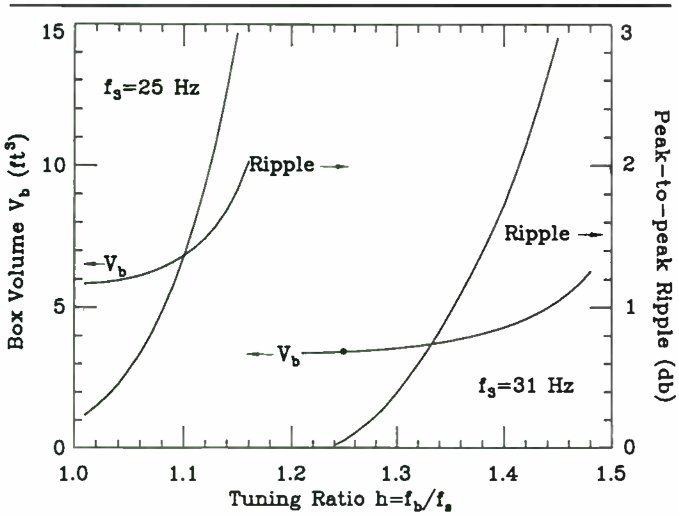

FIGURE 1: Isosychnitics for f_3 = 31 and 25Hz for the driver described in the example. Superimposed on each is the response curve's peak-to-peak ripple. This results from the indicated values of the tuning ratio h and box volume V_B.

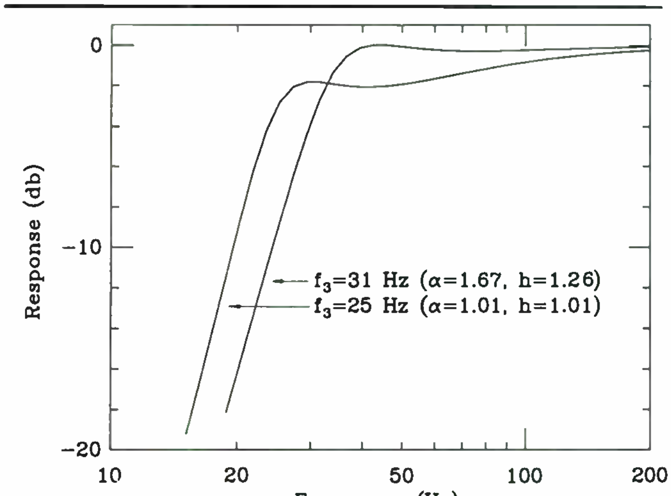

FIGURE 2: Response curves for the two alignments described under the heading "The Bass Ideal."

World Radio History

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

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

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

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

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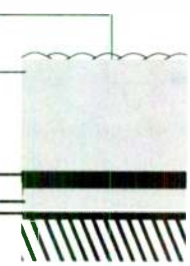

Barrier septum, 1/8 inch thick. Made of limp flexible vinyl copolymer loaded with non-lead inorganic fillers, it is a "dead wall" that isolates the vibrations in the walls of your cabinet from the vibrations created inside the enclosure.

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

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

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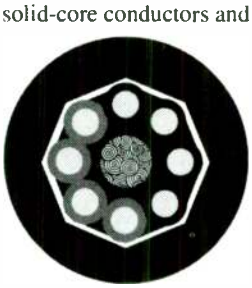

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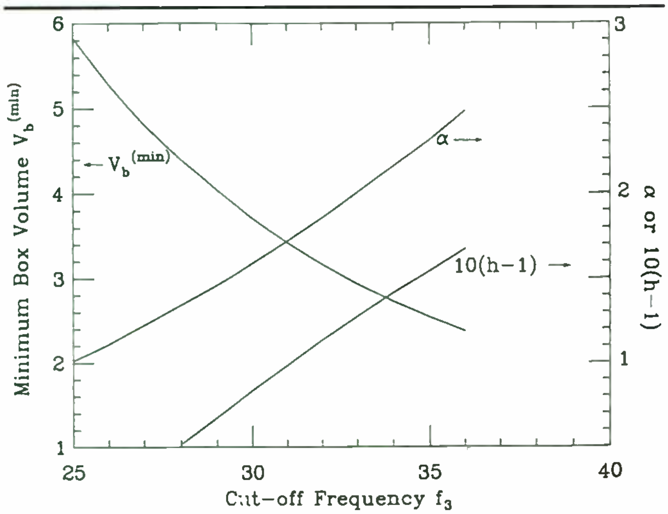

FIGURE 3: Minimum box volume $V_{B(MIN)}$ compatible with a cut-off frequency f_3, and the corresponding values of α and h. Box volume is in ft³.

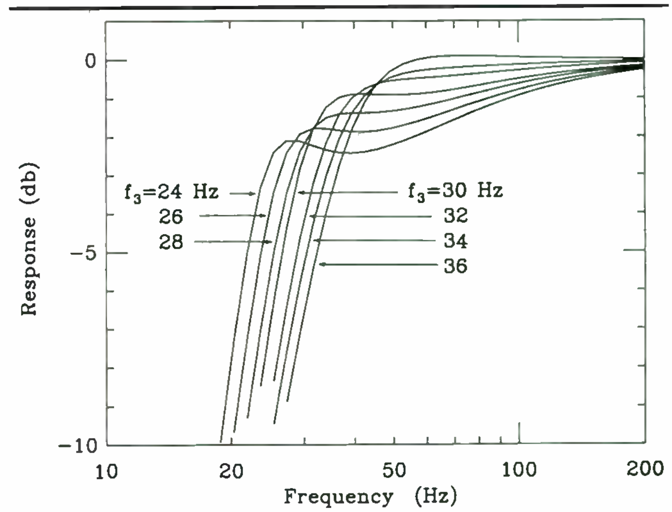

FIGURE 4: Resulting response curves from alignments determined by specifying $V_{B(MIN)}$ and f_3.

Continued from page 26

cause a slightly miscalculated volume can seriously detune the system. Hence the oft-mentioned advice to build the box too large and bring it back to the desired volume by filling the space with wood blocks.[4] The corresponding point on the ripple curve predicts a modest valley and peak, borne out by the frequency response curve in *Fig. 2*. All calculations are carried out with the assumption that $Q_L = 7$.

Suppose I am a bass junkie and wish to coax more bass from this driver. I will try to design a vented enclosure yielding a 25Hz cut-off frequency. I will put up with a ripple of ±1dB in the response curve. *Figure 1* shows the isosychnitic for f_3 at 25Hz and the heavy price I'll pay in box volume for lowering f_3 by 6Hz.

The good news is that at minimum volume in the 25Hz case, V_B equals 5.84 ft.³, and the result is a ripple in the response curve just within specifications. When you return h and V_B (i.e., a = 1.01) to *Equation 1* for verification, however, we get the bad news: The low-end droop in the response is more than 2dB. I, for one, would avoid this alignment. I would find a more suitable driver or reconsider my f_3.

SMALL BOX CURE. If box volume as well as f_3 is a concern, you should know which minimum box volume is compatible with a given cut-off frequency. Choosing the smallest volume and the corresponding values of α and h while generating isosychnitics for a cut-off frequency series is a simple matter (*Fig. 3*). The minimum box volume V_B(min) in *Fig. 3* is plotted against the value of f_3 to which you can tune the box. I have used the same driver as shown in the previous example. The corresponding values of α and h are also given as a function of f_3. Since it hovers around 1, I plotted h by subtracting 1 and multiplying the remainder by 10.

I have now used all the available parameters for determining f_3. Choosing a volume and a cut-off frequency is tantamount to picking an alignment. You can determine just what kind of response those alignments produce by plugging α and h back into *Equation 1*. *Figure 4* shows a series of response curves for the driver in boxes with minimal volumes. When f_3 equals 24 and 26Hz, the curves are not good. The 28Hz curve, however, might be acceptable in some circles. At the high end, although 34 and 36Hz curves are wastefully flat, you need search no further if you are more concerned with box size than the cut-off frequency. As it turns out, the engineers at Swan Speaker Systems accepted some ripple in order to lower f_3, and reduced the box size to nearly minimum volume.

You may wish to determine the value of f_3 when you know all the parameters to plot *Equation 1*. The problem is to solve *Equation 5* for x_3. In general, you can solve it numerically or graphically. Many computers come with "root finders," but the following is specifically tailored for *Equation 1*. If the alignment causes the response curve to cross the half-power point only once, then this technique, called Newton's method, is fool-proof. Let

$$g = -2x^8 + (x^4 - \alpha_2 x^2 + 1)^2 + (\alpha_1 x^3 - \alpha_3 x)^2 \qquad (9)$$

The following is simply *Equation 5* with all fractions cleared. Now take the derivative of 9:

$$g' = -16x^7 + 2(x^4 - \alpha_2 x^2 + 1)(4x^3 - 2\alpha_2 x) + 2(\alpha_1 x^3 - \alpha_3 x)(3\alpha_1 x^2 - \alpha_3) \qquad (10)$$

Guess at a solution x_{old} = 70Hz say, and calculate the quantity:

$$x_{new} = x_{old} - \frac{g(x_{old})}{g'(x_{old})} \qquad (11)$$

Iterate by substituting the answer x_{new} for x_{old} on the right side of *Equation 11*. After a few iterations, the answer will stabilize. The cut-off frequency is then $f_3 = x_{new} f_s h^{1/3}$. You can read more about the theory behind Newton's method in almost any college-level calculus book.

You can identify the peak and valley in the response curve by solving $g'(x) = 0$ using Newton's method, but it is more convenient to select the minima and maxima from the points in *Equation 1* as they are being calculated on the computers. With this method, you will determine the desired points with more than enough accuracy.

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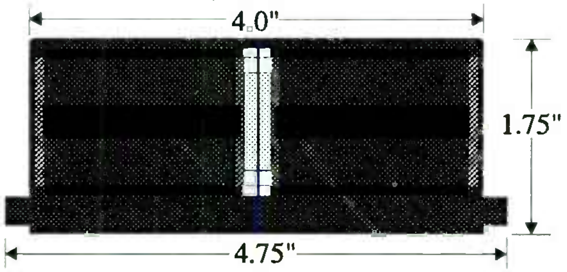
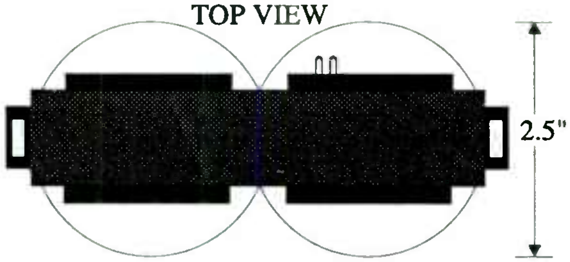
Linaeum™

FRONT VIEW

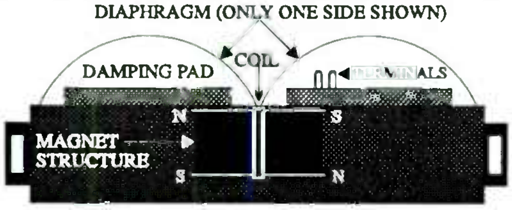


TOP VIEW



TOP VIEW(SHOWING MOTOR ASSEMBLY)

DIAPHRAGM (ONLY ONE SIDE SHOWN)



The Linaeum diaphragm is made of two pieces of specially formed mylar sheets. The diaphragm is anchored at one end to the outer edge of the frame. The other end of the diaphragm is attached to the voice coil, which is suspended within a balanced magnetic gap at the frame center.

Electrical signals flow into the coil, interacting with the fixed magnetic fields of the magnet structure. This interaction causes coil movement and creates a wave motion through the diaphragm. This wave motion causes the rapid pressure fluctuations that we hear as sound.

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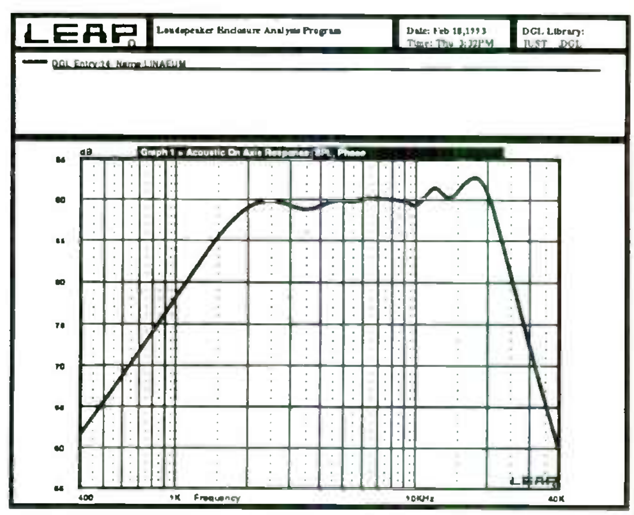
DC Resistance	4 ohms
Power Capacity, Continuous	10W RMS
Nominal Power (DIN 45573) (2500 Hz, 12 dB, octave network)	80W
Recommended Frequency Range	2500Hz-25KHz
Characteristic Sensitivity	88 db 1w 1m
Resonant Frequency	800 Hz



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Part II

THE IMP

BY BILL WASLO

In Part I of this series, I described the capabilities and construction of the IMP spectrum/network/impedance analyzer system hardware. In this part, I will explain the functions and operation of the IMP software.

INSTALLATION. If you will be operating from a hard disk, create an IMP directory on it and copy the contents of the IMP program disk there. (If you are unfamiliar with this process, see your DOS manual for details.) If you will be operating from a floppy disk, first make a backup copy of the program disk. Be sure you also copy the .BGI files, or the IMP.EXE program will not execute. When you are running the program, make sure you are logged on to the drive and directory where IMP is installed.

GENERAL INFORMATION. The IMP software program is used to control the IMP module for data collection and for processing the data into response, impedance, or waterfall plots. It also includes provisions for saving or reading measured data to and from disk and for editing and combining data from multiple measurements. Note that the program can be used for data manipulation, analysis, and experimentation even without an IMP board if previously acquired or synthesized data files are available or can be made.

When you execute the program, a title screen will appear. Pressing any key will switch you to the main screen.

Operation is menu-controlled, in a manner similar to that of many spreadsheet programs. The third text line from the top of the screen provides a menu list of option keywords. Select the desired option by pressing the letter key that is capitalized in the keyword. For example, in the highest-level menu, you can choose **Setup** by pressing [S].

Selection of a keyword will result in either an action, a prompt for specific information (such as for the frequency to which a marker should be moved), or the presentation of yet another menu of keywords. This system minimizes the number of keystrokes required.

DATA STRUCTURE. The program can deal with four main blocks of measured data at any one time. Each of these blocks can be up to 4,096 data points long. Data analysis consists mostly of transforming or editing these blocks and displaying the results. *Figure 1* will help you to follow the data flow.

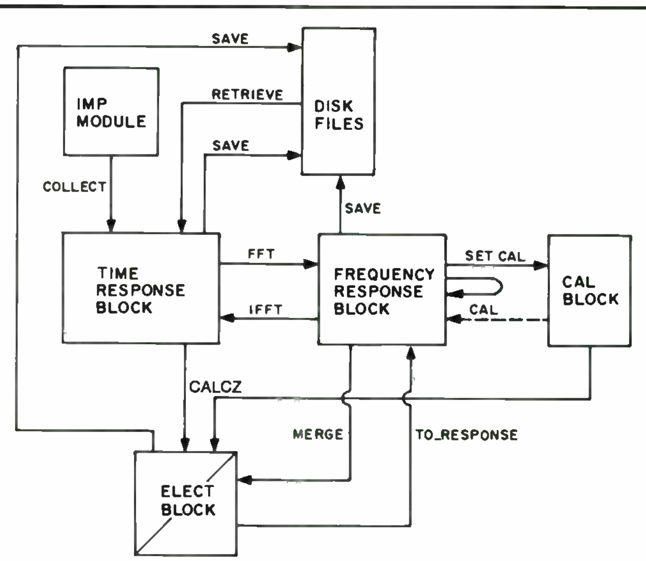

FIGURE 1: Data flow and transformation chart for IMP software.

The first block represents a time response (i.e., voltage as a function of time). The Time Response block is displayed in the bottom plot after the data has been read in from disk or collected from the module. The x-axis can be thought of as representing sample number (only those up to the value **SIZE**, as shown at the beginning of the second screen line, are displayed) or as milliseconds of time. *Figure 2* is a sample screen showing Time Response data.

When data is collected from the IMP module or retrieved from disk, it is put

You may type in other menu options while the program is performing a previous operation. This is handy for longer operations. In addition, a menu of **auto_Measure** operations allows you to enter some commonly used long sequences with a single keystroke.

A cartoon meter, or dial, appears at the top right of the screen whenever the computer is doing something that might take a while (other than plotting). In general, don't panic unless the dial doesn't move for more than about five seconds.

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into the Time Response block. Although both time and frequency data can be written to a disk file, only Time Response data can be read from a disk into the program. When the lower plot is of the time response, the upper plot shows that portion of the same time response that is between the two markers which appear as arrowheads at the bottom of the screen.

This selected portion can be transformed, via the Fast Fourier Transform (FFT), into frequency data which is stored in the second data group, called the Frequency Response block. This is done using the **Transform, Fft** sequence, performed by the keystrokes [T] and [F]. The initial Time Response data will remain unchanged after this transformation, but any data previously placed in the Frequency Response block will be replaced with the new data.

The frequency response is displayed in log frequency format, as this seems the most appropriate format for loudspeaker work. After this data is created from the Time Response data, the magnitude of frequency response will be shown in the bottom plot in decibels. (The markers will now be designated in hertz instead of milliseconds.) The top plot will still show the section of time response from which the Frequency Response data was transformed.

By using other menu options, you can display the phase of the frequency response in the top plot, as shown in *Fig. 3*. You can also reconvert the frequency response to a time response (with delays or gain changes) by use of the **Ifft** option, but the Frequency Response data will be destroyed in the process. The acronym IFFT stands for Inverse Fast Fourier Transform, used to convert frequency domain data to time domain data.

In the **Transform** menu, the option **Set_cal** copies the current contents of the Frequency Response block into the third block, which I call the Cal block. This is normally done when the Frequency Response block contains the spectral content of the electrical signal at the amplifier output terminals, as picked up by Cal probe #1.

The Cal block is used to normalize Frequency Response data by dividing each data point of the Frequency Response block by the corresponding point of the Cal block and putting the result back into the Frequency Response block. This allows you to remove response errors caused by the amplifier, IMP board filters, and pulse shape from your data. If you use the **Cal** option (in the **Transform** menu) right after **Set_cal**, you will normalize data with itself and get a straight line of 0dB.

You can also use **Cal** to see the effects of, for example, tweaking the crossovers. Just get Cal data from the untweaked frequency response and normalize the responses acquired and transformed after any changes; the resulting curve is the change (in decibels) from the status quo.

with certain powers in the IMP world. They are as follows:

The Escape key [Esc] is used to back up one menu selection or as a "never mind" when you are being prompted for values. Escape will terminate waterfall plotting should you change your mind. If you get in trouble, hitting [Esc] will usually get you out safely.

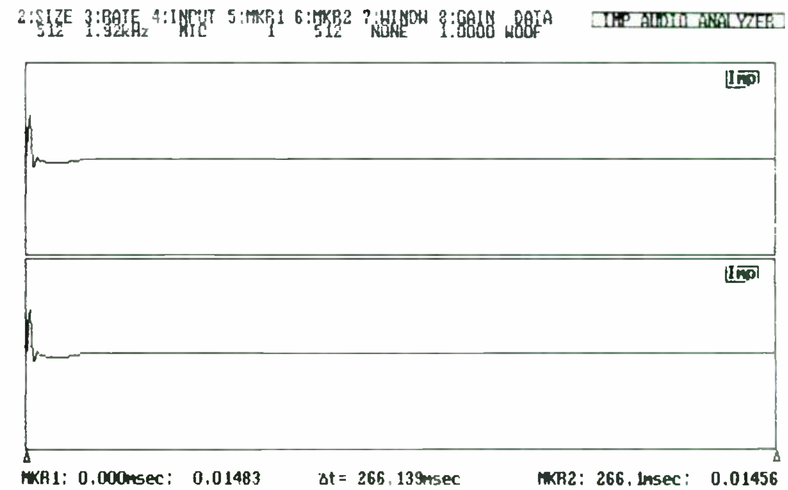

FIGURE 2: IMP display of a woofer's near field impulse response.

The last block is Elect, so named because I initially used it only for storing the calculated electrical impedance data. Elect Response data, like Frequency Reponse and Cal, also represents a function of frequency. Impedance data is formed from Time Response data (voltage across the measured impedance, when driven by an impulse through a known resistor) and Cal frequency response data, which is derived from the impulse as it appears at the amplifier output (other side of the resistor). The option in the **Transform** menu is **calcZ**. A sample display of the impedance of a ported woofer system is shown in *Fig. 4*.

The Elect block also functions as the workspace for making merged responses, which are summed or pieced-together frequency responses from multiple measurements. Because **Merge** and **calcZ** share the same data space, you can't merge responses while keeping impedance data present in memory. The merged response in Elect can be copied back into the Frequency Response. You can then use **Ifft** to convert this data into a time response, using facilities in the **Merge** menu.

SPECIAL KEYS. A number of special keys and key combinations are endowed

The Asterisk is used to return you immediately to the highest-level menu, as an alternative to backing out via the Escape key. Should you get lost in the menu structure, just press [*] and you'll be back at the start. I use this quite a bit when typing ahead if I'm not sure where my previous keystrokes might have left me.

The Back Space key will work in prompt situations. If you give an empty string or invalid input when prompted, the value being prompted for will usually be the same as before the prompt.

With most displays, the Left Arrow key will tentatively move the most recently used data marker on a plot one data point (frequency or time) to the left. If you hold down the Control key [Ctrl] while pressing the left arrow, the marker will tentatively go ten points to the left. Some information about the point to which the marker is directed is usually displayed near the top of the screen. The Right Arrow key functions similarly.

Data about finalized marker locations is usually displayed at the bottom of the screen. The marker position is not finalized (or does not have its data read out at the bottom of the screen) unless you press the Enter key. If you use [Esc] or [*] instead, the marker will revert to its former position (and therefore can be used to just read off data points without

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permanently disturbing anything). Markers will be discussed in more depth later.

FUNCTION KEYS. Some function key numbers and their assigned names are displayed on the left of the top line of the screen. The parameter values or selections associated with these are displayed directly below them in the second line. The word **DATA** at the right indicates the disk file name of the current Time Response data. If the data has just been collected from the IMP module, **INPUT** will appear as the name.

You can press the function keys at almost any time to allow manipulation of the related features. Following is a summary of what the function keys do:

[F1]: This key is not displayed at the top of the screen, as it performs a simple function. Pressing [F1] causes the time response plots to be redrawn. This is useful for updating the display after changing **SIZE** or to allow readjustment of time marker positions for echo elimination after frequency domain data has been displayed.

[F2]: **SIZE** is the number of points to be used in the current Time Response block. Minimum is 256 points; maximum is 4,096; and only powers of two are allowed. The size goes up each time you press this key, except 4,096 will change to 256 on its turn. When a time response is transformed to frequency response, the frequency response will be of the same size (but half the points are for negative frequencies and for our purposes will be ignored).

When a time file is saved to disk, **SIZE** is also the number of points being saved. If **SIZE** is larger than the number of valid data points, as might happen after a disk file has been retrieved, the rest of the file up to point number **SIZE** will be padded out with the voltage value corresponding to the right marker position.

The bigger **SIZE** is, the finer will be the frequency resolution of the resulting frequency response, but the longer will be the calculation time and the larger the saved files. Be aware that the time data display will not be updated to the new value of **SIZE** until a marker has been moved or the plot redrawn (quickly done by typing [F1]).

[F3]: **RATE** has only two possible values: 61.44kHz or 1.92kHz. This is the sample rate at which data will be collected. (Expect reasonably accurate results only up to a frequency of about one-third the sample **RATE**.) The value 1.92kHz is for low frequencies and impedances; 61.44kHz can be used for measuring frequencies above 650Hz. **RATE** will alternate when you press [F3] and will automatically be set to match the disk data when it is read in. You should use [F3] when you want to collect data from the IMP module at a different **RATE** than is shown.

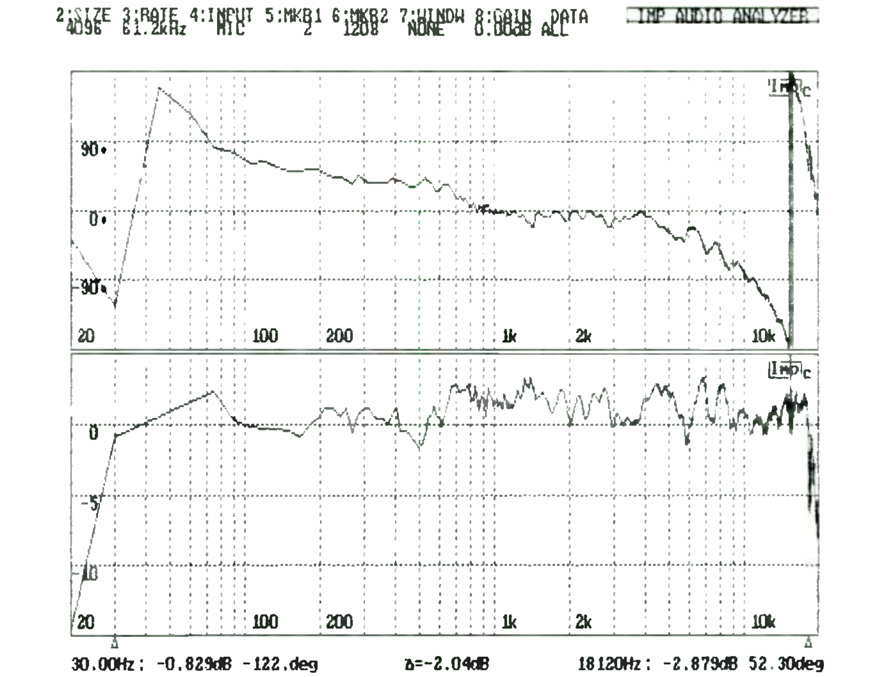

FIGURE 3: Display of a three-way system's full-band frequency response. This curve was formed from four measurements of both the near and far field using the Merge facility.

[F4]: **INPUT** determines whether data to be read into the time response block by the IMP module is to be from the microphone or from one of the two probes. The selection will change round-robin style each time you press [F4].

[F5]: **MKR1** is the left marker (which can go to the right of the right marker in frequency response plots). The number shown is the data point index number. You can move the marker around by pressing [F5] and then either using the arrow keys or typing in numbers.

If the plot shown in the lower part of the screen is time response and the readouts at the bottom are in milliseconds, the numerical data you type will be interpreted as an index number (from 1 to **SIZE**). If frequency data is shown, numbers will be interpreted as frequency in hertz, with "k" meaning thousands. When using the arrow keys, remember to hit [Enter] if you wish to make the move final, or [Esc] if you were only tentatively moving the marker around to read values.

A common error I make is forgetting to set the **MKR1** position back to 1 before transforming time data from one of the probe inputs (particularly the Cal input). There is seldom any dead time before the probe response, so if **MKR1** is moved to the right, it can easily overstep most of the critical Time Response data. If you notice that an FFT yields no, or extremely low, output, look at the setting of the first time marker.

[F6]: **MKR2** is the right marker. It is similar to [F5].

[F7]: **WIND[O]W[S]®** are a complicated subject. This does not refer to the Windows operating environment, but to a mathematical operation you can elect for your time response when transforming via FFT. Basically, it involves tapering the data at either end of the response plot smoothly to zero to avoid extraneous responses caused by sharp edges formed when cutting out a section with the markers.

The choices are **NONE** (no windowing), **BLACKMANN** (much), **HAMMING** (moderate), and **BINGHAM** (mild). For all of these except **NONE**, the impulse time response should be centered in the time period selected for the FFT, or all the important action will get tapered to zero. This is sometimes practical, sometimes not. Give it a try after you have the hang of the rest of the system. WIND[O]W[S] are essential if you are analyzing speaker distortion using a sine wave generator.

[F8]: **GAIN** is used to scale either time response or frequency response. If the lower screen plot is time response (again,

Continued on page 34

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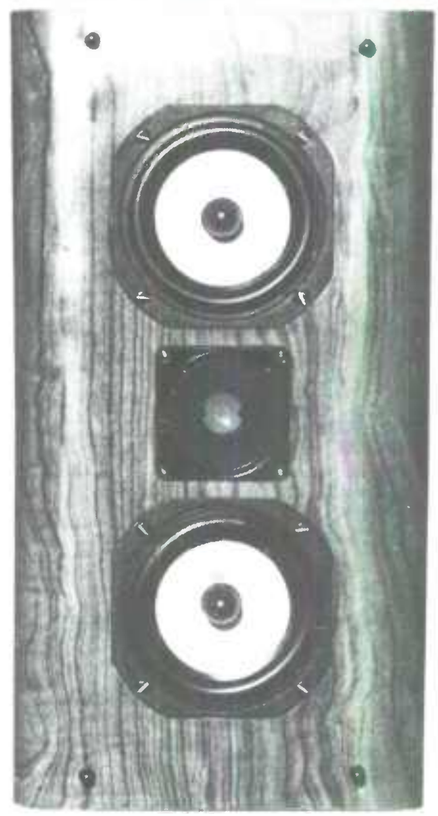

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markers will be in milliseconds), **GAIN** is the factor that each value in the lower plot will be multiplied by for display in the upper plot, for saving to disk, and for performing an FFT. **GAIN** also can be negative to invert the trace.

When Frequency Response data is on the screen, use **GAIN** to set a decibel offset for display, for performing an IFFT, and for combining into the **Merge** area. The value will be shown as "dB" in the second screen line. Waterfall plots must be restarted to show the effect of changes in **GAIN**.

[F9]: This key is not displayed on the screen, but you can use it to adjust the time delay associated with the Frequency Response data. The effect of this will show up in phase plots and in "summed merge" plots, as well as in IFFTs.

[F10]: This key, also not shown on the screen, rapidly moves you to the **Display/Show** section of the menu structure, so you can switch more easily from frequency data to time data, or vice versa, or choose another view of things.

[Shift F10]: This transports you to **Merge/View** in the menu. I'll talk more about this location later.

[Shift F5] and [Shift F6]: These allow you to make rapid adjustments to the displayed range of frequencies for which data will be plotted, rather than going through the menu sequences. Get to know these; they are very useful.

[Shift F8]: This allows you to quickly change the displayed decibel-per-division (scale) of frequency response plots.

THE MENUS. Here we will look briefly at what each menu option does and how it can be used. Besides being useful as a general reference, this section should give you some idea of the flexibility of the IMP software. Let's start from the main menu, which offers the following options: **Display**, **File**, **Transform**, **Acquire**, **Setup**, **auto_Measure**, and **Quit**.

We'll take these options in order and follow their submenus downward as you will encounter them. To facilitate finding out how to get to each option from the main menu, the previous keywords in the sequence, if any, are listed in brackets.

DISPLAY OPTIONS. Display: This submenu lets you change the axis scales, frequency ranges, and various other parameters of the graphic display (**Format**); direct the printer to print a graphic copy of your results (**Print**); or choose which data to display on the screen (**Show**).

[Display Format] freq_Range: Here you can set the lower and upper limts of the frequency range to be displayed for frequency responses, merged response plots, impedance plots, and waterfall plots. The value you enter will be rounded to one significant digit and limited to the range 2Hz-30kHz. You can reach this area of the menu rapidly via [Shift F5] or [Shift F6].

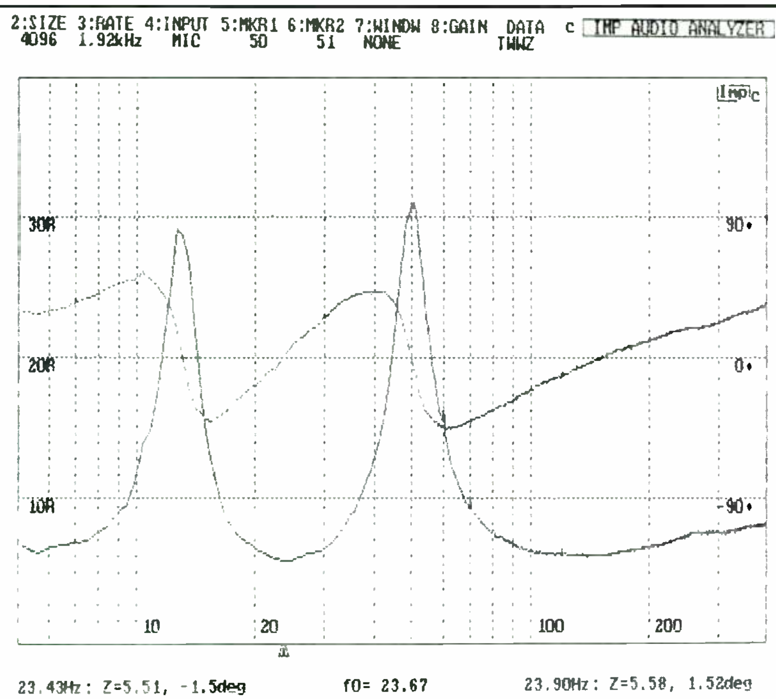

FIGURE 4: Impedance plot of a ported bass section.

[Display Format Scale] dB/div: This sets the integer decibel scale for frequency-domain magnitude displays. It is also reachable via [Shift F8]. Phase angle displays will always be 90°/division.

[Display Format Scale] Ohms/div: This is the scale for impedance magnitude plots. Again, the angle scale is fixed at 90°/division.

[Display Format Scale] Ref_resistor: This allows you to tell the computer which value of series resistor is being used while the impedance measurements are being taken. I will discuss the series resistor further when examples of system use are given.

[Display Format] Delay: A delay in the Frequency Response data can be compensated for by entering the value of delay you wish to remove (negative values add delay). You can use this to observe the phase linearity of a frequency response plot by adjusting for air travel time of the pulse to the microphone (watch the phase while adjusting). Mathematically, the phase is shifted by delay (in seconds) × 360 × frequency (in hertz). [F9] gets you here quickly.

This does not affect Time Response data displays directly, but you can use it on Frequency Response data before performing an IFFT to generate the expected shift in the time-domain plot. You will find that if you shift the impulse back in time beyond zero, it will reappear in time domain at the far right end of the plot. The reasons for this are beyond the scope of this article, but don't allow that to surprise, or upset you.

They are related to the use of a finite number of discrete samples to represent the frequency domain data, which is in actuality a continuous function of every frequency. This results mathematically in the time data being treated as periodic: following the last sample point in the sequence is again the first point and the sequence repeats forever.

[Display Show] Impuls_resp: This draws the full impulse time response (or the first **SIZE** points of it) on the lower half of the screen and the region between the markers stretched across the upper half of the screen. The upper plot also will be scaled by the **GAIN** value.

[Display Show] Freq_resp: This displays the magnitude (offset by **GAIN**, in decibels) of the frequency response on the lower plot and the phase angle of the frequency response (corrected for **Delay**, in milliseconds) on the upper plot.

[Display Show] imP+freq: This draws the magnitude of the frequency response (in decibels) on the lower plot
Continued on page 36

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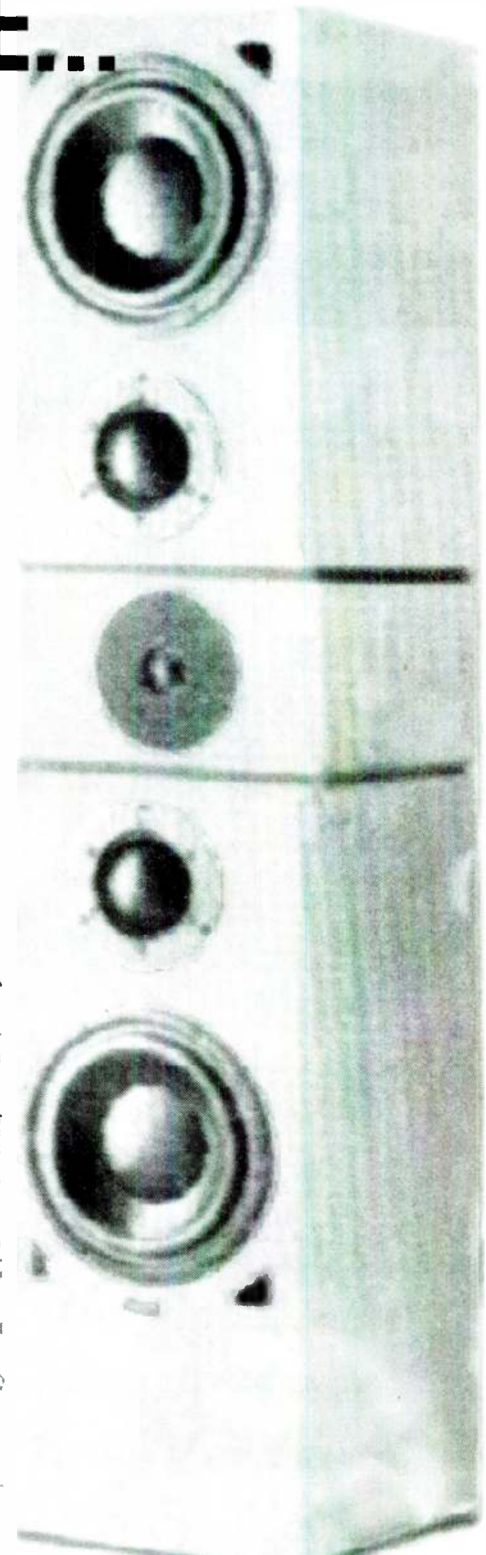

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and the selected impulse time response segment in the upper plot. It is shown right after an FFT is executed.

[Display Show] Z_plot: This shows the precalculated magnitude and phase of impedance on a single plot. Markers can be used to read out these values or the equivalent series resistor-capacitor or resistor-inductor components that would give the same measurement at the marker's frequency. The markers with these plots can be used to measure capacitors and inductors.

If one marker is on a positive phase angle point and the other is on a negative phase angle point, the computer will show a value called "f0," which is the computer's interpolation of the frequency at which the impedance angle is zero. For best results, the two marker points should be as close together as possible. In most cases, "f0" can be taken as a series or parallel resonant frequency. In *Fig. 4*, the markers have been set to pinpoint the box resonance frequency (at an impedance minimum).

[Display Show] Driver_data: This is a dual display of frequency response magnitude and impedance magnitude and angle. Both must have been calculated previously. The idea is to provide a unified view of driver characteristics.

[Display Show] Cal: This displays the response stored in the Cal block. It is particularly useful for making sure that a valid Cal is there.

[Display] Print: If you have an IBM or Epson dot-matrix printer, an HP Laserjet® (II or later) printer, or a printer that can emulate any of these, you can copy your screen to paper with this option. You will have to disconnect the IMP module from your printer cable if you have only one printer port. You can select from 13 print options in the IBM/Epson mode. I suggest that you try them all to determine which gives the best results with your printer. (Mine works best with modes 4 and 10.)

FILE MANIPULATIONS. File: This submenu contains options relating to disk file manipulation.

[File] Retrieve: This allows you to load a previously saved time response file for processing. It must be in the directory specified using the **Change_dir** option.

[File] Save: Here you can save the current time response, frequency response, impedance, or driver data to a disk file. The relevant options are **Timeresp**, **Freqresp**, **Zdata**, and **zAndfresp**, respectively. Again, only the time data can be read back into this program. The other options are for use in spreadsheets, simulation packages, graphing routines, and the like. The format for each line or sample of nontime data is frequency, magnitude, and angle.

In saved time response files, only the first **SIZE** points are saved. If you wish to save the untruncated data, set **SIZE** to 4,096 or however much you are willing to store. If you want to duplicate impedance plots from disk with the IMP software, you must save a time response file for the Cal as well as for the Z measurement.

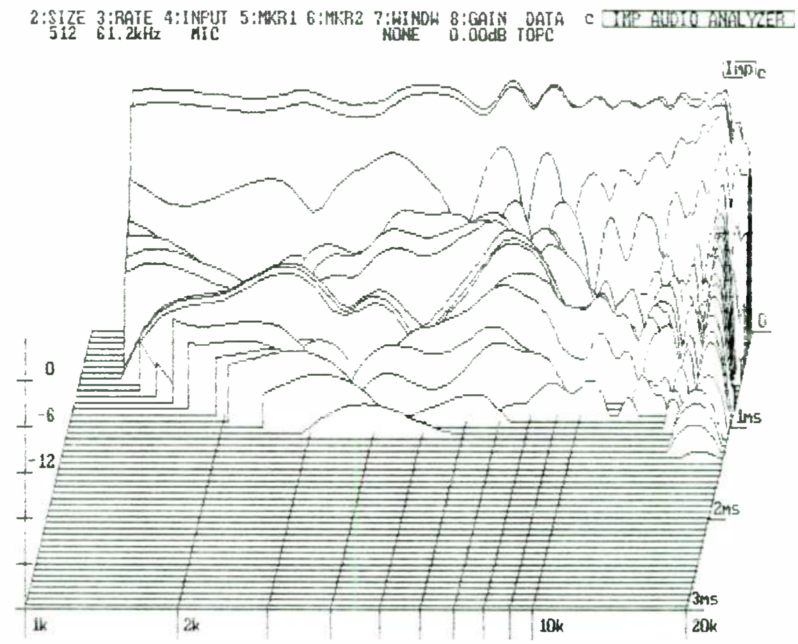

FIGURE 5: Waterfall plot of a tweeter and midrange set.

[File] List_files: This gives you a listing of all the existing files of each type as listed in **Save**, so you can make sure that files have been saved or see what time response files you can play with. Only the directory (and drive) specified in **Change_dir** is searched, with the default being the directory from which IMP is being run.

[File] Change_dir: Here you can specify which drive or directory to use for storing or retrieving files. Some possibilities are A: or C:\IMP\.

TRANSFORMATIONS. Transform: This is the menu where most of the processing action takes place. The wiggly line provided by the microphone output is transformed into detailed information about what your speaker-design-in-progress is really up to.

[Transform] Set_cal: The data in the Frequency Response block is copied to the Cal block for use in normalizing further frequency response plots. Previously existing data (if any) in the Cal plot is lost, but the Frequency Response data is left intact. A small "c" will appear just to the left of the **IMP** title block at the top of the screen to indicate that a Cal file has been declared.

[Transform] Cal: The data in the Frequency Response block is complex divided by the data in the Cal block. The resulting Frequency Response data represents the change in response between the previous Frequency Response data and the Cal data. If the only difference is what happens to the signal between acoustic pressure and amp out (Cal), the result is the speaker's (and, alas, the microphone's) response. There must be at least as many points (**SIZE** before the FFT) in the Cal data as in the Frequency Response data, and both must be at the same sample rate.

[Transform] Fft: This option starts an FFT. Impulse time data between the markers is transformed to frequency domain data.

[Transform] Ifft: This starts an IFFT. Frequency data is converted back to time data, but any data previously in either file is *destroyed*. A good place to save frequency Response data before using a IFFT is in the **Merge** region. If the IFFT result is not what you expected, you can pull the Frequency Response data back using **[Transform Merge To_**

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THE TSW D-1 KIT

A petite two-way system using our TSW 5" woofer and a 13mm tweeter in a 10" high x 7" wide x 5" deep oak veneer enclosure. Designed originally as a dialogue channel system for AV systems, the **D-1** has been equally popular for AV rear channel application for bedrooms and offices and as a satellite system with our **D-10 SUBWOOFER.** Available in stained oak, black oak and white oak.

COST: A petite $62.25 each.

THE TSW TUCSON

A serious two-way system comprised of a SEAS 8" woofer and a SEAS 1" dome tweeter. The crossover is designed to give outstanding sonic performance from this medium sized book shelf system. The furniture quality oak veneered cabinets available in stained oak, black oak or white oak compliment most any decor. **THE TSW TUCSON** has long been our best selling loudspeaker system. Their 19" height x 12" width x 10" depth enclosure produces tight and unbelievably low bass.

COST: An unbelievably low $259.50 per pair.

TSW D-10 SUBWOOFER

Our own **TSW** 10" poly dual voice coil woofer with 125 Hertz second order roll off and first order satellite roll in. Subwoofer is 4 ohm and set up for 8 ohm satellites. We do not supply an enclosure but recommend 1.5 cu. ft. sealed. Works well in a down fire or front fire configuration.

COST: All parts except enclosure $72.50.

THE TSW MINI MONITOR

Maybe it's not a Rogers, but maybe it's pretty close! We feel the cost may be the most significant difference. The SEAS 6.5" woofer and the SEAS .75" dome tweeter are painstakingly melded together with a carefully designed crossover and installed in an oak veneered enclosure 13.5" high x 8" wide x 7" deep. **TSW MINI MONITORS** fare well as an independent system or may be used as satellites with our **D-10 or D-12 SUBWOOFER SYSTEMS.**

COST: A mini $194.50 per pair.

THE TSW BUCKINGHAMS

This three-way system equipped with our own **TSW** 12" woofer, a PEERLESS 4" poly midrange and a SEAS 1" aluminum tweeter was rated by the president of the Arizona Audiophile Association as being equal to any $2000 system he has heard. Prejudice aside, we are inclined to agree. Magnificent cabinetry in stained oak, black oak or white oak veneers compliment **THE BUCKINGHAM'S** superb sound. **BIWIRE INPUTS AND MID AND TWEETER LEVEL CONTROLS** make this system a best buy. Cabinet 25" high x 14" wide x 12" deep.

COST: A paltry $449.50 per pair.

TSW D-12 SUBWOOFER

Our own **TSW** 12" poly dual voice coil woofer with 100 Hertz second order roll off and first order satellite roll in. Subwoofer is 4 ohm and set up for 8 ohm satellite roll in. We do not supply an enclosure but recommend 2.5 cu. ft. sealed. Works well down into the 20s in a down fire or front fire configuration.

COST: All parts except enclosure $89.50.

ANY QUESTIONS — CALL US

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World Radio History

Continued from page 36
response_data] and try a different variation.

[Transform] **Waterfall**: This is, without a doubt, the most satisfying function (from a programmer's standpoint) this program can perform. Also known as a cumulative spectral decay plot, it can provide very useful information about cabinet resonances and reflections and tweeter ringing. It also can make impressive plots that mean nothing whatsoever if configured carelessly. If you want to make people think you are beyond amateur rank, flash one of these three-dimensional plots around. *Figure 5* shows a relatively well-behaved example.

What is a waterfall plot? Basically, you start with a normal frequency response plot at the back of the graph, showing the spectrum (frequency output) the speaker would get with a pure impulse input (truncated to avoid echoes). Then you move the starting point of the time response to be transformed forward a bit, calculate the spectrum of this shorter time trace, plot it a little closer on the graph, and repeat many times. The time axis which indicates the relative starting point is the one coming toward you on the plot.

Now, if the speaker is perfect, its acoustic output will be a pure impulse with a peak at one instant and zero thereafter. If the starting point of the trace to be transformed is then moved beyond the nonzero part of the impulse, nothing will be left, and this has a spectrum of nothing. The plots from beyond this point show no energy at all, which is represented as a straight line at the floor or minimum point of the graph (all values below floor level are displayed at floor level). The spectrum decays in one steep drop from all to nothing.

Less perfect speakers, like the one analyzed in *Fig. 5*, will not have all their spectrum-producing time data concentrated in one shot, so the response will decay more gradually. And if any components such as cabinets, cones, or dust caps are causing ringing or poorly damped output, a decreasing ridge will appear at the resonating frequency. Long nondecreasing ridges usually mean stray pickup of spurious signals, computer-generated electromagnetic interference (EMI), or hum.

It is tempting to use these plots for evaluating speaker performance ("My decay is cleaner than yours!"), but a little playing with waterfalls will reveal some pitfalls (*waterpits?—Ed.*). A small change in "dB/div" scale or the initial starting point will drastically change the subjective appearance of the plot, as will the **GAIN** setting. That floor will hide all the junk below it, as if getting just below the floor is the difference between perfect and flawed. But not using a floor makes the plot a scrambled mess. This curve is a wonderful tool for developing speaker designs, but the plot is not a substitute for listening.

[Transform] **calcZ**: This performs the calculation that transforms the Time Response and Cal data into a plot of impedance, both magnitude and angle. For this to have any meaning, the Cal data must have been subjected to an FFT based on time data taken at the power amplifier output, and the current time data must be from the other side of a test resistor fed from the amplifier. The impedance being measured during the test is from this resistor lead to ground. **SIZE**, **RATE**, and **GAIN** must remain constant throughout data collection. I will provide examples of this later.

MERGING. [Transform] **Merge**: The capability for merging files is very handy, but it is probably one of the more difficult parts of the program to use. It is also the most likely to have bugs, as there are so many possible variations. Merging involves taking several sets of Frequency Response data and merging them one at a time into a single plot.

The Frequency Response data doesn't have to be at the same sample **RATE** or **SIZE**, although you will want to use the largest feasible **SIZE** for the higher sample rate data if you are mixing rates and will convert the data back to the Frequency Response block. There are two basic ways to merge data: pasting and summing. Using them can produce a plot of a speaker's full audible response.

Pasting is connecting data end to end—for example, making everything in the plot above 400Hz come from response A, with everything below 400Hz coming from response B. This is useful for completing the bass from a truncated time sample with a response from a nontruncated near field measurement, or for combining responses from different sample rates.

Frequency response has magnitude and angle, and you should match both up before pasting. Use **Delay** to get the phase to match and appear continuous (or, more scientifically, measure the difference in distance and then use the speed of sound to calculate the delay correction required).

Summing performs complex addition at each point, as if the two responses were being combined acoustically in the air. Only data from the same sample rate can be summed, so if your merged plot-in-progress already has a section from a different sample rate, the new data will not be added at those frequencies. Make sure the response to be summed in has no significant output there. Summing is good for combining the responses from

Continued on page 40

Related Products

The following products are available from *both* Liberty Instruments *and* Old Colony:

SOF-IMP1B5GD (5¼") or **SOF-IMP1B3GD** (3½")	IMP software demo disk (usable as credit toward later purchase of full package)	$ 5.00
SOF-IMP1B5G	IMP software disk 1 × 5¼" DS/DD	49.95
SOF-IMP1B3G	IMP software disk 1 × 3½" DS/DD	49.95
PCBW-4	IMP double-sided PC board	39.95
KW-4	Unassembled IMP parts kit, incl. software (specify disk size) and PC board	249.00

The following products are available from Liberty Instruments *only*:

	TLC274CN op amp, **MAX190** A/D converter, **6264** static RAM chip	**Inquire for prices**

The following products are available from Old Colony *only*:

KD-2	Unassembled Mitey Mike test microphone	149.00
KD-2AM	Assembled Mitey Mike with calibrated cartridge and MLSSA data in hard copy form only	199.00
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Continued from page 38

multiple drivers, ports, passive radiators, or other multiple near field measurements that have significant output in frequency range. Set gains and delays appropriately.

[Transform Merge] Clear: This erases the **Merge** file, so you can start (or start over) with a clean slate.

[Transform Merge] View: This lets you select full-screen plots of the merged magnitude plot or angle plot (**Mag** or **Ang**), dual plots including both (**maG& ang**), or dual plots of **Merge** and frequency response magnitude (**magResp**) or angle (**aNgresp**).

[Transform Merge Paste] Abovemkr1: All of the data in the Frequency Response block above the frequency of **MKR1** (left marker) will replace the same range of data in the **Merge** block. Go back and set the marker position first. You can preview the results using **previewGain** or **previewDelay**. The results are not final until you use **Fix**.

[Transform Merge Paste] Belowmkr2: All of the Frequency Response data below the frequency of **MKR2** (right marker) will replace that in the **Merge** block. See **Abovemkr1**.

[Transform Merge Paste] previewGain: This lets you look at the magnitude result of pasting before doing permanent damage to the **Merge** block.

[Transform Merge Paste] previewDelay: You also can preview the phase result before doing the **Fix**.

[Transform Merge Paste] Fix: This makes pasting a permanent change to the **Merge** block. Be sure to use **Fix** before going to the next **Merge** process.

[Transform Merge] Sum: Summing is more straightforward than pasting. Just set the frequency response gain and delay and preview the magnitude and angle results using **previewGain** and **previewDelay**. When everything looks okay to you, use **Fix**. You cannot sum until there is some data pasted in first to sum to, so pasting will always come first.

[Transform Merge] To_response_data: This takes the combined **Merge** data and moves it back to the Frequency Response block. The lower sample rate data will always lose some detail (i.e., some frequency sample points). Detail is best preserved when high-sample-rate data has been transformed with maximum (4,096 point) **SIZE**. The resulting frequency response will always be at the high sample rate.

DATA ACQUISITION. Acquire: This submenu has only two choices, **Collect** and **Repeat**.

Collect: This gathers a number of time responses (the quantity determined by values in the **Setup** submenu) from the active input, showing the averaged time response plot at each step. The collection can be cut short (data still intact) by pressing [Esc]. **Collect** is used for taking data for analysis.

Repeat: This takes repeated samples until you press [Esc], displays each one, and then throws it away. Use **Repeat** only when you are adjusting the input level controls to the optimum levels.

SOFTWARE SETUP. Setup: Here you can set machine-specific parameters, select how many sample sequences you want to average to avoid noise problems, or choose the printer port to which you will attach the IMP module.

[Setup] Cpu_speed: Enter the speed (in megahertz) at which your CPU runs. This is used to slow down the input/output to the printer port so as not to overwhelm the IMP board. If problems occur, tell the program your machine runs at 100MHz or more. The setting does not affect processing time, only port delays. You likely won't need to set this at all.

[Setup] Impport: This allows you to specify to which LPT port the IMP board is connected, should you have more than one. Otherwise, the software will look for the board at the highest port active (LPT1, LPT2, or LPT3).

[Setup] Prntport: Select which port the printer is connected to. If one port is used for both the printer and the IMP module, don't forget to swap cables first.

[Setup] Average_num: You can select how many impulses to average when acquiring data from each of the three inputs. The higher the numbers, the cleaner and quieter the data, but the longer it will take. The microphone input is particularly subject to noise, so it should have the highest **Average_num** value.

[Setup] coLor: If you have a color monitor, you can switch to a monochrome picture here. In this way, you can use your own graphics screen dump TSR routines to print your plots if you don't like or can't use the routine provided in the **Display** menu. Otherwise, all colors, including backgrounds, would print black.

MACRO OPTIONS. auto_Measure: This submenu contains some canned measurement procedures that are particularly useful when you are tweaking a design or taking data on a lot of drivers. Be sure to set levels using [**Acquire Repeat**] first for all relevant inputs. Also, to avoid echoes markers should be set on data from the microphone input (if used) just before the **auto_Measure** operation.

[auto_Measure] Setup: This is for specifying whether **WIND[O]W[S]** will be used in automatic measurements (I generally don't use them) or whether new Cal data should be taken with each measurement. Cal runs generally need not be done each time if the amplifier's output impedance is tolerably low.

[auto_Measure] Acoustic: This collects data from the microphone (and from Cal probe #1, if so set up). Then it transforms, calibrates, and shows the frequency response. This will get a workout when you are in the process of tweaking your speakers.

[auto_Measure] Electric: This collects data from Z probe #2 (and Cal probe #1, if so set up). It transforms and spits out an electrical frequency response plot. This is useful when you are working on your crossover.

[auto_Measure] Impedance: This takes complete impedance measurements and plots the data. Cal is retaken each time for maximum accuracy.

[auto_Measure] Driver: This collects and transforms both acoustic response and impedance data, and then displays both. You can make a library of driver responses and impedance curves. Be sure to set the markers to frame the acoustic impulse response just before calling this the first time.

[auto_Measure] justCal: This acquires, transforms, and declares Cal data.

I don't think I need to describe the intricacies of the **Quit** option, so I'll take a breather here before moving on to some examples of measurement procedures in Part III.

SOURCES

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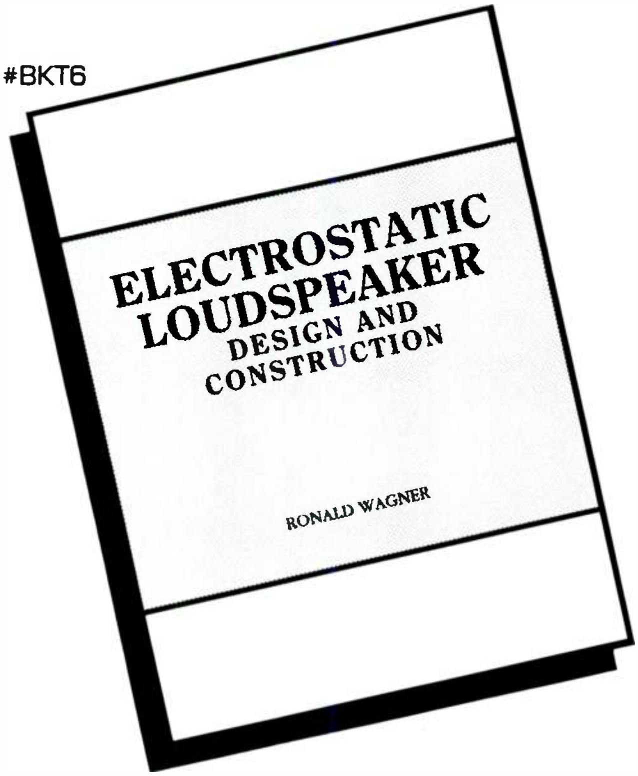

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Part III

WHAT MAKES YOUR ROOM HI-FI?

BY JOSEPH SALUZZI

In Parts I and II, I discussed how room dimension and shape affect a room's sonic character.[1,2] I selected a rectangular room with the dimensions 21′2″ × 16′4″ × 8′9″, and I touched on surface treatment for controlling RT_{60} and diffusion. I also discussed the construction of this room.

In Part III, which concludes this series, I discuss in greater detail the construction of portable wall modules, as well as a rear wall diffuser. I also address the initial time delay gap and how to control it.

WALL CONSTRUCTION. I constructed the portable wall modules using 1″ × 8″ clear Douglas fir, which is fairly inexpensive, stains rather well, and looks attractive. *Figure 1* shows front, back, and side views of a module.

Each unit measures 2′ × 6′ × 8″. I used standard 2″ × 8″ stock for strength and to divide each unit into three compartments. As illustrated in *Fig. 2*, one compartment houses a Helmholtz resonator for low-frequency absorption, while the other two contain 3½″ building insulation for control of the higher frequencies. For the 1¾″ × 1¾″ channel, which is used to hang each unit on the wall, I used scrap 1″ pine.

I used groove and dado joints throughout and carpenter's glue for assembly of each module. To ensure true right angles, I used miter clamps for the corners. For aesthetics, I covered each module with decorative burlap, which I stapled to a ¼″ × ¾″ screen molding frame. I made the frame with end-lap joints, assembled it with glue and miter clamps, and attached it to the module with brads.

To make the wall molding, which is used as a track for the movable units, I used 2″ × 2″ lumber. To make the molding more attractive, I used a mold-

Continued on page 47

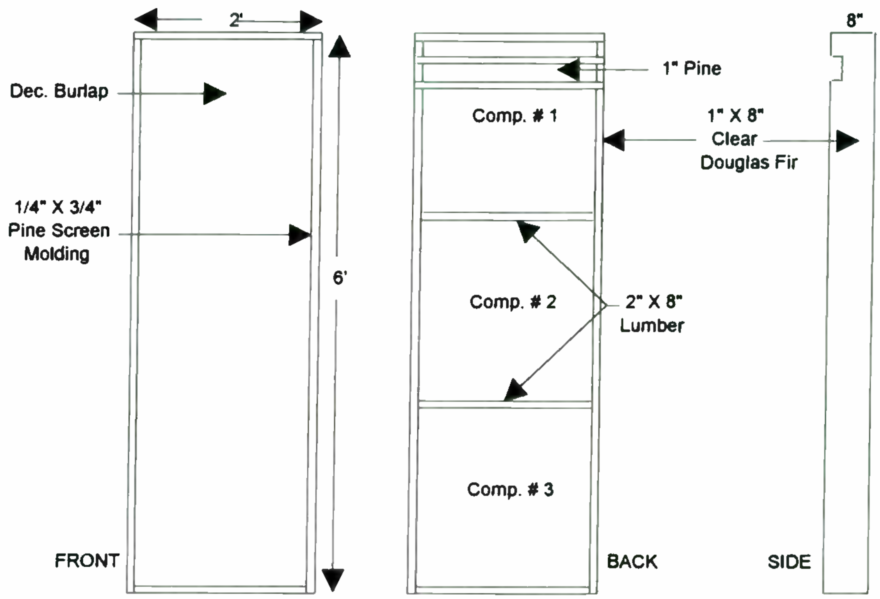

FIGURE 1: Portable wall modules, which control sound absorption and diffusion.

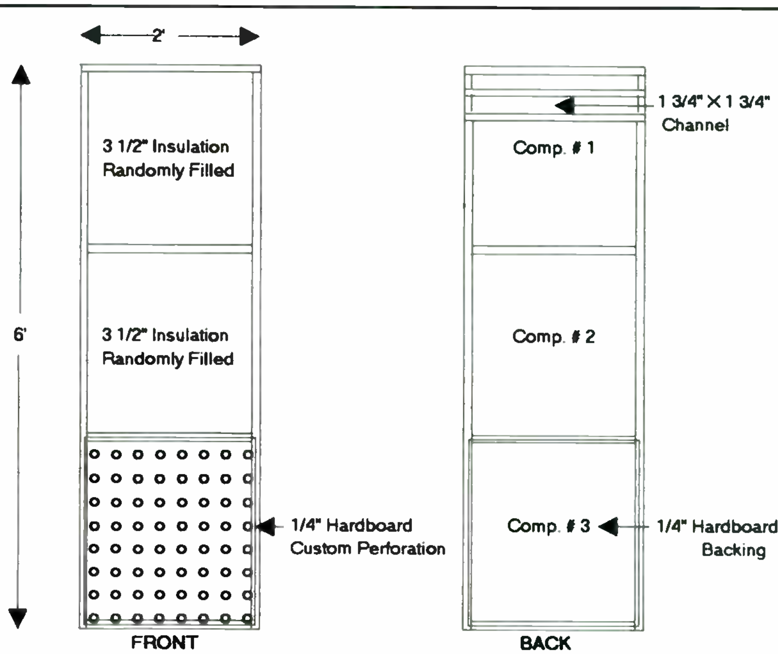

FIGURE 2: Typical wall module with front decorative cloth removed.

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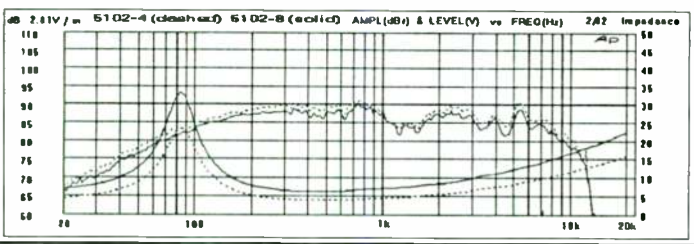
Madisound 5102 4.5" Polypropylene Bass-Mid 4 or 8 Ω

	5102-4	5102-8
Fs (Hz)	76	78
Rscc (Ω)	3.46	5.7
VcL (mH@1K)	0.09	.23mh
Qms	2.78	2.33
Qes	.43	.44
Qts	.37	.37
Mmd (g)	7.4	7.1
Cms (μm/N)	560.09	561.21
Vas (Ltrs)	3.57	3.57
Efficiency (db 1w/1m)	87.6	89.1
Xmax	3.5mm pk	
Power	50 w	
Magnet	12 oz	
Voice Coil	1" 2-Layer Kapton	
Cone	Black Poly	
Surround	Foam	
Cutout/Depth	4.25"/2"	
Price	**$20.00**	

	Vented		Sealed	
	4 Ω	8 Ω	4 W	8 Ω
VB ltrs	3	3.5	1.4	1.8
FB Hz	84	78	~	~
F3 Hz	84	79	145	136
Port Diameter	1"	1"	Qtc=.7	Qtc=.7
Port Length	2.4"	2"	~	~

**5102-4 / Dashed; 5102-8 / Solid



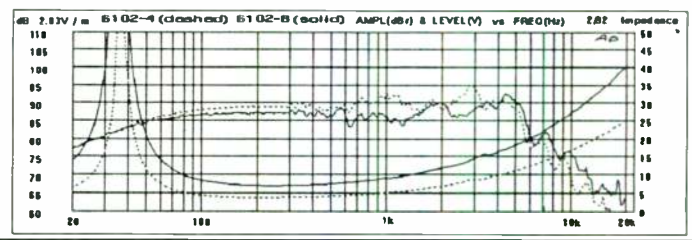
Madisound 6102 6.5" Polypropylene Woofer 4 or 8 Ω

	6102-4	6102-8
Fs (Hz)	30	30
Rscc (Ω)	3.35	6.6
VcL(mH@1K)	.087	0.18
Qms	6.6	7.5
Qes	.35	.45
Qts	.33	.42
Mmd (g)	14.5	11.2
Cms (μm/N)	1812.8	2312.9
Vas (Ltrs)	39	49.7
Efficiency (db 1w/1m)	87	87
Xmax	3.5mm pk	
Power	50 w	
Magnet	12 oz.	
Cone	Black Poly	
Surround	Foam	
Voice Coil	1" 2-Layer Kapton	
Cutout/Depth	5.62"/2.87"	
Price	**$24.00**	

vented pole piece

	Vented		Sealed	
	4 Ω	8 Ω	4 W	8 Ω
VB ltrs	18	40	11.4	28
FB Hz	36	30	~	~
F3 Hz	41	33	58	47
Port Diameter	1.5"	2"	Qtc=.7	Qtc=.7
Length	4.6"	5.2"	Rg=.4	Rg=.4

**6102-4 / Dashed; 6102-8 / Solid

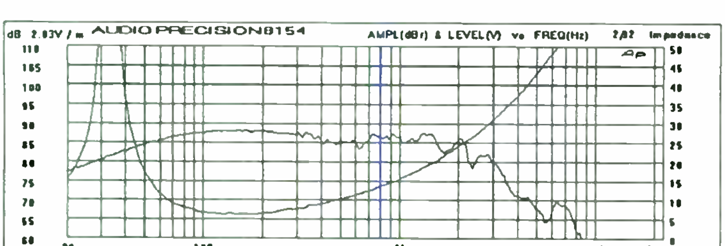


Madisound 8154—8" Polypropylene Woofer 8 Ω

Fs	30.6Hz
Rscc	4.55Ω
VcL @1K	.25mh
Qms	9.7
Qes	.28
Qts	.27
Mmd	34g
Cms (μm/N)	798.5
Vas	49.5 Liters
Efficiency	89db 1w/1m
Xmax	3.5mm pk
Power	75 w
Magnet	20 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" 4-Layer Kapton
Cutout/Depth	7.12"/3.37"
Price	**$31.00**

vented pole piece

8154 B4 Alignments			
	Rg = 0	Rg = .4	Rg = .7
Vb Liters	15	19	23
F_3 Hz	51	45	42
Fb Hz	46	43	40
Port Dia	2"	2"	2"
Length	6.1"	5.3"	5.1"

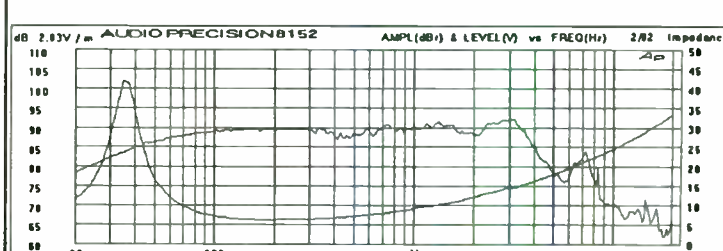


Madisound 8152—8" Polypropylene Woofer 8 Ω

Fs	33Hz
Rscc	5.1Ω
VcL @1K	.13mh
Qms	3.5
Qes	.45
Qts	.4
Mmd	23g
Cms (μm/N)	889
Vas	55 Liters
Efficiency	89db 1w/1m
Xmax	2.5mm pk
Power	75 w
Magnet	20 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" 2-Layer Kapton
Cutout/Depth	7.12"/3.37"
Price	**$31.00**

vented pole piece

8152 B4 Alignments			
	Rg = 0	Rg = 0	Rg = .4
Vb Liters	30	50	63
F_3 Hz	43	35	33
Fb Hz	34.8	34.8	32.5
Port Dia	2"	2"	2"
Length	5.1"	2.5"	2.2"



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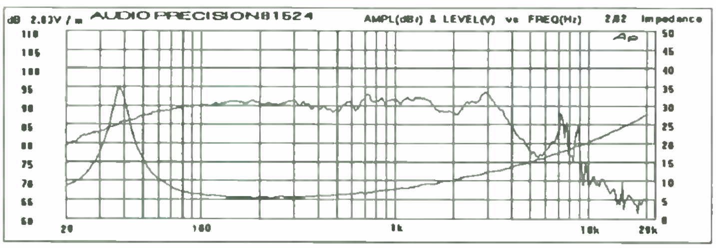
Madisound 81524—8" Polypropylene Woofer 4Ω

Fs	36Hz
Rscc	3.7Ω
VcL @ 1K	.1mh
Qms	3.9
Qes	.44
Qts	.4
Mmd	22g
Cms (μm/N)	819.59
Vas	51 Liters
Efficiency	89db 1w/1m
Xmax	2mm pk
Power	75 w
Magnet	20 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" 2-Layer Kapton
Cutout/Depth	7.12"/3.37"
Price	**$31.00**

vented
pole piece

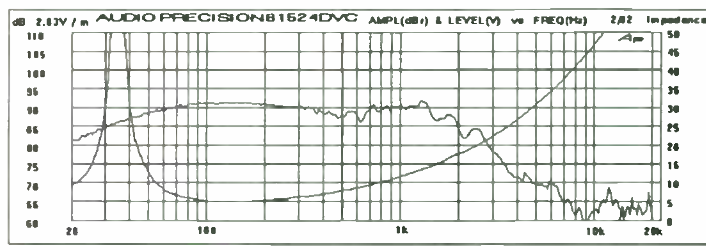
81524 B4 Alignments			
	Rg = 0	Rg = 0	Rg = .3
Vb liters	28	45	56
F3 hz	45	38	33
Fb hz	37	37	34.8
Port Dia	2"	2"	2"
Length	4.7"	2.3"	2"



Madisound 81524DVC—8" Dual Voice Coil Polypropylene Woofer 4Ω/4 Ω

Fs	31.7Hz
Rscc	3.5Ω
VcL @ 1K	.34mh
Qms	9.2
Qes	.32
Qts	.31
Mmd	38g
Cms (μm/N)	631.44
Vas	39.2 Liters
Efficiency	87.5db 1w/1m
Xmax	5mm pk
Power	80 w 40/40
Magnet	20 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1" 2-Layer Kapton
Cutout/Depth	7.12"/3.37"
Price	**$34.00**

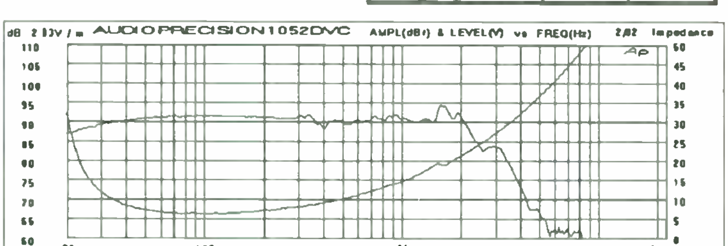
81524DVC B4 Alignments			
	Rg = 0	Rg = .5	Rg = 1
Vb liters	22	33	46
F3 hz	39	34	30
Fb hz	34	33.5	30
Port Dia	2"	2"	2"
Length	6"	5"	4.3"



Madisound 1052DVC—10" Dual Voice Coil Polypropylene Woofer 8Ω/8Ω

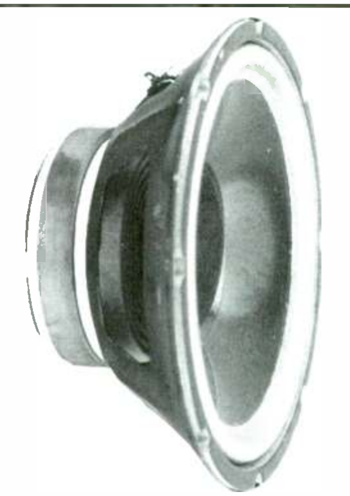
Fs	20.4Hz
Rscc	6.1Ω
VcL @1K	.46mh
Qms	3.68
Qes	.28
Qts	.26
Mmd	46g
Cms (μm/N)	1220.1
Vas	197 Liters
Xmax	6mm pk
Efficiency	90db 1w/1m
Power	50/50 w
Magnet	30 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" 2/2-Layer Kapton
Cutout/Depth	9.12"/4.45"
Price	**$41.00**

1052DVC QB3 Alignments			
	Rg = 0	Rg = .5	Rg = 1
Vb Liters	47	57	69
F_3 Hz	38	35	33
Fb Hz	31	28.6	26.8
Port Dia	3"	3"	3"
Length	9.9"	9.3"	8.6"

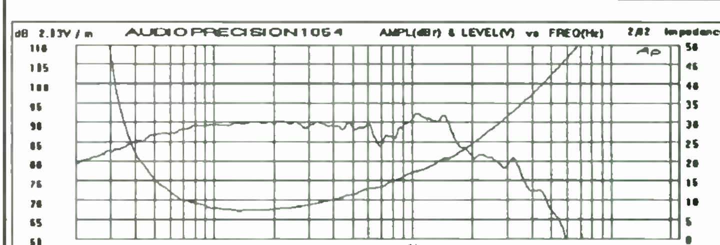


Madisound 1054—10" Polypropylene Woofer 8 Ω

Fs	24.6Hz
Rscc	6Ω
VcL @1K	.24mh
Qms	4.07
Qes	.25
Qts	.237
Mmd	42g
Cms (μm/N)	997.57
Vas	160 Liters
Xmax	3.5mm Pk
Efficiency	92db 1w/1m
Power	125 w
Magnet	30 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" 4-Layer Kapton
Cutout/Depth	9.12"/4.45"
Price	**$38.00**



1054 QB3 Alignments			
	Rg = 0	Rg = .5	Rg = .9
Vb Liters	29	35	42
F_3 Hz	52	46	43
Fb Hz	41.7	38	35.7
Port Dia	3"	3"	3"
Length	8.7"	8.3"	7.8"



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Madisound 10204DVC—10" Dual Voice Coil Woofer 4Ω/4Ω

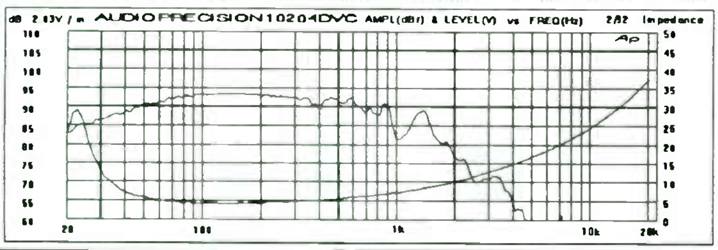
Fs	21.2Hz
Rscc	3.6Ω
VcL @1K	.35mh
Qms	3.5
Qes	.21
Qts	.2
Mmd	50.4g
Cms (μm/N)	1045.4
Vas	168 Liters
Xmax	5 mm Pk
Efficiency	90.7db 1w/1m
Power	100/100 w
Magnet	40 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2" 2/2-Layer Alum.
Cutout/Depth	9.12"/4.45"
Price	**$49.00**

Can be used with both voice coils in series for 8Ω or in parallel for 2Ω

vented pole piece

10204DVC B4 Alignments

	Rg = 0	Rg = .5	Rg = 1
Vb liters	21	30	42
F3 hz	52	45	39
Fb hz	41.5	36.8	33
Port Dia	2.5"	2.5"	2.5"
Length	8.7"	7.4"	6.3"



Madisound 10207—10" Dual Voice Coil Woofer 8Ω/8 Ω

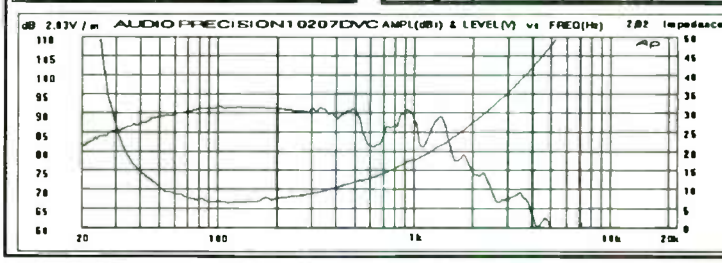
Fs	16.2Hz
Rscc	5.7Ω
VcL @1K	.51mh
Qms	3.43
Qes	.23
Qts	.22
Mmd	57g
Cms (μm/N)	1138.6
Vas	184 Liters
Xmax	5 mm Pk
Efficiency	89.4db 1w/1m
Power	200 w 100/100
Magnet	40 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2" 2/2-Layer Kapton
Cutout/Depth	9.12"/4.45"
Price	**$49.00**

Can be used with both voice coils in series for 16Ω or in parallel for 4Ω

vented pole piece

10207DVC QB3 Alignments

	Rg = 0	Rg = .5	Rg = 1
Vb liters	26	33	40
F3 hz	45	41	37
Fb hz	35.5	32.5	30
Port Dia	2.5"	2.5"	2.5"
Length	9.5"	9"	8.6"



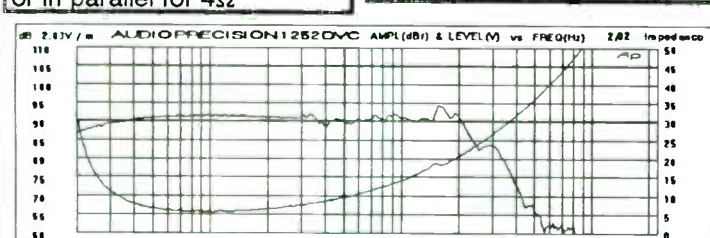
Madisound 1252DVC—12" Dual Voice Coil Woofer 8Ω/8Ω

Fs	15Hz
Rscc	5.6Ω
VcL @1K	.3mh
Qms	4.1
Qes	.39
Qts	.36
Mmd	78g
Cms (μm/N)	1331.4
Vas	533 Liters
Xmax	6mm pk
Efficiency	88.5db 1w/1m
Power	100 50/50w
Magnet	30 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" 2/2-Layer Kapton
Cutout/Depth	11.12"/5.0"
Price	**$42 00**

Can be used with both voice coils in series for 16Ω or in parallel for 4Ω

1252DVC B4 Alignments

	Rg=0	Rg=0	Rg=0	Rg=0
Vb Ltrs	85	100	130	142
F3 Hz	32.2	31	30	26
Fb Hz	QTC	QTC	QTC	17
Port Dia	.96	.9	.8	3"
Length	Sealed			11"



Madisound 12204—12" Dual Voice Coil Woofer 4Ω/4Ω

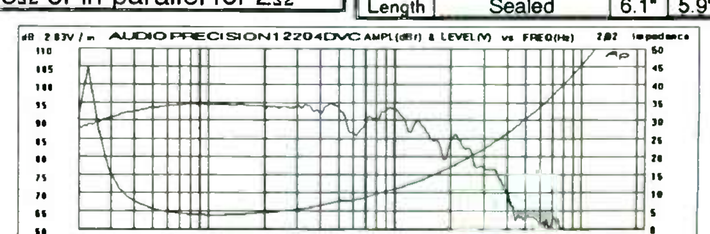
Fs	22.8Hz
Rscc	3.6Ω
VcL @ 1K	.26mh
Qms	4.58
Qes	.42
Qts	.38
Mmd	68.8g
Cms (μm/N)	550.6
Vas	220 Liters
Xmax	5 mm Pk
Efficiency	90.3db 1w/1m
Power	200 100/100 w
Magnet	40 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2" 2/2-Layer Kapton
Cutout/Depth	11.12"/5.0"
Price	**$53.00**

Can be used with both voice coils in series for 8Ω or in parallel for 2Ω

vented pole piece

12204DVC B4 Alignments

	Rg=0	Rg=.5	Rg=5	Rg=0	Rg=.5
Vb Ltr	85	85	100	113	142
F3 Hz	42	38	37.5	31	28
Fb Hz	QTC			24	21.6
Port D.	.75	.85	.8	3"	3"
Length	Sealed			6.1"	5.9"



World Radio History

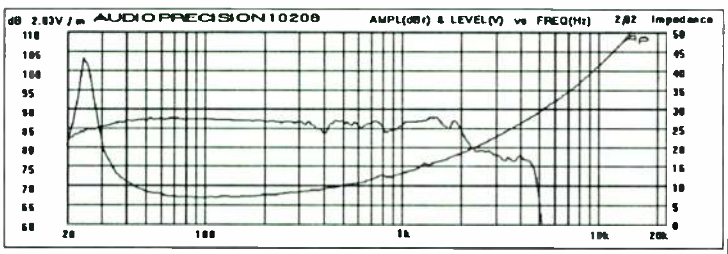
Madisound 10208—10" Sealed Box Woofer 8Ω

Fs	24Hz
Rscc	5.7Ω
VcL @1K	.13mh
Qms	4.62
Qes	.62
Qts	.54
Mmd	45g
Cms (μm/N)	900.5
Vas	145 Liters
Efficiency	87.5db 1w/1m
Xmax	6.5 mm pk
Power	100 w
Magnet	30 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2" Kapton
Cutout/Depth	9.12"/4.45"
Price	**$49.00**

vented pole piece

10208 Sealed Box Alignments				
	Rg=0	Rg=.5	Rg=0	Rg=.5
Vb Ltr	99	99	142	142
F3 hz	32	31	31.3	29.4
Qtc	.86	.93	.78	.84

The use of fill will reduce the Qtc. This driver may be okay for free air applications to 45 Hz.



Madisound Driver Measurements

- All measurements made in a 37 m^3 anechoic chamber equalized to give response for an infinite baffle.
- All frequency responses measured corresponding to 2.83Vrms @ 1 meter, same voltage for 4Ω and 8Ω drivers.
- Dual voice coils are measured at 2.83Vrms per coil.
- Dual voice coil Theil-Small parameters are measured with voice coils in series using Delta Mass method with Audio Precision and Leap.
- Suggested box alignments are sometimes given with an (Rg) value, which is added resistance from inductors in series with the woofer. If you need specific box alignments, please call.
- Aperiodic dampening devices such as the Dynaudio Variovent and Scan-Speak Flow Resistor are very useful in sealed box applications. These vents reduce the impedance maximum at the resonance point, allowing for a more clear and defined bass, as well as the use of a driver in a box that is smaller than optimum volume.
- Some volume and linear equivalents: 1^3 foot = 28.3 liters = 1728^3 inches; 25.4mm = 1"

Madisound Speaker Components
(8608 University Green)
P.O. Box 44283
Madison, WI 53744-4283 U.S.A
Voice: 608-831-3433
Fax: 608-831-3771

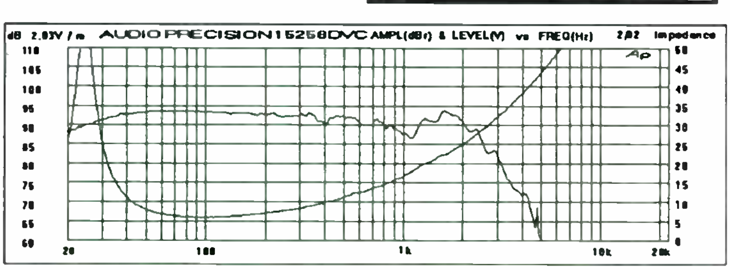
Madisound 15258DVC—15" Dual Voice Coil Woofer 8Ω/8Ω

Fs	22.5Hz
Rscc	5.5Ω
VcL @1K	.36mh
Qms	5.35
Qes	.52
Qts	.47
Mmd	121.5g
Cms (μm/N)	367.38
Vas	220 Liters
Xmax	5.5 mm pk
Efficiency	91db 1w/1m
Power	200 100/100 w
Magnet	60 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2 (2") Kapton
Cutout/Depth	13.87"/6.0"
Price	**$73.00**

vented pole piece

15258DVC Sealed Box Alignments				
	Rg=0	Rg=.5	Rg=0	Rg=.5
Vb Liters	100	100	142	142
F_3 Hz	37.8	36.6	35.4	33.8
Qtc	1.03	1.12	.9	.98

It is recommended to use fill and flow resistive vents with this driver.



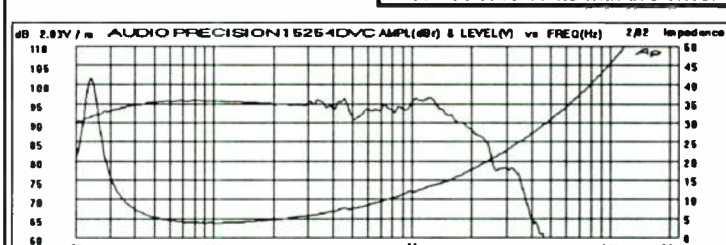
Madisound 15254DVC—15" Dual Voice Coil Woofer 4Ω/4Ω

Fs	23Hz
Rscc	3.7Ω
VcL @1K	.25mh
Qms	5.71
Qes	.47
Qts	.44
Mmd	122g
Cms (μm/N)	346.1
Vas	347 Liters
Xmax	5.5 mm pk
Efficiency	91.5db 1w/1m
Power	200 100/100 w
Magnet	60 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2 (2") Kapton
Cutout/Depth	13.87"/6.0"
Price	**$73.00**

vented pole piece

15254DVC Sealed Box Alignments				
	Rg=0	Rg=.5	Rg=0	Rg=.5
Vb Liters	100	100	142	142
F_3 Hz	40	37.7	38	35
Qtc	.92	1.04	.8	.91

It is recommended to use filling and flow resistive vents with this driver



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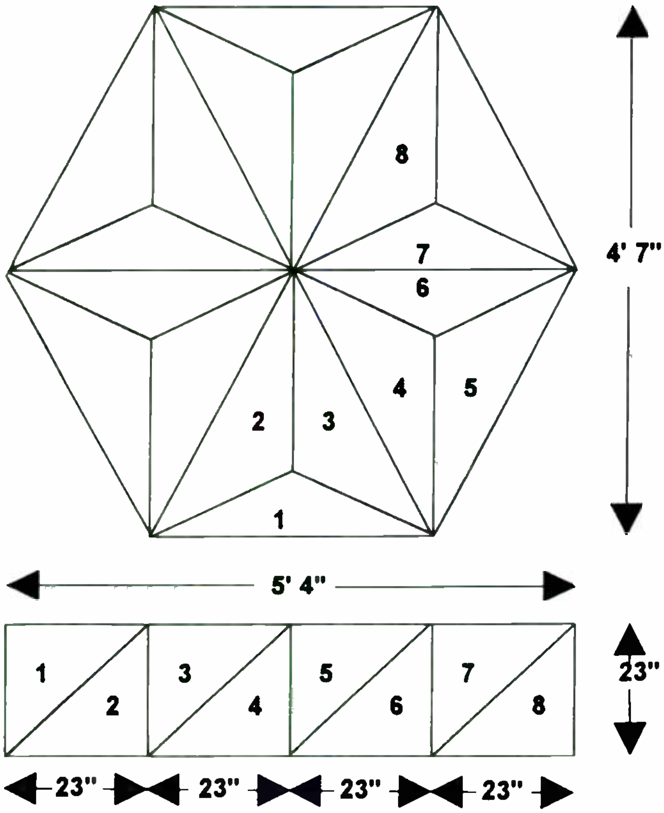

FIGURE 3: Geometric star diffuser made from 23" × 23" × ½" plywood squares cut into isosceles triangles, each with 23" legs and a 32" hypotenuse.

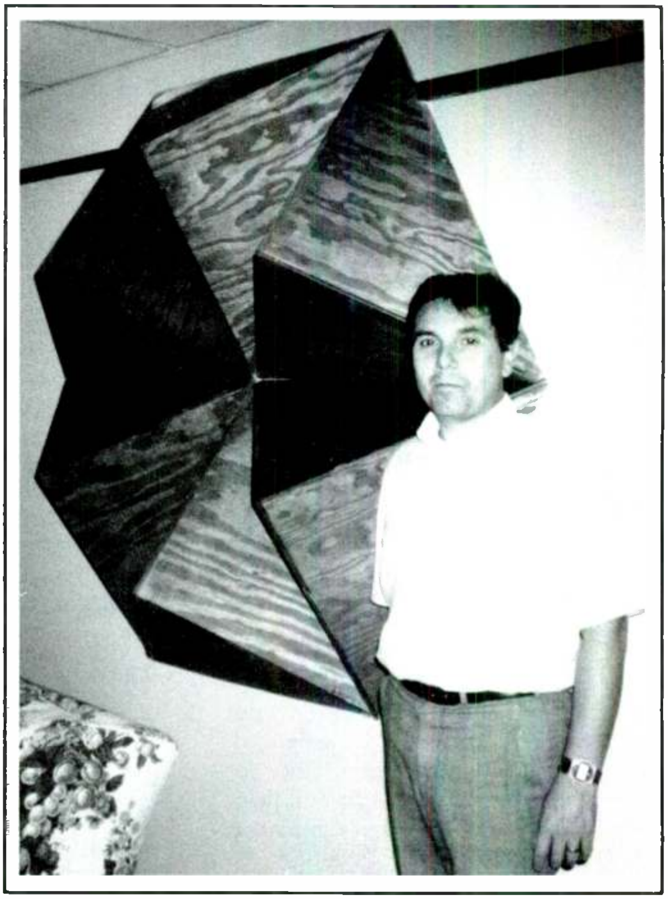

PHOTO 1: The author standing in front of his geometric star.

Continued from page 42

ing head set attachment with a three-bead cutter for my radial arm saw.

I randomly changed the configuration of the compartments and varied the location of the Helmholtz resonator (in the top, middle, or bottom compartment) for better diffusion. In addition, I attached the insulation in a random fashion, with either the paper or the insulation facing the sound source. I avoided duplicate configurations for units on opposite surfaces.

Construction of the Helmholtz resonators involved drilling my own custom holes. This is because common Peg-Board has 3⁄16-inch diameter holes on 1" centers, or a perforation of 2.75%. According to the formula for Helmholtz resonators, this corresponds to a frequency of about 300Hz, which is too high.[3]

I arbitrarily chose a frequency range of about 50-70Hz as the design goal for the Helmholtz resonators. I calculated that I needed to drill ¼" holes (for convenience) on 2.5" to 4" centers, since I used ¼" hardboard and the depth of the modules was about 7½".

For example, consider a 60Hz resonator. According to the formula for Helmholtz resonators, the perforation percentage (p) is:

$$p = \frac{F_O^2}{200^2} \times \frac{d}{t}$$

$$= \frac{60^2}{200^2} \times \frac{7.5}{0.25 + 0.8(0.25)}$$

$$= 1.5\ (\%)$$

To calculate the hole spacing, I used this result and solved for $S_1 \times S_2$ as follows:

$$S_1 \times S_2 = \pi \times \frac{\frac{D^2}{4}}{p} \times 100$$

$$= \pi \frac{\frac{(0.25)^2}{4}}{1.5} \times 100$$

$$= 3.27\ \text{in.}^2$$

This means that I had to drill ¼" holes on 3¼" centers to achieve a resonance frequency of 60Hz. I varied the hole spacing and the corresponding resonance frequencies, within the above constraints, to obtain a more diffuse soundfield. I attached the perforated front and back panels with wood screws and glue, filled each resonator with 3½" insulation to broaden its absorbancy peak, then sealed the inside cavity airtight with silicone caulk.

I also attached Helmholtz resonators to the ceiling. Instead of modules, I used smaller, more manageable resonators bolted to the ceiling. I painted them black to camouflage them above the egg crate panels. For control of the higher frequencies, I either stapled insulation directly to the ceiling or draped it over the panels.

REAR WALL DIFFUSER. I attached a geometric diffuser to the center of the rear (or south) wall of the listening room. This structure, which is located right behind the listening position, is shown in *Fig. 3* and the photo. It is constructed of 18 isosceles triangles made from ½" plywood. I elected to use 23" × 23" squares to minimize waste and because the project required only slightly more than one sheet of plywood.

The diffuser occupies 5'4" × 4'7" of wall space, which allowed me to place a module on either side of it. The purpose of this unit is to delay the sound waves by directing them to the rear walls, ceiling, and floor, then finally to the listener's ears. The net effect is a series of reflections arriving at varying times after the initial time delay gap (ITDG).[4]

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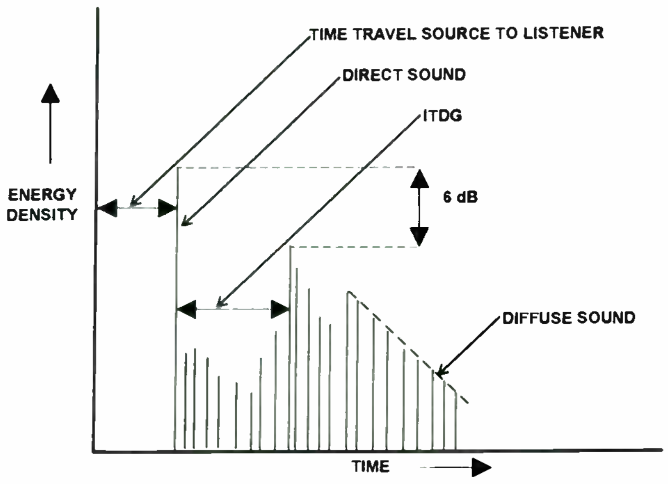


FIGURE 4: Initial Time Delay Gap (ITDG) for small rooms.

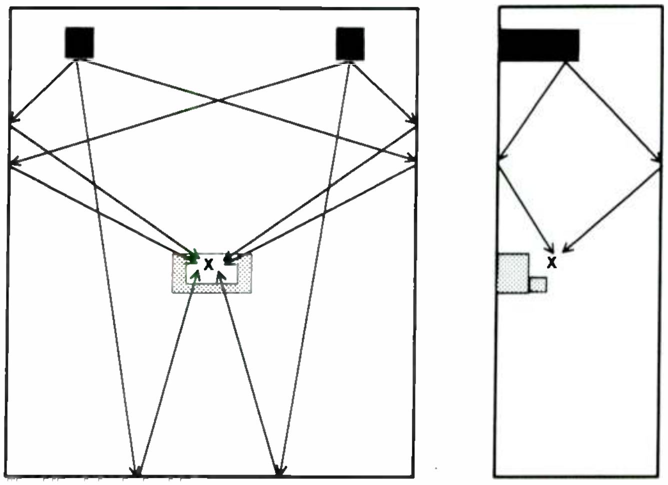


FIGURE 5: Early boundary reflections contributing to room coloration.

INITIAL TIME DELAY GAP. The ITDG is an important parameter that can have a dramatic effect on a room's sonic character.[5] It is defined as the time interval between the arrival of direct sound at the listener's ears and the arrival of the first significant reflection. Since in small rooms there is no reverberant field in the classic sense, the first significant reflection in this instance is defined as the first reflection that is within 6dB of the highest reflection level. *Figure 4* is a simplified graphic representation of the ITDG for small rooms.

In the home listening environment, which is usually considered a small room, the walls, ceiling, and floor are close to the listener. As a result, the reflected sounds are generally comparable in level and arrive at the listener's ears too early with respect to the direct sound. *Figure 5* demonstrates this phenomenon, which primarily occurs for midrange and high-frequency reflections. Because of the wavelike behavior of lower frequencies, this phenomenon does not apply to them.

Note that there are four reflective points for the side walls and only two for the ceiling and floor. The speakers in *Fig. 5* are of the standard dynamic variety. If they were bipolar, the rear wall reflections would have to be dealt with as well.

Unfortunately for audiophiles, early and intense reflections with respect to direct sound are common and can have a detrimental impact on sound quality. ITDGs, which can range from 1 to 5ms in untreated listening rooms, may cause poor imaging, including false localization and frequency coloration and resonances. Often the sound is smeared, and overall clarity is diminished. In addition, spatial textures may be corrupted, and it is believed that early reflections contribute to a room's lack of spaciousness.

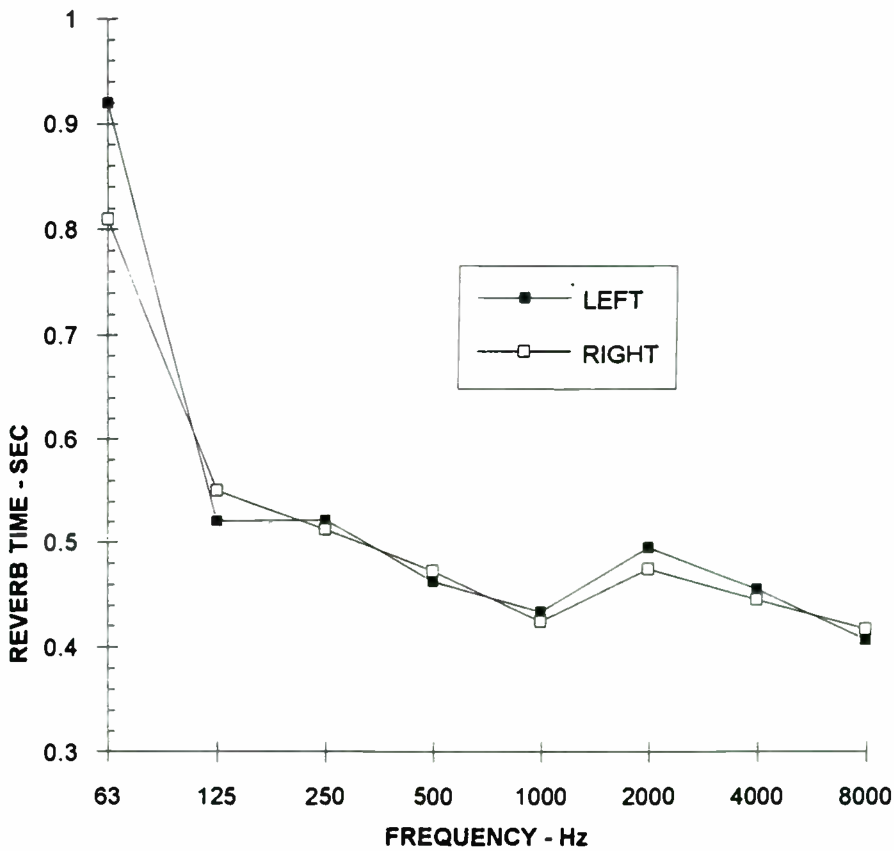


FIGURE 6: RT_{60} versus frequency: four wall modules and one ceiling resonator.

Over the years, I've often wondered why I've been able to obtain more enjoyable listening results by setting up my speakers along the longest rather than the usually recommended shortest wall. I may have been increasing the ITDG without knowing it. Unfortunately, speaker placement is a somewhat limited means of controlling the ITDG, especially since speaker location also affects other factors such as frequency response.

Fortunately, early reflections may be controlled or suppressed by absorption, diffusion, and reflection. Home listening rooms treated with commercial devices, such as RPG diffusers, may exhibit ITDGs in the neighborhood of 10ms, producing excellent results. For my project, the wall modules provided very satisfactory results in controlling early wall reflections and improving diffusion.

I took a different approach with the other surface boundaries. On the back wall, I hung a star diffuser and wall modules. For controlling ceiling reflections, I used blankets of insulation, or "clouds," strategically placed above the egg crate panels. On the floor, I laid small

World Radio History

pieces of carpeting and two reflective pyramids constructed of leftover ½" plywood triangles used to build the star diffuser. I strategically positioned the modules, clouds, and pyramids as follows.

As indicated in *Fig. 5*, each side wall has two principle points where the incident sound is reflected to the listening position. One corresponds to the left speaker and the other to the right speaker. While seated in the listening position, I had my assistant hold a mirror at tweeter level and slowly move it along the side wall away from the speaker and toward the listening position. When I saw the tweeter reflection in the mirror, she marked the location on the wall. This procedure works quite well, because it is assumed that sound, like light, travels in straight lines.[6]

I positioned a module at each of the four spots marked on the side walls. Unfortunately, I had to position a module in front of the outside door along the right side wall. This entrance is rarely used, so I left it in place.

I followed the same procedure for the floor and ceiling. In these instances, however, I used only two treatment points for each surface. I draped 8 ft.² of insulation over the egg crate panels at each ceiling location. On the floor, I placed about 6 ft.² of carpeting and a reflective pyramid at each spot.

SURFACE TREATMENT. Next I installed the star diffuser and four wall modules. First, I positioned the modules roughly in the middle of each wall (ex-

TABLE 1

REVERBERATION TIMES AT LISTENING POSITION

FREQUENCY	READINGS										
	1	2	3	4	5	6	7	8	9	10	Average
63	0.46	1.03	1.03	0.63	1.14	1.14	1.02	1.03	0.73	0.98	0.92
125	0.46	0.64	0.6	0.43	0.65	0.42	0.63	0.42	0.44	0.51	0.52
250	0.53	0.52	0.53	0.54	0.55	0.51	0.53	0.53	0.48	0.51	0.52
500	0.45	0.46	0.45	0.48	0.46	0.42	0.48	0.44	0.49	0.48	0.46
1000	0.41	0.44	0.48	0.45	0.4	0.44	0.42	0.41	0.46	0.39	0.43
2000	0.45	0.5	0.42	0.52	0.52	0.52	0.5	0.49	0.52	0.5	0.49
4000	0.48	0.48	0.47	0.42	0.45	0.46	0.39	0.45	0.47	0.41	0.45
8000	0.42	0.38	0.4	0.42	0.38	0.42	0.39	0.35	0.42	0.42	0.40

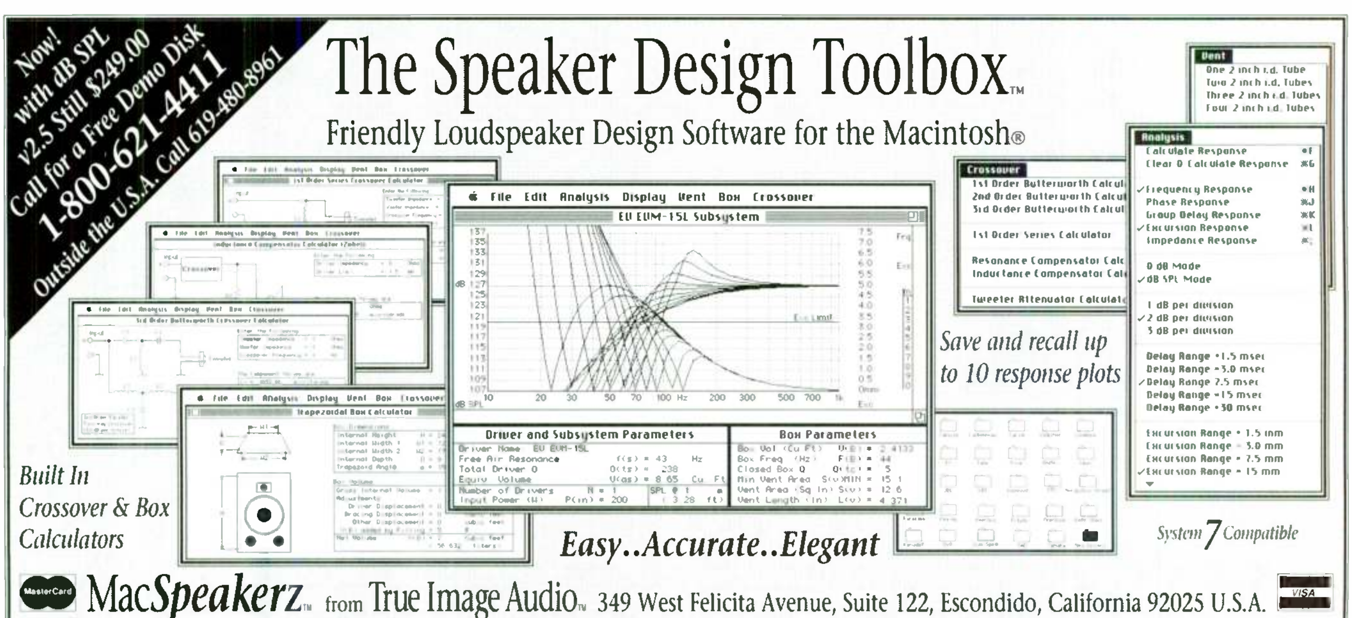
Source: left speaker. 40 ft.² of insulation, 20 ft.² of Helmholtz resonators, 16 ft.² of scrap carpeting.

TABLE 2

REVERBERATION TIMES AT LISTENING POSITION

FREQUENCY	READINGS										
	1	2	3	4	5	6	7	8	9	10	Average
63	0.9	0.45	0.96	0.92	0.97	0.51	0.57	1.03	0.87	0.89	0.81
125	0.55	0.45	0.59	0.5	0.58	0.67	0.52	0.58	0.55	0.55	0.55
250	0.48	0.54	0.5	0.54	0.51	0.45	0.51	0.52	0.52	0.5	0.51
500	0.5	0.46	0.46	0.5	0.45	0.45	0.48	0.5	0.45	0.48	0.47
1000	0.41	0.42	0.42	0.41	0.46	0.39	0.41	0.38	0.42	0.44	0.42
2000	0.42	0.43	0.41	0.53	0.45	0.51	0.48	0.49	0.48	0.46	0.47
4000	0.41	0.43	0.45	0.4	0.46	0.48	0.45	0.46	0.39	0.45	0.44
8000	0.41	0.42	0.41	0.38	0.41	0.41	0.4	0.39	0.43	0.41	0.41

Source: right speaker. 40 ft.² of insulation, 20 ft.² of Helmholtz resonators, 16 ft.² of scrap carpeting.



Reader Service #33

cept the rear wall, which accommodated the diffuser). I did not install the decorative frames during the initial stages of surface treatment so that I could easily add or remove insulation as required.

On the drywall ceiling, I then attached a 2′ × 2′ Helmholtz resonator and stapled some patches of insulation with either paper or insulation facing the sound source. Finally, I randomly laid down small scrap pieces of thick carpeting on the floor.

The idea was to treat all the surfaces, rather than just one, with acoustic material. This approach tends to be more effective in controlling RT_{60}, and it helps to create a more diffuse soundfield.

For my first measurement of RT_{60}, I filled each module with 8 ft.^{2} of insulation and attached another 8 ft.^{2} to the ceiling for a total of 40 ft.^{2} I placed roughly 16 ft.^{2} of carpeting scraps on the floor and attached 20 ft.^{2} of Helmholtz resonators to the walls and ceiling. To save time, I made early measurements only at the listening position. During the final stages, I took readings at all four positions so as to monitor the room's diffusion characteristics. *Tables 1* and *2* and *Fig. 6* summarize the initial results.

The RT_{60}s for the frequencies 125Hz and above were fairly constant and within the acceptable range. However, there was a problem at 63Hz. At this frequency, the RT_{60} was about twice as great as at any other frequency. Although some researchers have found that a moderate and gradual bass rise in

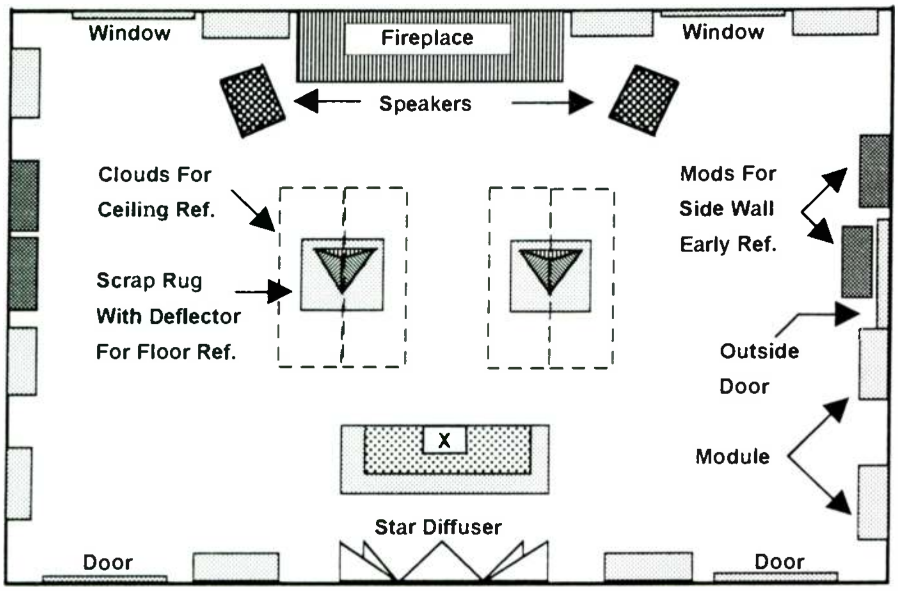


FIGURE 7: Final configuration of listening room.

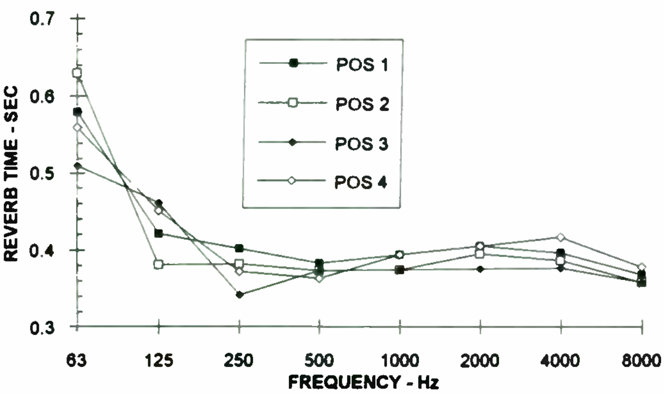


FIGURE 8: RT_{60} versus frequency: left speaker measured at four microphone positions.

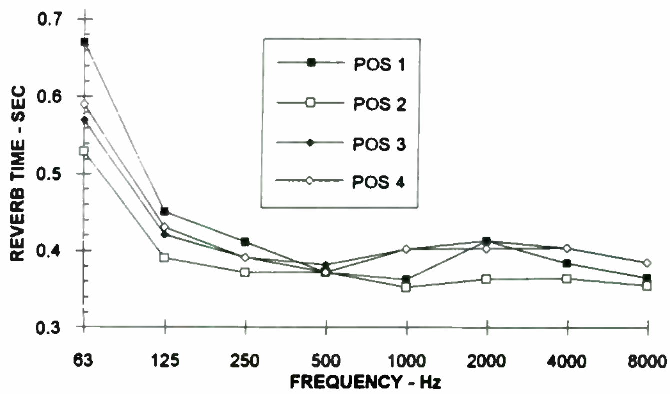


FIGURE 9: RT_{60} versus frequency: right speaker measured at four microphone positions.

TABLE 3

REVERBERATION TIMES AT FOUR MICROPHONE POSITIONS

FREQUENCY	MIKE POSITION 1	2	3	4	Average	Std Dev
63	0.58	0.63	0.51	0.56	0.57	0.05
125	0.42	0.38	0.46	0.45	0.43	0.036
250	0.4	0.38	0.34	0.37	0.37	0.025
500	0.38	0.37	0.37	0.36	0.37	0.008
1000	0.39	0.37	0.37	0.39	0.38	0.012
2000	0.4	0.39	0.37	0.4	0.39	0.014
4000	0.39	0.38	0.37	0.41	0.39	0.017
8000	0.36	0.35	0.35	0.37	0.36	0.01

Source: left speaker. 97 ft.^{2} of insulation, 72 ft.^{2} of Helmholtz resonators, 72 ft.^{2} of carpeting.

TABLE 4

REVERBERATION TIMES AT FOUR MICROPHONE POSITIONS

FREQUENCY	MIKE POSITION 1	2	3	4	Average	Std Dev
63	0.67	0.53	0.57	0.59	0.59	0.059
125	0.45	0.39	0.42	0.43	0.42	0.025
250	0.41	0.37	0.39	0.39	0.39	0.016
500	0.37	0.37	0.38	0.37	0.37	0.005
1000	0.36	0.35	0.4	0.4	0.38	0.026
2000	0.41	0.36	0.41	0.4	0.40	0.024
4000	0.38	0.36	0.4	0.4	0.39	0.019
8000	0.36	0.35	0.38	0.38	0.37	0.015

Source: right speaker. 97 ft.^{2} of insulation, 72 ft.^{2} of Helmholtz resonators, 72 ft.^{2} of carpeting.

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RT_{60} is acceptable, I attempted to control it because of the dramatic rise.

I constructed and installed more wall modules, primarily to add more Helmholtz resonators and to improve diffusion. I also attached more of these units to the ceiling. I added a moderate amount of insulation and in some instances removed some insulation from existing wall modules.

The process of surface treatment involved carefully adding and positioning the wall modules, clouds, and pyramids to obtain a constant RT_{60} of about 0.4 seconds. In addition, I made every effort to create a fairly diffuse soundfield and at the same time to control the ITDG as discussed previously.

I constructed ten additional modules, for a total of 14, and attached them to the walls. I bolted two Helmholtz resonators, each 4 ft.^{2} in size, to the ceiling. I attached eight smaller units along the upper walls above the egg crate panels. Altogether, I used 97 ft.^{2} of insulation and 72 ft.^{2} of resonators on the walls and ceiling. On the floor, I placed 72 ft.^{2} of carpeting scraps.

Figure 7 illustrates the end result: three modules on the front wall, two on the back wall, five on the left wall, and four on the right wall. The rear units were carefully positioned on either side of the star diffuser. Also shown in *Figure 7* are the locations of the ceiling clouds and floor pyramid reflectors.

Tables 3 and *4*, and *Figs. 8* and *9*, summarize the measurements of RT_{60} at the four microphone positions for the left and right speakers, respectively. Each value listed in the tables is the average of the ten readings. I also included the average of these values, along with their standard deviations. The standard deviations indicate that there was very little change in RT_{60} with respect to microphone position, and that a fairly well diffused soundfield was achieved.

Figure 10 displays the average values of all four positions for each speaker location. Note that the bass rise is less dramatic, and the RT_{60}s above 63Hz for both speakers are nearly identical. I have purposely used expanded scales to make the data points more discernible, which may make the results appear worse than they really are.

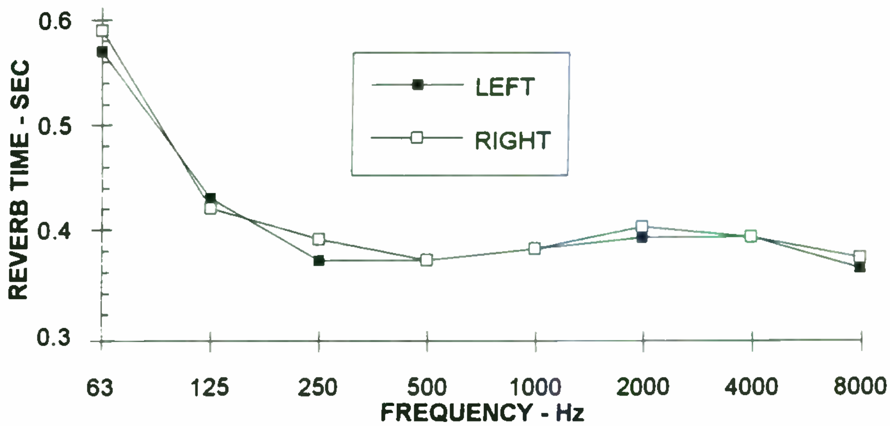


FIGURE 10: RT_{60} versus frequency: final configuration, average of four microphone positions.

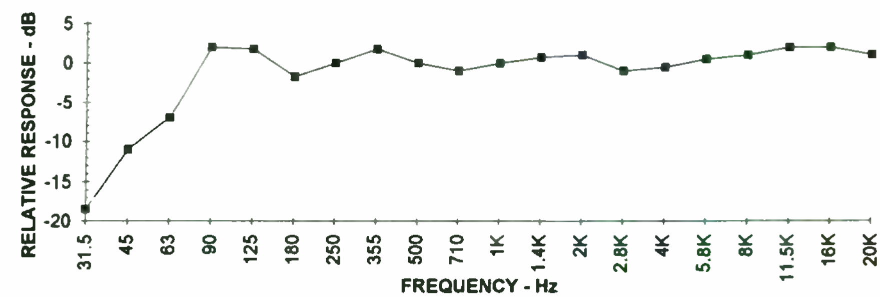
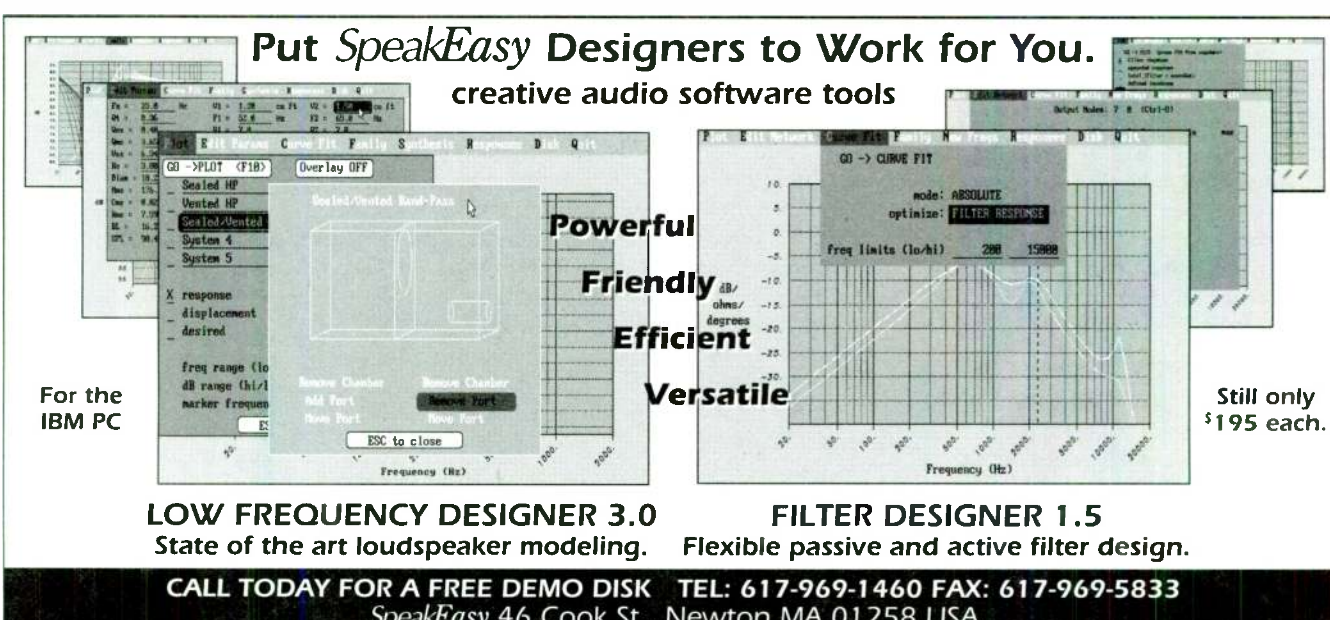


FIGURE 11: Mach II response, supplied by the manufacturer.

FREQUENCY RESPONSE. I was satisfied that I had achieved my goal—



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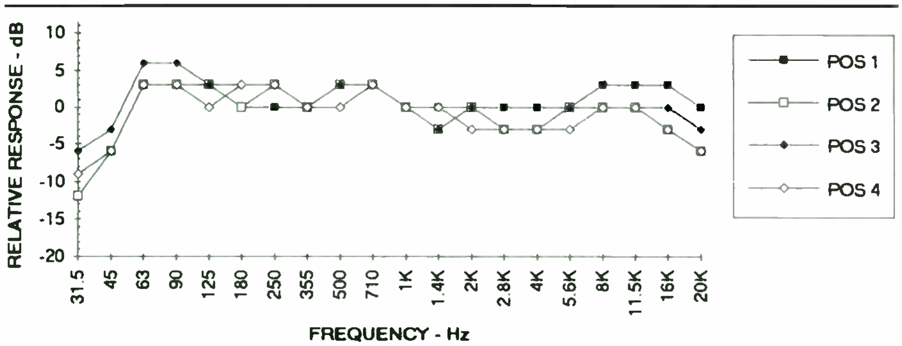

FIGURE 12: Room response, left speaker as source.

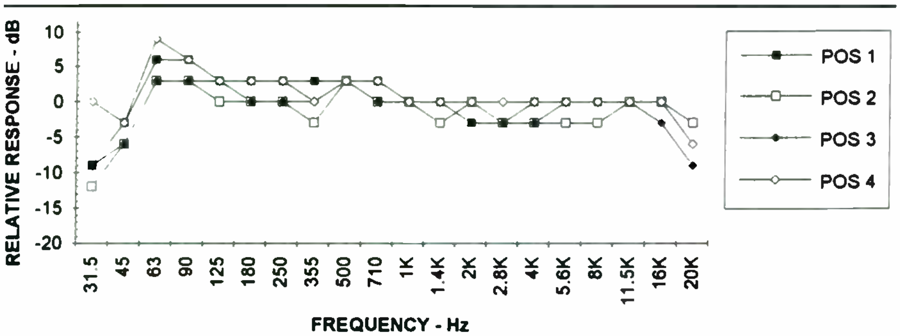

FIGURE 13: Room response, right speaker as source.

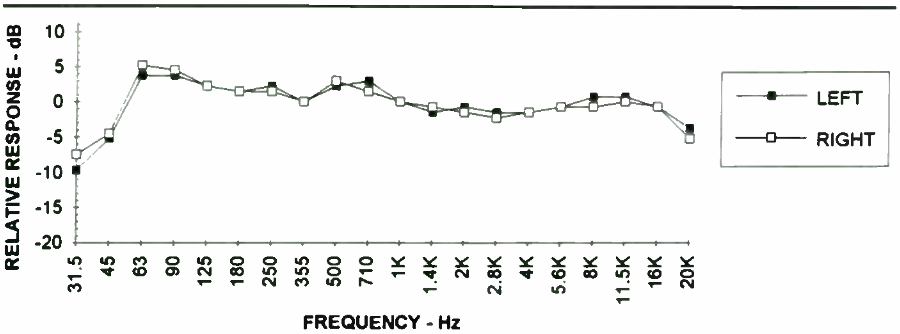

FIGURE 14: Room response averaged, both speakers as source.

namely, a fairly diffuse soundfield, a reasonable value for RT_{60} (0.4 sec.) over the frequency range, and control of early reflections and ITDG. I thought it would be interesting to take frequency response measurements of the room. There is a correlation between RT_{60} and frequency response, but a discussion of this correlation and the mathematics involved are beyond the scope of this article. Intuitively, we can accept the existence of such a relationship, since some acousticians recommend a passive approach to room surface treatment and control of RT_{60} to achieve a balanced room.[7] A balanced room is one that simultaneously exhibits flat frequency response, controlled reflections, and a diffuse soundfield.

I generated pink noise with a Heathkit Model AD-1309 Pink/White Noise Generator. I connected this easy-to-use, battery-operated unit directly to my amplifier, since it has its own volume control. Its pink noise section has a frequency response specification of ±1dB from 20Hz to 20kHz. To measure the frequency response, I used Heathkit's Model AD-1308 ½-Octave Real-Time Spectrum Analyzer. This unit comes equipped with its own calibrated omnidirectional microphone, and its frequency response specification is ±2dB on the analyzer display (with a pink noise source and an anechoic environment). The Heath unit reads frequency response in ½-octave increments from 31.5Hz to 20kHz. According to the manufacturer's recommendation for room response measurements, I set the unit to the "average" response mode with a 3dB/division display. I also set the unit to "flat" and the suggested "slow" mode for sound-level measurements.

I took readings at ear level and at the usual four microphone positions so as to compare this data with that obtained from the RT_{60} measurements. At each location, I pointed the microphone directly at the center of the speaker being measured, and then pressed the "memory store" button once the display stabilized. I retrieved the data and recorded the results by pressing "memory recall."

I used the Realistic Mach II speaker for these measurements, because of its flat frequency response when the midrange and high-frequency drivers are set to "flat." The frequency response curve supplied by the manufacturer is shown in *Fig. 11*. The results of my measurements are shown in *Figs. 12* and *13*, which display the room's response with respect to microphone location for the left and right speakers. *Figure 14* shows the mean curve for each speaker.

The data indicates that within the limitations of the experimental procedure and the equipment used, there were no major aberrations in response, except at the frequency extremes, which are probably speaker related. Almost all the response curves are within ±3dB from 63Hz–16kHz. In addition, note the slight rise in frequency response at 63Hz, which appears to agree with the RT_{60} data.

CONCLUSIONS. As mentioned in Part I, this project involved a considerable amount of research, a crash course in home improvements, and a significant construction effort. It also took several years to complete. Was it worth all the effort? Obviously, the data indicates that

Continued on page 79

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Wayland's Wood World

POWER TOOLS FOR SPEAKER BUILDERS

By Bob Wayland

In my first article, "Hand Tools for Speaker Building" (*SB* 1/93, p. 55), I addressed the issue of hand tools and conveyed some thoughts on safety. This article surveys power tools, both portable and stationary, and provides useful information on selecting them.

Portable Power Tools

Drills: Useful but not essential for speaker building, hand drills are for drilling as well as for sanding, polishing, and buffing. Speaker construction requires a few holes easily made with a mid-size drill. Because you will probably be using it for other jobs, choose a versatile one. Among the features to look for are variable speed reversible (VSR), cordless (rechargeable battery driven), and controlled low-speed screw-driving ability. A good set of bearings, with easy-to-replace motor brushes, is usually a sign of a well-designed drill.

For speaker building, a ⅜″ VSR drill is adequate, with a ½″ drill more suitable for heavier jobs. Buffing and finishing pads are inexpensive accessories that can speed finishing work. Sanding disk attachments require extreme care and good luck for proper use (see "Sanders").

One of the problems often encountered when using a hand drill is drilling straight holes. An alignment jig is helpful, especially when drilling holes for mounting speakers. (Hint: drill holes for the screws and bolts before you cut out the speaker opening.) A good jig is the Portalign Drill Guide, available for about $30 from Highland Hardware.

Wood bits make your drilling far more precise than high-speed steel bits. For holes less than ½″ in diameter, brad-point drill bits are preferred. The cutting spurs should be knife-edged to produce a clean, straight, tear-out-free hole. For larger holes, Fostner bits are a good choice to produce clean flat-bottomed holes. Try using a guide (e.g., the Portalign) for the best results.

Biscuit Joiners: Of all the hand power tools, biscuit joiners are the newest and among the most useful. A 4″ saw blade produces a shallow cut on each side of the pieces to be joined. A flat, football-shaped biscuit (*Photo 1*) is then glued in the cut. Make cuts at regular intervals along the joined edges. Because of the shapes of the cuts and the biscuits, it is easy to adjust the two pieces for perfect alignment.

Biscuit joinery is faster and more accurate than doweling. If you use butt joints and then veneer over the completed enclosure, you can construct a carcass from cut sized panels in about an hour. The finish work will take longer than the structural work.

The finest joiners cost a few hundred dollars (for instance, the Elu 338 at $300, and the Lamello Top 10 at $600), but less expensive models will serve your needs just as well. Examples are the Freud JS100 ($180) and the Ryobi JM-100K ($230). The major differences among the cheaper models are in the front fence which determines where the cuts will be made. The major fault is the inability to hold a setting.

A number of accessories are available for biscuit joiners. Three-inch face-frame blades are useful if you're making grille cloth frames ($70 from Highland Hardware). The Lamello glue dispenser with a double-orifice tip (about $25) helps you to apply just the right amount of glue to cuts. If you wish to read about biscuit joiner characteristics in detail, see *The Biscuit Joiner Handbook* by Hugh Foster (Sterling Publishing, $14.95).

Routers: The router—a cutter mounted directly on the shaft of a high-speed motor—is a versatile tool that allows you to make perfectly fitting joints. The router's simple design and operation facilitate easy use. Possible uses extend from smoothing and squaring edges of boards and trimming wood veneer and plastic laminate to cutting irregularly shaped pieces. A router will perform the same operations as a spindle shaper without the added cost and space requirement. Useful features on modern routers include built-in dust collectors, lights, plunging mechanisms, and electronic variable speed control. The plunging capability is especially useful when making corner joints for enclosures.

A standard utility router, operating at about 22,000–25,000 rpm without attachments, costs $120–$150. The more powerful, electronic variable-speed-control plunge routers cost $200–$300. The Makita 3612 is a time-tested, single-speed workhorse noted for its reliability, power, and precision plunge routing, which sells for about $190.

Many companies sell jigs made for their

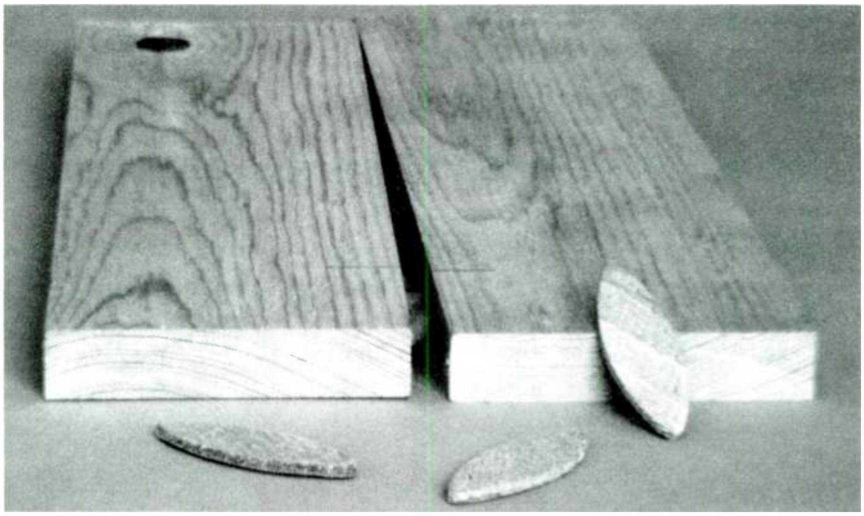

PHOTO 1: Two boards that have been prepared for edge gluing using a biscuit joiner. Note that the biscuits are made of compressed wood that quickly swells in the presence of glue, forming a very strong spline.

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routers. Universal jigs also are available. Circle jigs are very useful for cutting large speaker holes. Other useful accessories include bronze collet brushes, chemicals to remove burned-on gunk from bits, bearing lubricant, and medium and fine diamond paddles for resharpening bits.

Bit creep is one of the most annoying router problems. Poor collet design is usually the cause. The better-designed collets have three to six fingers in a swedge (a conical clamping mechanism) tightening/locking arrangement. It is important to keep all mating areas of the collet and bit shanks clean. Bits, especially ¼" shank ones, are often bent during use. Throw them away immediately. For smoother, better-controlled cuts, ½" shank bits are preferred. Check the bearings often if there is any sign of vibration. The spindle should turn freely without any movement in the motor housing. Sometimes collet wear will allow a bit to spin off center. This problem is common on the cheaper routers.

Patrick Spielman's *Router Handbook* is useful in choosing and maintaining this tool (Sterling Publishing, $10).

Sanders: Remarkable improvements in sanders have been made with the arrival of quick-change sanding pads and random-orbital sanding action. Quick change sanding pads are designed to accept self-sticking sandpaper. Two systems are currently in use: pressure-sensitive-backed paper (e.g., 3M's Stikit) and Velcro-backed disks. Although Stikit is inexpensive, you can use it only once. Velcro-backed disks are more heavy-duty and are readily attached, removed, and reused. The cost per use seems to be about the same for both systems.

Random-orbital sanders combine the aggressive cutting efficiency of disk sanders with the fine finishing action of orbital sanders. The ability to sand without a preferred direction allows sanding of difficult grains, even across end grain, without scratching, while producing swirl-free, extraordinarily efficient finishing. Buffing pads for rubbing or waxing and polishing are also available. High-end units have the useful feature of electronic variable speed control.

The Porter-Cable 7334 or 7335 (variable-speed) random-orbital sander uses self-adhesive 5" sanding disks. They have an optional perforated pad and disks for use with a dust-collection attachment. The new model PC#333 is a dustless random-orbital type which uses Velcro-backed disks.

The variable-speed Bosch 3283 DVS uses 5" Velcro-backed sanding disks and has a built-in dust vacuum. Bosch also has an industrial-grade unit (1370 DEVS) that can be used as a straight 6" direct-drive or random-orbital sander.

Ryobi and Makita make cheaper units ($80 versus $120–$150). Sanders are a quickly changing technology so you should check the latest products before deciding which to buy.

Circular Saws: For speaker builders, a circular saw is almost a necessity. Cutting up large plywood or medium-density fiberboard (MDF) panels, and cutting dadoes, bevels, and miters are just a few of the possible uses. Selecting a circular saw is a very personal choice. Go to your hardware store and "heft" them. If you can talk the salesperson into it, use each one on the material you will primarily be cutting (e.g., ¾" plywood).

Things to look for are which side of the motor the blade is on, whether the handle is on the top or back (so that you can push the saw), and whether the gear drive is straight or worm. The weight also is important. If the saw is too light, it will be hard to control; if it's too heavy, it will wear you out. For most people, a saw weighing 8-10 lbs. is about right, but try out all the available models.

The feel of the cutting action will affect the smoothness of the cut. Changing the cutting speed so that the rpm is close to maximum, and not so slow as to cause burning, will establish which saw works best for you. Unless you plan to cut stock thicker than 2", a 6½ or 7½" saw should

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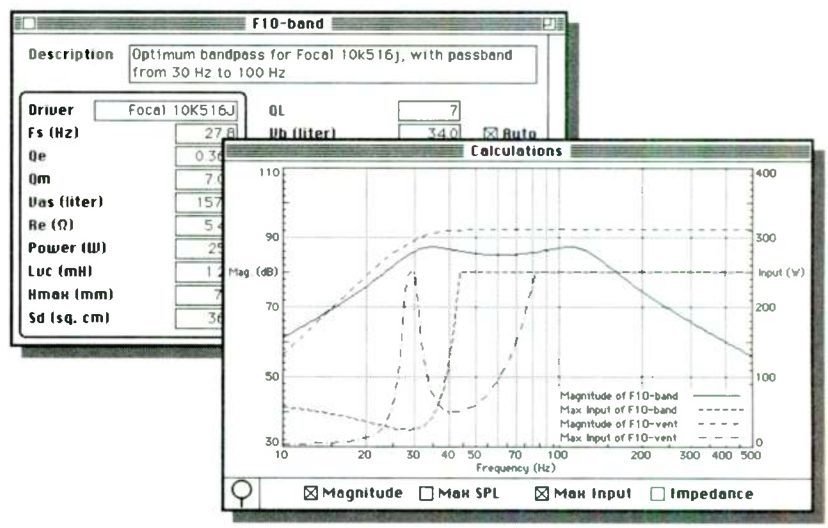

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meet your needs. The very popular Porter-Cable 345, the "Saw Boss," is good for 1¾" cuts, but uses a 6" blade and weighs about 8 lbs. A heavy workhorse, the Makita 5007NBA 7¼" saw weighs in at 11½ lbs., however it should meet your most demanding needs.

Using the correct blades for specific applications will greatly enhance the usefulness of your circular saw. The generic difference in blades is between steel and tungsten carbide. It is possible to get a sharper edge on steel blades, but they dull quickly when cutting plywood or MDF. Tungsten carbide blades remain sharp longer, but are usually twice as expensive, and the carbide is brittle. They also require special diamond sharpening tools.

If you are sawing solid wood, a good choice is a carbide combination blade. For plywood and MDF, the Sears plywood and veneer steel blade, if kept very sharp and properly tensioned, can produce a satin-smooth cut with minimum splintering.

It is easy to bend or distort circular saw blades by improper techniques. The result is hard-to-control cutting with much splintering. The services of a first-class sharpening shop will save you both money and frustration. Cleaning the saw blade whenever there is any indication of gum or pitch buildup will pay large dividends. I suggest using the Resin Remover ($3.95/pint, $5.95/quart, or $19.95/gallon) for cleaning saw blades.

Stationary Power Tools

Stationary power tools generally provide greater accuracy and ease of operation than hand power tools, but the cost is substantial. Whether you prefer the pleasure of using a solid, well-built stationary power tool or the freedom of a hand power tool is strictly up to you. Your choice will reflect your approach to speaker building and your pocketbook. If you like working with exotic hardwoods (such as wenge, a very hard, dense wood, or purpleheart), stationary power tools offer an advantage over portable ones. Mark Duginske's *Mastering Woodworking Machines* (Taunton Press, $25) offers detailed information regarding the use of stationary tools.

SOURCES

Grizzly Imports
2406 Reach Rd.
Williamsport, PA 17701
or
PO Box 2069
Bellingham, WA 98227
Taiwan-made copies of Delta saws

Highland Hardware
1045 N. Highland Ave. NE
Atlanta, GA 30306
(800) 241-6748
Portalign Drill Guard, 3" face-frame blades

Woodcraft
210 Wood County Industrial Park
PO Box 1686
Parkersburg, WV 26102-1686
(800) 225-1153
Resin Remover

TABLE 1

SUGGESTED TOOL KITS

ITEM	ESSEN.	INTERMED.	HIGH END
hand drill	$ 40	$ 80	$ 80
biscuit joiner		$ 180	$ 230
router		$ 150	$ 200
sander		$ 100	$ 150
circular saw	$ 40	$ 80	$ 150
saw blades	$ 20	$ 30	$ 50
table saw		$ 400	$ 600
radial arm saw			$ 250
drill press		$ 150	$ 250
Total	**$100**	**$1,170**	**$1,960**

Table Saws: In a table saw, the saw blade is mounted on an arbor turned by a motor, with the blade extended through the tabletop. Two basic designs are available: either the arbor or the table tilts. The Shopsmith and the Inca model 259 have tilting tables, but most commercial saws have a tilting arbor.

The table saw's most important features are accuracy, capacity, power, and machine size. The advantage of a table saw over a circular saw is increased accuracy and the ability to make complex cuts with greater control. The disadvantages are size and cost, and the potential for woodworking accidents. More accidents occur on table saws than on any other piece of woodworking equipment.

The question of accuracy depends on the care exercised in assembling the parts. You must be able to adjust the saw blade, rip fence, blade projection, miter gauge, and blade angularity carefully. In addition, adjustments should remain true during normal use. Several books on adjustment are available. A good generic book is *Table Saw Techniques* (Sterling Press, $17) by Roger W. Cliffe.

Keep these matters in mind when assessing a saw's adjustment: (1) the table slots, rip fence, and saw blade must be strictly parallel; (2) the miter gauge can be accurately set to be perpendicular to the saw blade; (3) the saw should provide accurate, repeatable setting of the blade's angularity. A number of rip fences and miter gauges are sold separately to improve the accuracy of older saws. Newer models tend to incorporate these improvements into the basic design. A scoring saw attachment can produce chip-free cuts on laminated boards.

My comments on blades for circular saws also apply to blades for table saws. An additional consideration is the size of the blade. I have worked with 8, 10, and 12" models. The optimum size for most speaker builders is 10".

Ryobi offers the BT-3000, an accurate, reasonably portable (you can move it around the garage or shop fairly easily) table saw that retails for about $600. This saw has a sliding table-miter gauge and a positive-locking rip fence.

Delta has a motorized 10" saw (model 34-670, $400) with a nicely machined table and substantial rip fence. The miter gauge, however, is Delta's old stand-by—adequate, but nothing fancy.

Grizzly Imports has Taiwan-made copies of many of the better Delta saws, but the millwork is not great. If you are willing to do much of the millwork yourself, you can save some money by buying one of these copies.

Radial Arm Saws: The radial arm saw is an attempt to combine the rigidity of the table saw with the flexibility of the circular saw. It is a circular saw mounted in a yoke on an overhanging support along which it slides. The overhanging arm and yoke can be positioned to provide control of the blade's swing, tilt, and cutting direction, while also allowing the user to raise or lower the blade. Attachments are available to extend the saw's usefulness. These attachments allow the saw to cut dadoes, and molding heads, shape and rout, perform drilling and sanding operations, and provide a power source to drive flexible shafts.

The main difference between a table saw and a radial arm is that you push the wood past the fixed blade on a table saw, whereas you pull the blade through the wood on a radial arm saw. One serious problem with radial arm saws is that too fast a feed rate will cause the unit to lock up. Also, in rip operations, you must feed the wood against the blade's rotation, resulting in a resistance to the feeding. A dangerous kickback of the wood is often the result. Because you will be cutting through the fence, it must be replaced often.

To ensure accuracy, you must make frequent adjustments to maintain the proper relationship of the blade to the cutting table. Many woodworkers find this annoying. Of course, if you make only crosscuts, this type of saw is optimal.

If you are interested in some of the finer points of using a radial arm saw,

PREVIEW
Audio Amateur

Issue 1, 1993

- Line Level Preamp, Part I
- Continuous-Time Monolithic Filter
- Build the A75 Power Amplifier, Part II

World Radio History

consider Roger W. Cliffe's *Radial Arm Saw Techniques* (Sterling Press, $17).

Drill Press: The drill press may be the second most useful stationary power tool you own. Essentially, it is a spindle with a chuck at one end to hold drilling devices. The *head* is normally a mechanism for raising and lowering the spindle (*quill*), with a *feed lever* and a multiple-level pulley attached to the spindle. The inverse of this pulley is attached to a vertically mounted motor to allow a selection of speeds. Many of the newer presses have electronic speed control. It is normally possible to lock the quill in place or to limit its motion by a *depth stop*.

The base of the drill press is a table-like platform to which the column is attached. If the column is long enough for the operator to use the unit standing up, the drill press is a floor model. If it is designed to be used on a table, it's a bench model.

The material to be drilled is supported on a movable table attached to the column. On some models, this table can be rotated to nonhorizontal positions. My comments concerning bits for hand drills also apply to bits for use on a drill press.

A number of drill presses are available from Taiwan importers, many of them sold under well-known American company names. Most of the better-known name-brand presses are built to company specifications and carry full guarantees.

Many useful accessories are available for drill presses. A good one for cutting small speaker holes is the fly cutter. Be sure that the cutting bit can be aligned to produce a square-faced hole, is easily cleaned and sharpened, and has sufficient length to provide the required cutting depth. The fly cutter can be used for holes up to 6" in diameter. When using it, keep the feed and speed as slow as possible on the clamped work.

It is possible to do shaping operations on a drill press. You should realize, however, that the slower rpm of the drill press forces slower feed rates.

Drum sanders of different diameters are useful for edge-smoothing operations. A number of inexpensive drum sanding sets are available. Most include a variety of grit sleeves.

For mortise-and-tenon joints, a drill press offers a simple way of making mortises. You can buy special mortising jigs for this purpose that mount on the quill and drill square holes.

Other Stationary Power Tools: Limited use tools for speaker builders include the planer, joiner, and shaper. A planer is a powered plane that removes a selected amount of material from stock surfaces, leaving them parallel and smooth.

A joiner is also a powered plane. It removes a selected amount of material from stock edges, leaving them square and smooth.

A shaper is basically a router mounted on a fixed table. However, shaping operations can be done on a drill press, radial arm saw, or table saw with a molding head. A router can do all the operations a speaker builder needs to do.

Essential Tool Kits

Few power tools are absolutely essential for a speaker builder. You *can* use a handsaw to cut your panels, but a circular saw is more practical. Although a hand drill isn't nearly as practical as a circular saw, it can, in a pinch, also be used as a sander and, with a jig, as a biscuit joiner.

In choosing the essential tools in *Table 1*, I was guided by the ideal that you should be able to perform any operation in building a speaker and produce a high-quality enclosure. The intermediate selection includes those tools that will make your work easier and more pleasant. In some cases, this means upgrading the quality of the tools a bit. The high end is what you would expect a full-time woodworker to use.

Nothing is sacred about these lists. You should develop your own approach to speaker building and gather the tools you need to enjoy it.

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Reader Service #20

World Radio History

Kit Report

Black Dahlia Mk II Loudspeaker

By Gary Galo
Contributing Editor

Black Dahlia, A&S Speakers, 3170 23rd St., San Francisco, CA 94110, (415) 641-4573, FAX (415) 648-5306.

Specifications: Tweeter: MB MCD25M; Woofer: Dynaudio 17W75XL/8; Frequency response: 70Hz–30kHz, ±3dB; Sensitivity: 82dB; Power handling: 130W RMS; Crossover: 24dB/octave at 3kHz.

Price: Assembled: $643.00/pair; Full kit with enclosure: $593.00/pair; Kit without enclosure: $381.50/pair. Individual parts also available; contact A&S for prices.

In the November 1990 issue of *Stereophile* (p. 94), Contributing Editor Dick Olsher described the Black Dahlia, his latest loudspeaker design for do-it-yourselfers. Speaker builders may recall two other loudspeaker designs offered by Olsher: the original Dahlia (a transmission line system) and the Dahlia-Debra. The Black Dahlia Mk II is similar to the loudspeaker described in *Stereophile*, with two important differences.

The enclosure has been modified with double-thick enclosure walls and an additional internal brace for improved rigidity. To maintain the original enclosure volume of 0.81 ft.³, the new enclosure has considerably larger external dimensions, and is *very* heavy. Its tweeter is also different from the one used by Olsher. The enclosure dimensions are shown in *Fig. 1*.

Both Black Dahlia versions are public domain designs. Distributors are free to sell kits and parts; Olsher receives no royalties from sales.

The Black Dahlia Mk II was designed with the aid of Calsod and LEAP, two popular computer optimization programs. A copy of the original *Stereophile* article is included with each kit; Olsher's description of the design process makes for an interesting read. The woofer is a 7" Dynaudio 17W75-XL, a newer version of the veteran 17W75. The Danish-built 17W75 has a Q_{TS} of 0.74 and is recommended by Dynaudio for sealed, aperiodic or transmission line enclosures.

The XL version has a larger magnet system and a lower Q_{TS} of 0.44, making it well suited for small vented loudspeakers. The cone is made of Dynaudio's proprietary Phase Homogeneous Area (PHA) plastic, designed for excellent phase linearity, with a rubber surround. The 3-inch high temperature voice coil is wound with Dynaudio's Hexacoil technique for faster heat dissipation.

Olsher used a West German MB Electronics MCD25M tweeter with a 1" titan-

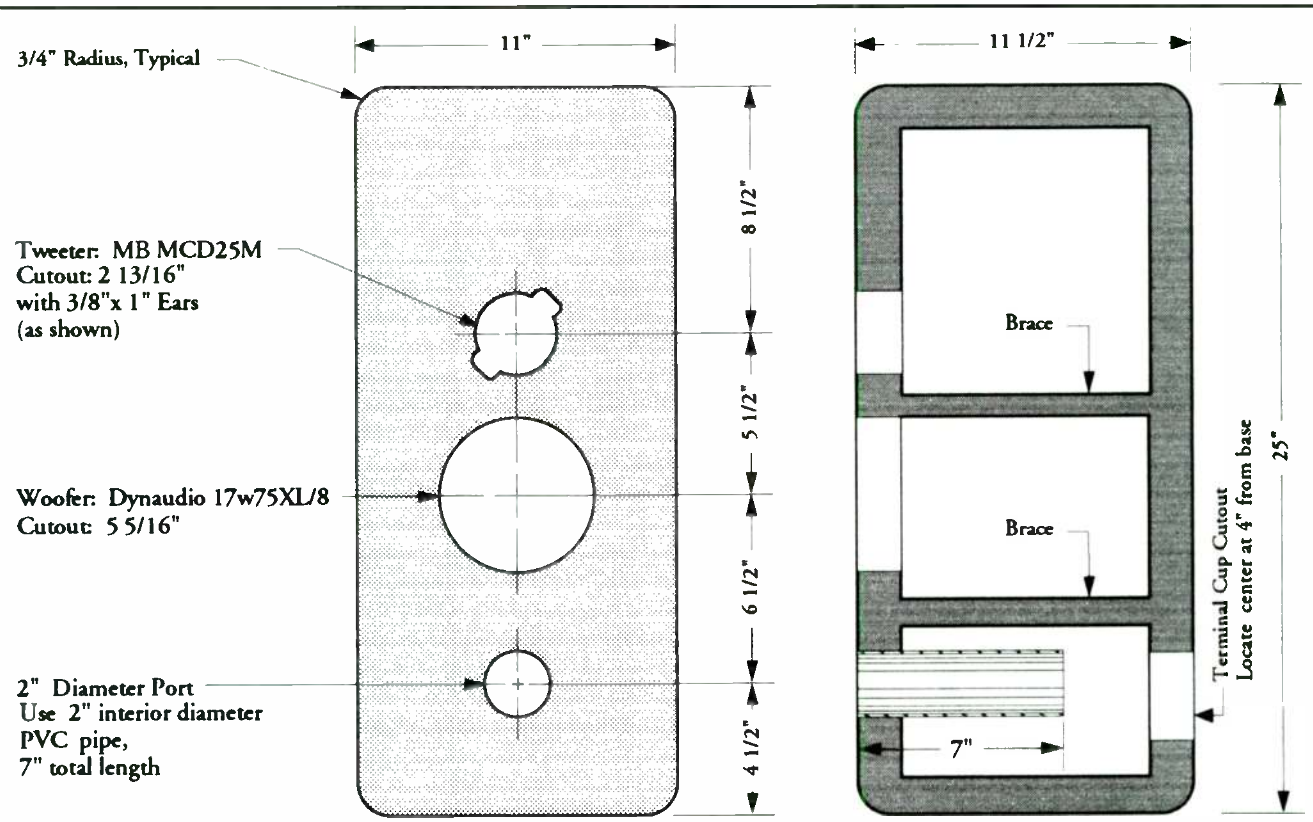

FIGURE 1: Front baffle and side section.

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PHOTO 1: A completed Black Dahlia Mk II loudspeaker.

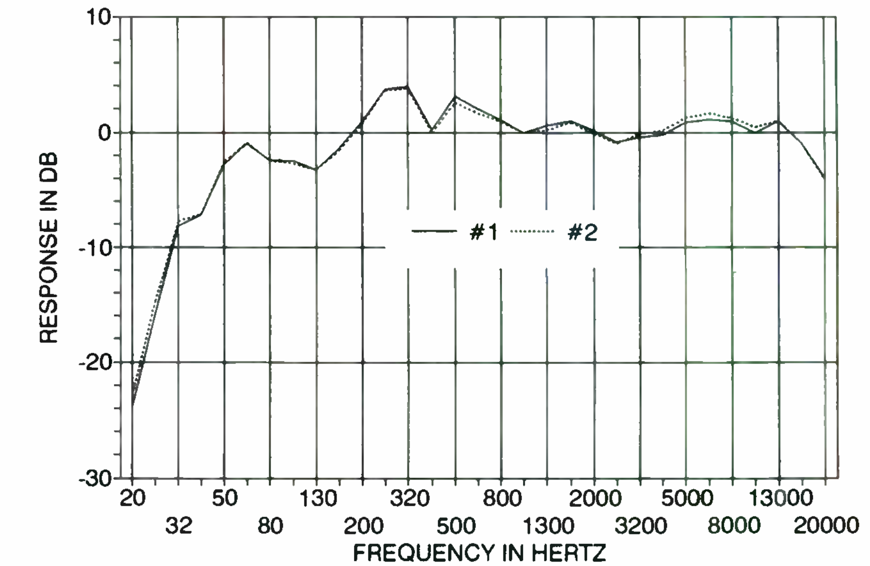

FIGURE 3: ⅓-octave, 1W/1m warble tone response. The two samples are virtually identical.

ium dome in the original Black Dahlia. He later found the stock tweeter "a bit too alive, with a slight metallic aftertaste." He modified the original tweeter by spraying the dome with Tuffilm fixative to damp low-level resonances in the titanium. This seems to be a difficult procedure for builders to undertake with consistent results. It also doesn't seem possible using the tweeter supplied with the A&S kit.

A&S also specifies the MCD25M in their plans. You can get a copy directly from them, or from their ad in *SB* 3/92 (p. 21). The tweeter they actually supply with the kit, however, is the MCD25R. The difference is in the mounting flange—the M version is square, while the R version is round. Olsher's tweeter modification begins with removing and discarding the plastic faceplate grille. According to the photograph in *Stereophile*, the tweeter still has a square mounting flange even with the plastic grille removed, and the metal dome is fully exposed.

The R version has a protective metal screen rather than a plastic faceplate. The screen and mounting flange are one assembly; the screen can't be removed. Removing the flange would not only leave you unable to mount the tweeter, but also makes the voice coil/dome assembly look as if they would loosen when removing faceplate screws. Since the tweeter terminals are molded to the faceplate, it would be risky to disassemble it.

Besides, A&S's assembly instructions do not mention any tweeter modifications. The front baffles of the A&S enclosures are routed for the R version, so it would be impossible to mount the M tweeter properly. I built the Black Dahlia Mk II kit as specified in the instructions.

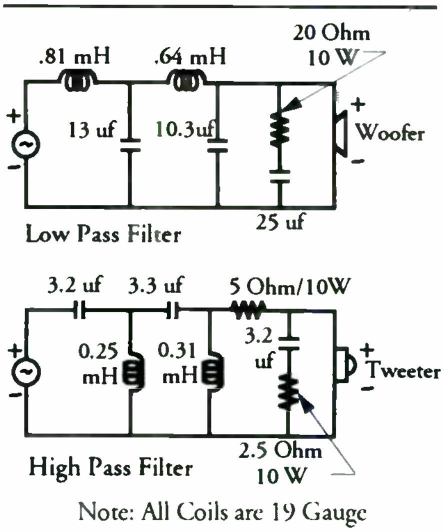

FIGURE 2: Crossover network.

The crossover schematic is shown in *Fig. 2*. The fourth-order crossover is actually a Legendre characteristic, utilized to meet one of Olsher's design goals—a 20° listening window. Using computer simulations, he found the Legendre network to have better polar response than a Linkwitz-Reilly within the desired window. The Legendre characteristic has the cutoff sharpness of a Chebyshev filter, but with only 0.1dB of ripple.

Olsher also notes that some final crossover tweaking—by ear—was necessary during the final stages of development. He used two Zobel networks, one to compensate for the tweeter rising high-end response, and the other to keep the woofer's impedance uniform.

The component quality in the crossover networks is first-rate. Capacitors are Chatteauroux polypropylenes and all inductors are air core. I wasn't happy with the appearance of two solder connections on my crossover boards, so I reheated them. The internal wiring is nothing exotic. Builders are, of course, free to substitute other wiring; Dick Olsher used Tara Labs' Space and Time cable.

The Kit

The A&S Black Dahlia Mk II kit is exactly the type I like to see: it is complete. The kit contains everything needed to finish the project, right down to the damping material, internal wiring, rear terminal cup, and the screws. You'll need only four tools to assemble it: a Phillips head screwdriver, soldering iron, wire stripper, and a drill with a ⁵⁄₆₄" bit.

Assembly is easy and A&S's two-page instruction sheet is perfectly clear. To begin, set the drivers in place and drill pilot holes with the ⁵⁄₆₄" bit. Mark the hole positions, remove the drivers, and then do the drilling. The instruction sheet suggests drilling with the drivers in place, which seems a bit risky. Repeat this procedure for the rear terminal cup.

The high- and low-pass sections of the crossover are on separate boards. Glue both to the inside of the enclosure with silicone adhesive, and allow overnight curing. Solder the input leads to the rear terminal cup, then the high-pass filter's output leads to the tweeter.

Next, install the long-hair wool. I divided the supplied amount into two equal piles before filling the enclosures. The wool should not obstruct airflow through the vent. I carefully positioned wool on either side of it, but not behind it. Finally, solder the low-pass leads to the woofer, and use screws to mount the driver. It's all incredibly simple—the most time-

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consuming part of the assembly is waiting for the silicone glue to cure. A completed Black Dahlia Mk II is shown in *Photo 1*.

Performance

Figure 3 shows the ⅓-octave warble tone response with 1W/1m. As you can see from the curves, the two samples are virtually identical, indicating excellent quality control in the drivers and crossover components. The near field response of the woofer and vent output are shown in *Fig. 4*. My vent measurement verifies Olsher's claim of a tuning frequency of 40Hz. *Figure 5* shows the impedance curve. The two low frequency peaks can be seen at 56Hz and 20Hz. The impedance never drops below 4.5Ω.

Dick Olsher recommends using the Black Dahlias on rigid stands, which puts the ears midway between the woofer and the tweeter. I used a pair of Audio Concepts AC stands, which are just the right height. Olsher recommends toeing in the loudspeaker so the axes intersect at the listening chair. I found that the loudspeakers delivered their most realistic presentation with a bit less toeing, so the listener is slightly off-axis.

For my listening tests, I used the Black Dahlia Mk IIs in two different locations. First, in my production studio at The Crane School of Music, where I used many DAT live performance master tapes. Equipment used with them included an Adcom GFP-555II power amp and a slightly modified GFA-565 preamp, along with a Panasonic SV-3900 DAT recorder. In my home listening room, they were fed an Adcom GFA-585 power amp, my extensively modified GFP-565 preamp, Pooge-5/DAC960 digital-to-analog converter (see *TAA* 2/92, p. 10, and 3/92, p. 34) and a highly modified Magnavox CDB-650 transport. I used Livewire Indigo loudspeaker cables and Grado Signature interconnects.

The most immediately appealing feature of the Black Dahlia Mk II's performance is their soundstaging. They reproduce a realistic, three-dimensional soundstage which is very deep and fairly precise. They are also very clean and detailed, especially in the high frequencies. At 82dB for 1W of input, the Mk IIs aren't very sensitive, especially for a vented design. But, given sufficient drive from the power amps, they are punchy and dynamic. I believe they require at least 100W/channel for best performance. Fortunately, the impedance curve in *Fig. 5* shows that they are a relatively easy load to drive. Your power amp won't need to sink huge amounts of current into very low impedance loads.

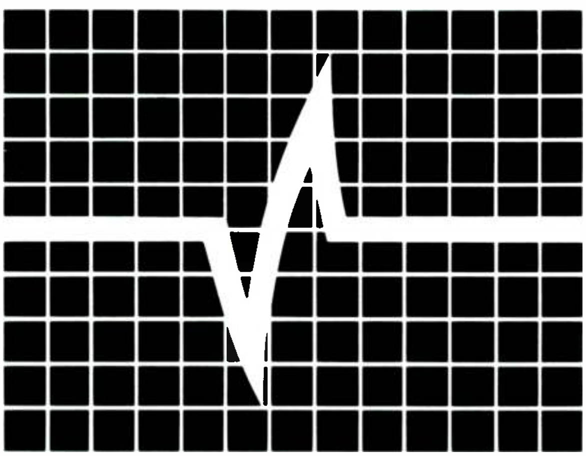
The Black Dahlia Mk IIs sound crisp and have excellent transient detail. The low end, within its operating range, is tight, well-defined and punchy. Bass drums and tympani have crisp attacks, and tympani have a reasonably full tonal balance. They are also impressive in their ability to maintain their clarity at reasonably high volume levels.

The negative side of the Mk IIs, at least as supplied by A&S, is their tonal balance. They have two tonal balance aberrations. First, the unmodified MB tweeters are just as Dick Olsher described them in *Stereophile*: they're simply too bright and hard. On recordings with a lot of high-frequency energy, this can get a bit tiresome. Unfortunately, builders can't modify the R version of the MB tweeter supplied with the A&S kit. It would be nice if Dick Olsher could collaborate with A&S to find an off-the-shelf tweeter which would provide a more natural tonal character.

The second tonal balance aberration is in the upper midrange. With the Mk IIs, this critical portion of the musical spectrum sounds unnaturally recessed, most seriously affecting strings. The reduction of the critical harmonic content of cellos and violas makes them sound as though they have sinus congestion. Brass instruments and vocals also sound a bit muffled, and midrange presence is lacking.

The frequency response curve in *Fig. 3* shows at least part of what I hear, with those two peaks in the response between 200Hz and 1kHz. *Figure 3* doesn't show an upper midrange recession relative to the top two octaves. In fact, the curve

The Perfect Pitch



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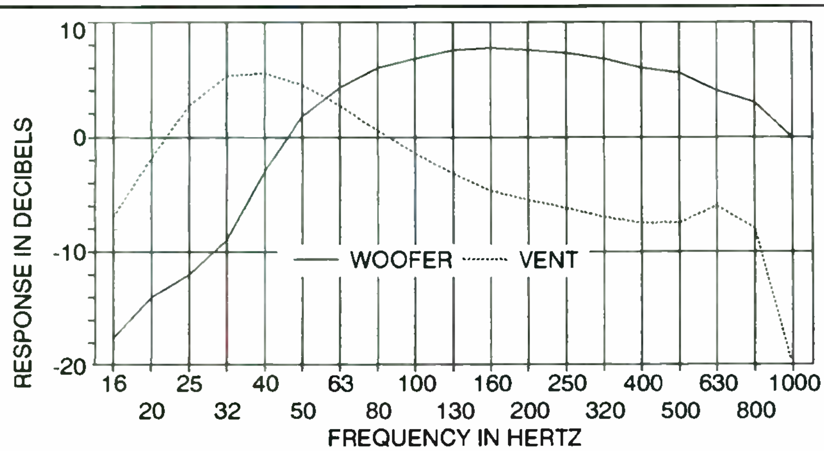

FIGURE 4: Near field response at 1W. The solid line is the woofer response and the dotted line is the vent output.

doesn't correlate with the brightness I hear. I suspect the problem is related to the resonances Olsher complained about in the unmodified tweeter. The combination of an elevated lower midrange and high-frequency tweeter resonances probably explains the subjective recession in the upper midrange.

Because of the tonal balance problems, I don't consider the Mk IIs accurate enough to reproduce classical music, or any music in which a live, unamplified sound is the reference. Rock and pop enthusiasts may find the dynamic, punchy sound appealing and be unconcerned by the upper midrange recession.

Conclusions

A&S's Black Dahlia Mk II kit is an enjoyable loudspeaker project. Its strengths are its crisp, punchy soundstage reproduction, and fine bass performance for a driver its size. Its weaknesses are confined to tonal balance problems. Individual preferences ultimately determine the gravity of this problem.

Dick Olsher, Designer of Black Dahlia and Sr. Contributing Editor Stereophile *Magazine replies:*

I would first of all like to thank Speaker Builder *for giving me the opportunity to respond in print, and also for providing a much needed forum for loudspeaker kit evaluation. It may be worthwhile to recount the differences between the original and Mk II version of the Black Dahlia.*

The most obvious difference has to do with the cabinet construction (neither the internal volume nor the bass alignment have changed). The enclosure is now double walled and better braced. There is also a small change to the tweeter network. Note, however, that the driver complement has not changed. The tweeter is still the MB MCD25. Either the round (R) or square (M) mounting flange version of this tweeter may be used. Let me get A&S Speaker's Arthur Rosenblum off the hook: it was I who suggested that the cabinet baffle be routed for the R version of the tweeter because it is of more recent vintage and appears to more closely meet specs.

It's true, as Galo points out, that the protective screen of the round version of the tweeter makes it impossible to apply the Tuf-film fixative coating I described in the orig-

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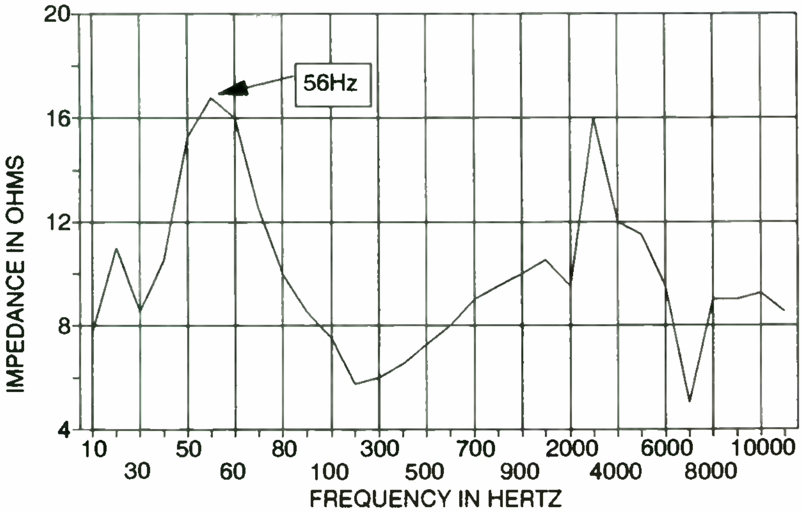

FIGURE 5: Impedance curve of the Black Dahlia Mk II. The vented alignment produces a large peak at 56Hz and a small peak at 20Hz.

inal article. This mod is difficult to apply, and in any event only makes a small difference in the sonic flavor of the MB tweeter. Anyone building their own cabinets certainly has a choice in the matter, and may opt for either version; they're electrically and acoustically interchangeable. This is a great tweeter, and one which has found a home in some high-end designs (e.g., Hales). I much prefer it to a host of recent aluminum domes. Please note that the tweeter smooths out considerably after a 30-hour break-in period. No critical listening should be undertaken until after the drivers are fully broken in.

Gary's first subjective impression was of a bright and hard treble presentation. As soon as Arthur Rosenblum first mentioned this to me and well before I actually read a preview of Gary's copy, it clicked: oh no, he must have used a transistorized amp together with a digital front end. Yes, he did, and, consequently, the results were predictable: solid-state hardness and digital brightness. The Black Dahlias demand a vacuum tube amp. They were voiced around tubes and require at least an amp the caliber of a modified Dynaco Stereo 70 for starters.

The whole issue of the loudspeaker-amplifier interface is crucial to the proper evaluation of any loudspeaker. The notion of just dropping a speaker under test into one's system and then passing judgement really prickles me to no end. This interface must be explored and optimized after the speaker is evaluated with at least a couple of different amps and speaker cables. Some amps work well with some loudspeaker loads and not others. To discover such synergy and incompatibility requires the willingness to experiment. An audio reviewer is duty bound to do no less.

I'm a bit more puzzled by the subjective impression of an upper midrange recession. Granted, the core of the midrange is a bit more colored than that afforded by the Dahlia-Debra which uses an Audax TPX 8" driver, but a recessed upper midrange? One possible explanation may be the listening axis chosen by Gary. I did not receive an advance copy of Galo's measurements, but I gather that even his measured response disclosed no anomaly here—at least on axis. The Black Dahlia was designed to have a well-defined sweet spot. It is important to toe

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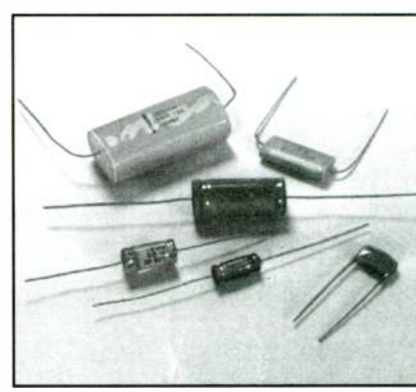

Nonpolarized Electrolytic Capacitors
•For crossover networks •Axial type

Mylar Capacitors
•Ideal for use in custom crossover networks
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in the speakers for an on-axis listening experience. Tonally, all bets are off for an off-axis listening seat. Hence, this is not a speaker that can be accurately evaluated by a listening panel whereby most listeners are forced to listen off-axis. Unfortunately, the most efficacious manner to enjoy the Black Dahlias is one-on-one.

Contributing Editor Gary Galo responds:

I'm a bit confused by Dick Olsher's comments on the two versions of the MB MCD25 tweeter. First, he says that he chose the round version for the kit "because it is of more recent vintage and appears to more closely meet specs." But in the next paragraph he states that "they're electrically and acoustically interchangeable." I'm not sure how both statements can be correct, and the second statement is inconsistent with his comments on the MB tweeters resonance problems in the original November 1990 *Stereophile* article. Sorry, Dick, but anyone who's read your comments on modifying the MB tweeter in *Stereophile* would probably conclude that the driver complement has changed.

Regarding break-in, I run every loudspeaker system I review for at least 48 hours on pink noise before conducting any listening evaluations. I've found that it's futile to listen to any loudspeaker prior to break-in, so I do this as a matter of course. In addition, the Black Dahlia IIs had at least 30 hours of music listening in my production studio prior to taking them to my home listening room.

I do not regard my digital playback system as bright, and with my Audio Concepts Sapphire IIti's connected to my modified Adcom GFA585, my system does *not* sound too bright. I've recently upgraded them with the modified Focal T120ti titanium dome tweeters now supplied by Audio Concepts.

I think *SB* readers might be interested in also reading Editor John Atkinson's review of the original Black Dahlia system in the same issue of *Stereophile*. His amplifier recommendations contradict Dick's: ". . . the bass alignment needs a gutsy solid state amplifier to get the best balance between weight and control, while the tweeter's top octave could do with being 2dB or so more sensitive, at least in my room." If anything, Atkinson found the top end a bit laid back, even with a transistorized amp. It would appear to me that the differences between the modified and unmodified tweeters are greater than Dick suggests.

I have read and reread Dick's original Black Dahlia article, and I can't find any reference to the necessity for tube amplifers and analog source material as a prerequisite for satisfactory performance. Nor does A&S's literature make reference to their need. If a loudspeaker is specifically designed for tubes and/or analog source material, the designer and manufacturer have an obligation to clearly state this up front.

The Black Dahlia Mk IIs certainly don't present any loading problems for my Adcom 585. These high current amplifiers were designed to drive the most difficult loudspeakers, and were extensively tested with speakers such as Infinity 9-Kappas, which have a 20Hz impedance of 1Ω with a phase angle of 90°. I'm sure Dick agrees that amplifiers sound different for reasons other than their ability to drive various loudspeaker loads. If a loudspeaker's performance depends on balancing complementary colorations, potential customers should be told this prior to purchase.

Regarding the upper midrange recession, my subjective impressions correlated, at least in part, with my own ⅓-octave *on axis* warble tone measurement, and also with *Stereophile*'s ⅓-octave, spatially averaged in-room response (*Fig. 23* in Atkinson's review). Naturally, our two measurements are not identical, but they certainly show the same general trends, including a dip on the order of 5dB in the 2–3kHz region. I concluded that the elevated lower midrange, shown in my measurements, combined with the tweeter's resonance problems, probably produced the subjective midrange recession. Please bear in mind that in the *Stereophile* arti-

Continued on page 79

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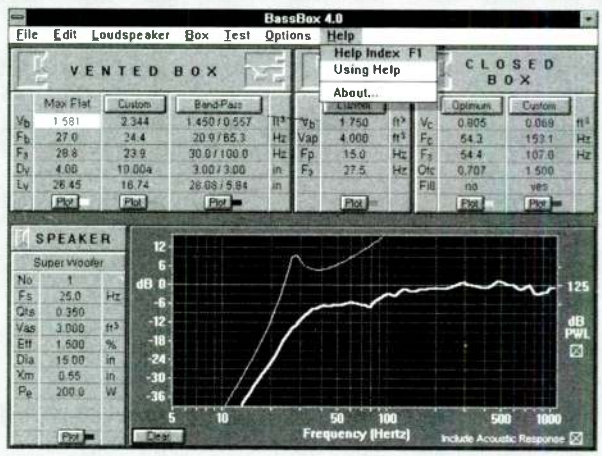

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Software Report

Thunder Box

Reviewed by Dan Ferguson

Thunder Box, Software for Loudspeaker Enclosure Simulation Using the Thiele/Small Model, $199.00. Distributed by MTX/Oaktron, 555 W. Lamm Rd., Freeport, IL 61032, (815) 232-2000.

As evidenced by their large line of auto sound woofers, MTX is one of the major producers of auto sound speaker systems. You won't have any problem finding their products at your local dealer. And while I don't have any facts to base this on, *Thunder Box* looks like it may have been tailored for use by their dealer/installers. One indication here is that data for 38 MTX drivers comes pre-loaded into the files.

In any case, *Thunder Box* is a relatively user-friendly, low frequency loudspeaker enclosure design program. Most functions can be performed intuitively from on-screen prompts. This is fortunate, since the documentation is sketchy in places.

As stated in the program's title, *Thunder Box* operates within the confines of the basic Thiele/Small filter model and is not at the level of sophistication of the larger programs like *LEAP*. It does, however, contain all of the essentials necessary for someone with little experience to successfully design and build a low frequency speaker/enclosure system. If you're in the auto sound business or just build a lot of systems, you'll like the convenient files and tables that permit rapid storage and retrieval of your past design data.

Scope

Thunder Box will help you design six different conventional types of systems:

1. Closed Box (without active equalization)
   a. With first-order equalizer
   b. With second-order equalizer
2. Vented Box (without active equalization)
   a. With first-order equalizer
   b. With second-order equalizer

In addition, a convenient design section on closed box bandpass enclosures is included. Unfortunately, the system is not designed to plot bandpass responses.

Getting Started

Driver and system design files are stored in a section called Boxdata. The first screen after program startup is the Boxdata selection menu. (This screen also contains the Utility menu which will be discussed later.) You can either browse all the driver records on file, directly load a driver (if you know its file number), add a driver to the data base, edit a file, or print reports.

Driver Selection

Enough text is stored in the browse list to make driver selection fairly easy. Once

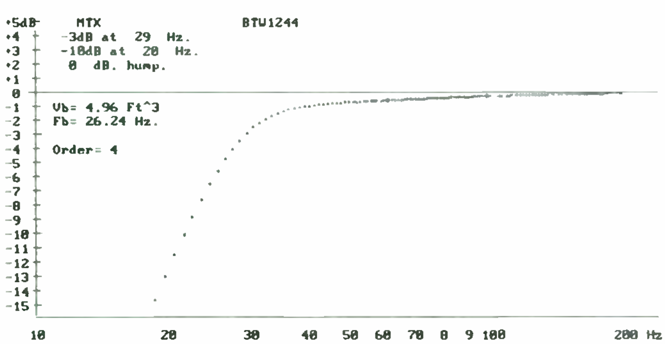

FIGURE 1: Frequency response plot for MTX BTW1244 12″ woofer in 4.96 ft.³ optimum vented box.

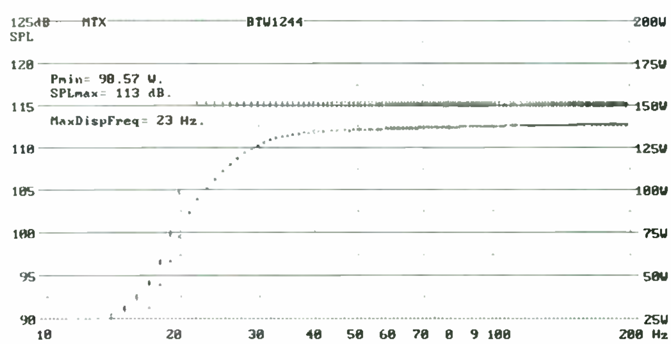

FIGURE 2: SPL and power handling graph for MTX BTW1244 12″ woofer in 4.96 ft.³ vented box.

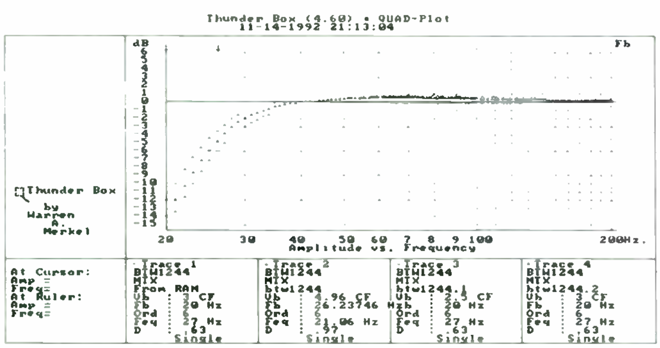

FIGURE 3: Quad plot frequency response for MTX BTW1244 in various sixth-order alignments.

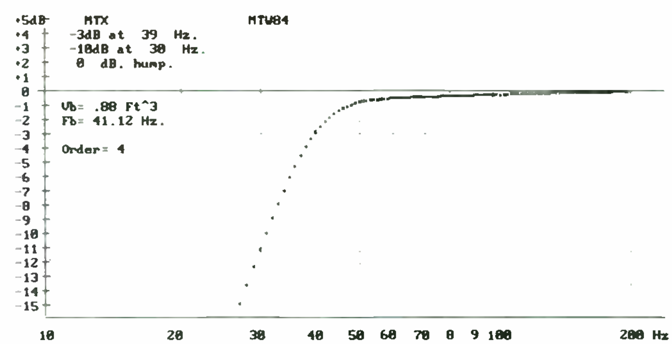

FIGURE 4: Frequency response of MTX MTW84 8″ woofer in theoretically optimum vented box.

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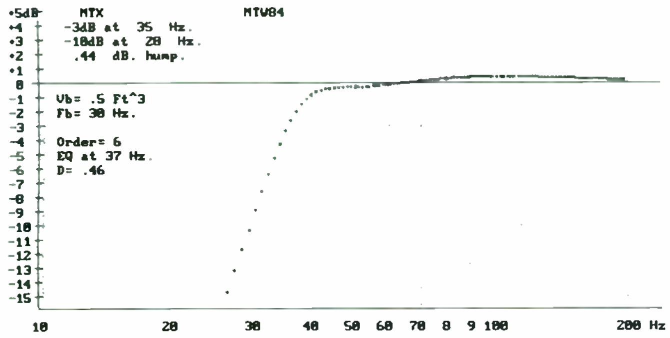

FIGURE 5: Frequency response of MTX MTW84 8″ woofer in sixth-order alignment with reduced box size.

```
Record Number   20
  Model          MTW84
  Brand          MTX

ALIGNMENT FACTOR:          Current value          File value

Box Volume                 .88  Ft^3              .5  Ft^3
Box Frequency              41.12  Hz.             30  Hz.
Order                      4                      6
EQ  Frequency              37  Hz.                37  Hz.
D factor                   .46                    .46

     Your options are...

                    (1)   LOAD the BOXDATA File values.

                    (2)   SAVE present values into the BOXDATA file.

                    (3)   QUIT (Go back to previous menu.)

     Your choice is...  (3)  ?
```

FIGURE 6: File save screen.

done, a screen showing the driver's manufacturer, model number, and Thiele/Small parameters are displayed. At that time, you can decide whether the box design will be for single or dual drivers. Note that *Thunder Box* always assumes a loss factor (Q_l) of 7, but you can enter another value if known. Based on a calculated performance index number (f_S/Q_{MS}), the system recommends whether the driver should be used in either a closed or vented box and whether or not it is suitable for a bandpass application. The bandpass enclosure design screen is also accessed from the T/S parameter screen.

System Order

This screen has the six menu choices listed in the introduction for closed and vented boxes in unassisted and assisted formats. (The latter is good news since I am very partial to T/S sixth-order alignments).

If you select an unassisted design (Order 2 or 4), the program calculates the theoretically optimum box volume and vent frequency (if applicable). For a closed box (Order 2), box volume is automatically sized for a Q_{TC} of 0.7. You can also enter a nonoptimal box volume here if you wish.

If you select any of the assisted or "equalized" designs, you're pretty much on your own as to the result. *Thunder Box* seems to have some preset values for the filter damping factor (1/Q) and corner frequency. However, this is not a problem as most box designs are probably done on a trial and error basis anyway to avoid having very large but theoretically correct boxes. The program author goes on to say that "...you must build" the filter required for the assisted designs. Once in the equalized design mode, you can do rapid iterations of filter damping factor and corner frequency adjustments.

One last comment regarding equalized system design. In most subwoofer applications, the high-pass filter which supplies the low frequency boost will be cascaded

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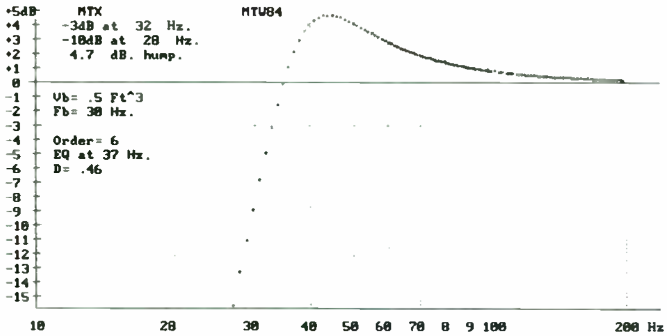

FIGURE 7: Erroneous response created by recalling file data from *Fig. 6*.

Thunder Box ■ Single-Reflex Passband Enclosure Design

Driver: MTX BTW1244

Fs= 21.80 Hz. Qts=0.310 Vas= 9.500 CF

Choose: Low -3dB point: 40 Hz Vent diameter: 3 in.

S factor ->		.4	.5	.6	.7
Front Volume	(CF) :	0.59	0.92	1.32	1.79
Back Volume	(CF) :	0.76	0.96	1.18	1.43
Total Volume	(CF) :	1.34	1.88	2.50	3.23
Front Vent Freq	(Hz) :	80.1	71.9	65.5	60.2
Single Vent Length	(in) :	2.9	1.8	1.2	0.7
Double Vent Length	(in) :	7.0	4.9	3.6	2.8
High -3dB point	(Hz) :	160.6	129.3	107.1	90.6
Boost over 2nd order	(dB) :	-2.0	0.0	1.5	3.0
Q'T factor	:	1.1414	1.0239	0.9322	0.8573

<SpaceBar> to make Changes ■ <P> for Print ■ Esc to Exit

FIGURE 8: Bandpass enclosure design screen.

onto a low-pass filter with a corner frequency about two octaves away. A fairly significant interaction occurs between them which you should not neglect. In general, the low-pass section will increase the apparent low frequency boost by tilting the passband response. Therefore, to attain a flat passband, the real-world high-pass filter damping factor will have to be somewhat higher (or Q lower) than indicated by this program.

To facilitate trial and error optimization, you can have *Thunder Box* print out a blank worksheet so you can write in the results of up to seven program runs. This is a handy tool, except I wish the worksheet was held resident in the program.

Pressing Enter starts the program and 200 frequency response data points are rapidly calculated within the range of 10-200Hz. The system uses floating point decimal arithmetic to speed up the number crunching, which the author states to be nearly as fast as a math coprocessor.

Output

The Output Choice menu is displayed next. At the top of the list is the familiar Bode plot, followed by the excursion limit plot. The latter shows the expected SPL and power handling capability versus frequency. Examples of both are shown as *Figs. 1* and *2*. Incidentally, I did some spot checks of *Thunder Box* by entering alignments from Bullock's tables (References 1 and 2) and got perfect agreement.

The Output menu includes the "Quad Plot," which allows you to display up to four response plots simultaneously. You can select Amplitude, SPL, or Power handling to be displayed in Quad mode. I found the documentation for this section to be less clear than for others. However, on-screen information is adequate to take you through it. Because the graphs are on the small side, they can become cluttered with four simultaneous displays. To aid in interpreting the graphs, the program provides magnification features which are accessible with a mouse. An example of a Quad plot is shown as *Fig. 3*.

Saving Your Design

Once you settle on the best design, you can store the results in a file by selecting option "S" from the Output menu. This separate screen (*Fig. 6*) can be displayed each time that particular driver is retrieved from the browse files. However, it was here that I found a serious "glitch" in the program.

For example, *Fig. 4* is the response of an MTW84 in the theoretical fourth-order vented box. For a second run, I attempted to reduce the box size and adjust the tuning to improve the response with a second-order equalizer. The result is *Fig. 5*, which looks pretty good. I then saved the alignment in the Boxdata file by selecting option "S" on the Output menu. The "current" values and my "file" data are shown in *Fig. 6*. Option (1) says you can then load the file values. When I did this, I got *Fig. 7*. Not good. The system appears to overwrite the "file" data on top of the "current" data. The results are erroneous.

To actually save and retrieve *Fig. 5*, you must press F7 and save the data in a named "dump file" before selecting Option S. For convenience, I chose the driver name as the dump file name. Then, to retrieve the correct data, press F8 and enter the dump file name. This works

Continued on page 69

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Operational Amplifiers — BKB17 — $61.95

By R. Newby and G.B. Clayton. Third edition, 1992, 304pp., softbound.

Operational Amplifiers — BKB18 — $74.95

From the *EDN* Series for Design Engineers, this is an authoritative book skillfully combining design, philosophy, theory, and practice. Provides the reader with practical knowledge necessary to select and use op amps, as well as with an extensive treatment of applications. By Jiri Dostal. Second edition, 1993, 500pp., 7 x 10, hardbound.

Troubleshooting Analog Circuits — BKB19 — $39.95

A collection of excellent troubleshooting techniques for analog—and some digital—circuitry. By Robert Pease. 1991, 208pp., 7 x 10, hardbound.

Mystery Book — BKMY1 — $4.95

Old Colony occasionally receives from publishers books which are slightly bent, dented, marred, or otherwise imperfect. Rather than go to the time and trouble of returning them, we would prefer to sell them to you at a loss and move on to better things. So this mystery book is our choice of a perfectly readable and usable audio or electronics book which is otherwise slightly damaged in some way. All of these are worth more than $10, and most sell for $20, $30, and more. All sales final.

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Continued from page 66
without a hitch, but it took a while to figure out. Here especially, the documentation didn't help.

You can make any number of dump files and the file names can have a suffix like MTW84.1. This makes it convenient to store different versions of alignments of the same driver.

You can both view and print the response data points in tabular form within the frequency limits of your choice. Here, I wished for a feature enabling you to build a table of measured data to make it convenient to compare actual to theoretical responses.

Vent Lengths

The Vent Length calculation screen is another well-designed feature. It takes all the work out of port sizing while providing a large number of options. For each port option, the Mach number expected at maximum power input is displayed.

On this same screen, suggested rectangular enclosure dimensions are given. They are provided as a minor convenience to make the enclosure have the proportions and look of an auto speaker. There are no other enclosure design functions in *Thunder Box*. To aid installers, I would have included some more, especially for trapezoidal box cross-sections.

Bandpass Section

The bandpass calculation screen (*Fig. 8*) is accessed from the driver Thiele/Small parameter screen by pressing F3. As stated earlier, *Thunder Box* advises you whether or not a driver is suitable for bandpass applications. Note that you can enter the low −3dB point of your choice. If you're already into bandpass designs, this one is a snap. As stated in the introduction, the downside here is that *Thunder Box* won't graph the bandpass response. In order to make this section more meaningful, it definitely should.

Utilities

From the Main menu, you can select several utility programs. Perhaps the most useful of these is the Sort/Pack Boxdata file which lets you organize your driver lists in alphabetical order. Other utility features have to do with file path changes and merging of external file data.

Summary

All in all, I found *Thunder Box* to be a handy tool. It has a few shortcomings, but
Continued on page 79

REFERENCES

1. Bullock, Robert M., III, "Thiele, Small, and Vented Loudspeaker Design," Part I, *SB* 4/80, p. 7-13, 30.

2. Bullock, Robert M., III, "Thiele, Small & Vented Loudspeaker Design, Part V: Sixth-Order Alignments," *SB* 1/82, pp. 20-24.

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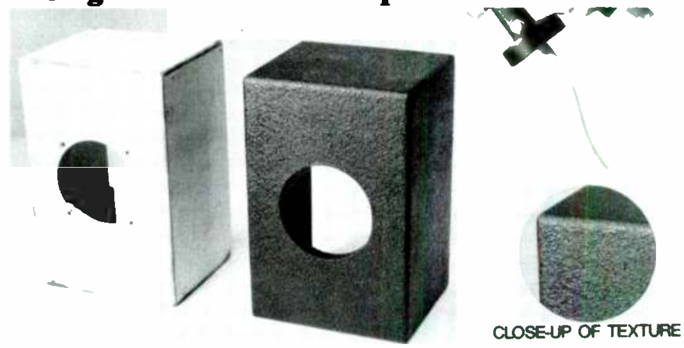

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Tools, Tips & Techniques

FLAT PINK NOISE

I recently built Old Colony's kit, Muller Stereo Pink Noise Generator (#KSBK-E4, $49), and am very pleased with its versatility and usefulness. It has instantly become the first test for speakers and their placement. If exact R and C values of the suggested pink filter are used, the deviation of the filter's response from ideal (3.01dB/octave, 10dB/dec) is approximately ±0.4dB; amazingly good—considering that these values are in the stock 5% series.

For those who require more nearly flat pink-filter response, changing the parts values and adding an additional pair of RC networks will yield 20Hz-20kHz response of ±0.06dB (using precise values). *Figure 1* shows the components: the Cs are standard 10% values, while the Rs are from the 1% series. Obviously, the caps will have to be selected to get optimum performance. The TL072 (or a TL082 or LF353) should be used for the post-filter amplifier; the circuit wants very low loading (> 10MΩ) but amp noise is not an issue.

Dick Moore
Silverdale, WA 98383

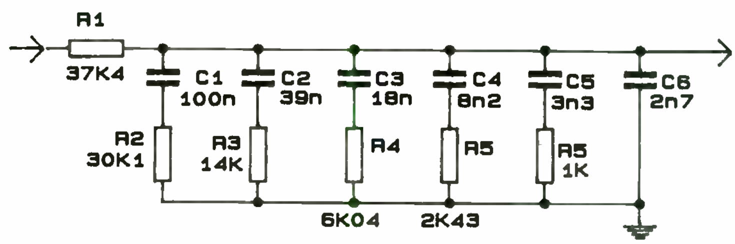

FIGURE 1: Enhanced pink noise filter.

FREE BOXSIZE PROGRAM

Several computer programs calculate cabinet specifications. Modeling programs such as BOXRESPONSE (#SOF-BOX1B5 for $25 and #SOF-BOX2B5G with graphics for $50) are available from Old Colony Sound Lab and have been published in *SB*, but I saw none that suited my needs. Being too frugal to buy one, I opted to write BOXSIZE.

Using a driver's published, or better, tested parameters, BOXSIZE will suggest cabinet volume and give you an indication of its performance. I have done some programming, but I'm not a programmer, so you may find ways to rearrange my code. BOXSIZE is a simple task written in VAX BASIC; however, I'm sure it wouldn't take too much to get it to work on other systems (see Note).

My principal goal is to make the program user friendly while maintaining flexibility and simplicity. To this end, BOXSIZE presently only generates cabinet volumes for closed-box systems. The algorithms used here have been well-known for several years. My primary source for the proper steps was the venerable guide, *The Loudspeaker Design Cookbook* by Vance Dickason.

Operation

This program allows you to work in metric or SAE (inches); however, you cannot mix the two. If your driver parameters are given on the spec sheet in both forms, you must make conversions first. I provide a place to enter a catalog number or a short description—if you run more than one driver, you can keep them straight.

The driver parameters required for BOXSIZE are resonant frequency (f_S) in hertz, electrical and mechanical Q (Q_{ES} and Q_{MS}), equivalent volume (V_{AS}) in liters or cubic feet, peak excursion (X_{MAX}) in millimeters or inches, and the driver piston diameter in centimeters or inches. Once all these are entered, the program will generate a table (*Fig. 1*) with ten recommended volumes based on choice of

Catalog number of driver selected	1232 - 8" Carbonneau
Resonant frequency of driver (fs)	27
Electrical Q of driver (Qes)	.496
Mechanical Q of driver (Qms)	2.43
Total Q of driver (Qts)	.411921
The equiv. volume in liters (Vas)	117.7
Peak excursion in mm (X max)	2.4
Driver piston diameter in cm	18.415

Qtc	Description	Vb (cu.ft.)	Vb (liter)	f3 (Hz)	fc (Hz)	SPL (dB)
.5	(2nd-order, critically damped)	8.78	248.64	50.9	32.8	91.8
.577	(2nd-order Bessel-D2)	4.32	122.34	48.1	37.8	90.8
.707	(2nd-order Butterworth-B2)	2.14	60.49	46.3	46.3	90.2
.8	(2nd-order Chebychev-C2)	1.5	42.46	47	52.4	90.4
.9	(2nd-order Chebychev-C2)	1.1	31.19	48.9	59	91.1
1.0	(2nd-order Chebychev-C2)	.85	24.05	51.5	65.5	92
1.1	(2nd-order Chebychev-C2)	.68	19.2	54.6	72.1	93
1.2	(2nd-order Chebychev-C2)	.56	15.72	57.9	78.7	94
1.3	(2nd-order Chebychev-C2)	.46	13.14	61.4	85.2	95.1
1.5	(2nd-order Chebychev-C2)	.34	9.6	68.8	98.3	97

FIGURE 1: Sample output for BOXSIZE.

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enclosure response (Q_{TC}). It will also report the −3dB point of bass rolloff (f_3), resonant frequency of the system (f_C) and sound pressure level (SPL) of that driver. BOXSIZE then lets you enter another driver or quit. The output is merely printed to the screen, but the program could be modified to print to a file or printer.

Final Comments

I chose to calculate the output for a variety of Q_{TC}s because everyone has different ideas of how their bass should sound. The table generated here gives you an easy comparison of the size and performance of the loudspeaker across a fairly broad range. Generally speaking, the lower the Q_{TC}, the "tighter" the bass will sound. For a more thorough explanation, refer to Vance Dickason's *LDC*.

The volumes given here do not account for components that reside inside the cabinet. Some compensation should be made for the crossover, braces, all of the drivers, and anything else that finds its way inside the enclosure.

I hope BOXSIZE helps to make your next speaker project more accurate and less painful.

David Mika
Broadview Heights, OH 44147

Note: For a copy of David Mika's BOXSIZE code (written in VAX BASIC), send a stamped, adressed envelope labelled "BOXSIZE" to the editorial department.

NEAT DRIVER REPAIRS

Do you like to modify woofers, repair loose surrounds, or replace dust caps?

My search for the right adhesive, one that looked like factory application, led me to GC Electronics #10-352 "Rubber to Metal Cement," available at many electronic stores. I thin it with a little MEK (methyl ethyl ketone), then dispense it from a disposable hobby syringe such as a Monoject.

This method will allow you to apply an accurate bead of adhesive either between surfaces or by capillary action at the periphery of a cone or voice coil.

I have used this adhesive for numerous repairs and modifications with excellent results. Successive light applications are necessary if the bonding surfaces are sensitive to solvents.

Alan Ersen
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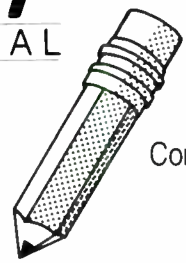

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Book Report

Music Speech Audio

Reviewed by Richard Campbell

Music Speech Audio by **William J. Strong and George R. Plitnik**. Soundprint, 2250 North 800 East, Provo, UT 84604, $35 postpaid. Available soon from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458-0243; please inquire.

This book is apt to appeal to a significant number of *SB* readers. It is a greatly expanded version of an earlier book titled *Music Speech High-Fidelity* (1977, 1983) and is billed as a one-semester college course in "descriptive acoustics"—another way of saying "no math." With those targets in mind, it's a wonderful book.

The first 84-page section is devoted to physical acoustics and sound waves and is extremely well done. Then come 60 pages on hearing, 42 pages on acoustic environments, and 200 pages on the human voice and musical instruments. (Haven't we all wanted to know, at one time or another, the input impedance of the trombone mouthpiece as a function of frequency?) The last 100 pages are painfully elementary (the horn loudspeaker cross-section doesn't show a phasing plug).

There are exercises at the end of each chapter, with selected hints and answers at the end of the book. The chapter bibliographies and final book list are comprehensive. The illustrations are clean and easy to understand.

If you are interested in vocalization or in musical instruments, this book will be a nice addition to your collection. If you are concerned about getting kids interested in audio and acoustics, it would make a great gift for your local high school or community college library.

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CORRECTION

The table accompanying Joseph Janni's letter (*SB* 6/92, p. 53) incorrectly specified 268 V_{AS} (ltrs.) for Woofer 2 at 4-8Ω. The correct number is 286. We appologize for any inconvenience this may have caused.

SHORT LINE SHUFFLE

When John Cockroft developed his short transmission line concept, he provided speaker building enthusiasts with a viable alternative to vented, sealed, and traditional transmission line enclosures. However, some of his explanations/assumptions of the short line concept need clarification.

How much of short line behavior can be attributed to that of classical transmission lines, since electrically, they behave more like a periodic relief CB? The Microline impedance measurements showed only one impedance peak at 101Hz. Since the woofer used had an f_S of 49Hz, this would indicate that any box with the same volume, port size, and stuffing amount as the Microline would produce similar impedance measurements.

Is V_{AS} not as important in designing short lines as Mr. Cockroft stated? My experiments show that woofers with the same f_S but different V_{AS} produce upper impedance peaks at different frequencies. The speaker with the higher V_{AS} has the impedance peak at higher frequency.

What is the port's optimum size? When short lines are partially stuffed, they show a lower impedance peak. The frequency of that peak will shift up or down, depending on the port size, not unlike the behavior of a ported speaker.

Finally, how important is woofer location? The Octaline, Microline, and Shortline all use woofers mounted on top of the enclosure, facing up. Mr Cockroft mentioned that he used this arrangement more for ease of construction than anything else. He also suggests that his speakers be placed as close to the wall as possible. Could this arrangement contribute more to the excellent sound production than any other factor?

I believe this arrangement provides an acoustical reinforcement to the woofer that is even across the frequency spectrum, without the "comb" effect and floor bounce which plague conventional speakers. This will explain why the Microline appears to be more efficient than the numbers would indicate. Speakers with upward firing woofers seem to sound smoother because on-axis distortion due to cone breakup is being directed away from the listener. Can somebody suggest an alternative tweeter placement? For those who believe in time alignment, having the tweeter in front of the woofer might be unacceptable.

Pete Manchev
Oklahoma City, OK 73135

Contributing Editor John Cockroft responds:

I am pleased that people are still interested in my short transmission lines. I, too, would be very happy if some of my assumptions were truly clarified.

Much of the design work on these short lines probably includes more intuition than it would be prudent to admit. Fortunately, I've been able to hide this fact from the speakers and they continue to behave in a correctly designed manner.

In trying to answer your first question, I can only say that my short lines sound very traditional. They are shorter, of course, for which they use a higher density stuffing to compensate. They also use a larger line cross section, and in some cases a higher speaker Q_{TS} in order to compensate for the higher density stuffing.

In each case where I have tried to locate the two impedance peaks of a normal transmission line, I have removed some of the line stuffing to allow the "missing" peaks to appear. With the stuffing densities I use, the peaks are sometimes damped to the point of disappearance. Since I've been happy with the sound of the lines, and since impedance peaks within sensible limits are not sound level peaks, especially with modern amplifiers, I haven't been too interested in looking further into that aspect. As you mention, the Microline displayed a single impedance peak at 101Hz (it measured 13.2Ω). I removed stuffing material from the line until I was able to locate the lower peak of 33Hz and 11Ω.

All my short line bass registers sound similar in quality and substance, and I have no doubt that if I were blindfolded and listened to something rich in bass, I couldn't identify which line it was. If I could identify it, the treble would probably be the snitch. This test would have to be conducted at sound levels compatibly suited to all of my lines, of course. The point I am trying to emphasize is the noncriticality of the short transmission line design.

If you have found that V_{AS} is an important factor in the design of short transmission lines, you already have more knowledge on the subject than I. I have never considered it a factor, and this has never seemed to cause a problem. You state in your letter that two speakers with the same f_S, but with one speaker having a higher V_{AS} (by higher, I presume you mean higher compliance), have upper impedance peaks at different frequencies. This may be true (and I'm sure it is because you measured the peaks), but I'm not sure this really affects the actual sound performance of a short transmission line with an adequate amount of stuffing. (Perhaps in actuality it does; I've never noted performance differences between high- and low-compliance drivers.)

One instance where it might be prudent to use a low rather than a high-compliance driver is if you are designing a system for maximum sound pressure level. The low-compliance suspension might be an additional aid in keeping the speaker under control at maximum power. At the levels that I play these things, I notice no lack of control, but

Glad you asked that! *Good Idea!*

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everything helps when working out a design. Perhaps, if there is a difference in the actual sound in your test, it could be due to the intrinsic sound that two distinctly different speakers make due to their different construction, and not merely due to their different V_{AS} values.

Concerning your third question, I don't believe an optimum size port exists in the same sense as in vented or bass reflex systems. In that case, the purpose is to create a resonant peak at a specific point in the bass range that exactly compliments woofer frequency roll-off at the same point. For success, the port must be accurately tuned so its action will coincide with that of the speakers.

The port at the end of a transmission line allows the exiting of the attenuated and, at some frequencies, phase-altered back wave of the woofer with as little back pressure as possible given enclosure constraints, stuffing resistance, and radiation resistance at the line/room air interface. In a classical transmission line, this is accomplished by allowing the port area to be at least that of the woofer's effective speaker cone area. You could even allow the area to be a little less, since the speaker forces are reduced as some of the sound is converted to heat due to stuffing friction.

With the denser stuffing of the shorter lines, however, there is increased back pressure. This can be improved by making the port area larger. Use the analogy of a garden hose. With a small-diameter hose, little water comes out at high pressure, while with a large hose connected to the same source, more water flows at lower pressure. I went into this in more depth in my article "The Unline" in *SB* 4/88 (p. 28). Again, a lot of intuition is involved. (In spite of this, the systems I've constructed on the basis of intuition have worked well.)

I believe my ports are conservative because I know of lines with smaller ports that are successful. In one case, I actually heard the system in question. In the others, I had to rely on reports of others. I would guess that a 25% area reduction would still produce acceptable results, but I have no idea just what area would be considered optimum.

Considering your last question, I'd say that the speaker location on a short transmission line is as important as that of any other loudspeaker system. The designer must make this decision. Every designer has his preference as to where the speaker should be placed to best create the desired effect. I developed my preferences many years ago, when I first heard Roy Allison's loudspeaker systems. Actually, the vertically facing speaker is my second preferred position, but it is the only one that can be used with a two-way system because of the high crossover frequency.

In my opinion, the system that gives the most natural bass reproduction is one in which the speaker is close to the rear wall and floor, with the speaker baffle's face jutting out at a right angle from the rear wall. In other words, the speaker would be on the lower side of the enclosure, as close as possible to the floor and the rear wall, and well away from room corners. This, of course, was also worked out by Roy Allison. This woofer should be crossed over to a midrange speaker at, approximately, 300-400Hz.

The center of the midrange speaker should be at least three-quarters of a wavelength above the floor. For 300Hz, that would be 33.9". For 400Hz, the distance would be about 25.5". I got this in-

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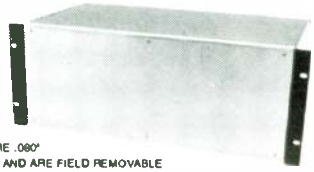

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formation from a paper by Allison entitled "The Influence of Room Boundaries on Loudspeaker Output" (*JAES*, Vol. 22, No. 5, June 1974). Perhaps it was printed in one of the *JAES* anthologies, available from Old Colony.

The woofer's vertical placement at the top of my lines seems to smooth things a bit in the upper bass and lower midrange. It also seems to give a feeling of spaciousness and solidity which are lacking when the speaker is facing forward. The assumptions you make at the end of your letter regarding this may be correct. I would never place a speaker in any position just for the sake of simplicity of construction.

I don't know how to help you time align your tweeter. One possibility is Motorola's 2" × 6" piezo horn, sold by Radio Shack as item #40-1379. It uses a different element than the other Motorola piezo speakers, and appears to have considerably less distortion. It should be installed with the long axis in a vertical position, although it is usually installed incorrectly.

I once improved one by coating it with a mixture of a flexible patching and caulking compound called Shur-Stik 100 textured, trowel-on. I placed some in a paper coffee cup and added dry sand for mass, and to make it stiffer and more manageable to use. I spread it on about ¼" thick with a putty knife, all over the back of the horn and throat, and on the back of the driver element housing. At that thickness, it might take several days to dry. Be careful that the coating won't interfere with the normal horn mounting. This material damps and stiffens the horn.

I parallel the horn terminals with an 8Ω resistor, which makes an almost perfect termination for a textbook crossover. It can be crossed over as low as 2kHz, but I generally use it at higher frequencies. I have yet to mount this tweeter in an enclosure, but I have bread boarded it with many speakers. I remain quite surprised at how well it performs. With this horn mounted on the front face of a Microline, or a short line type enclosure, the driving element might be quite close to the upward mounted woofer center.

I hope there is something in this lengthy letter that may be of help to you. If not, please feel free to write again.

John Cockroft
Sunnyvale, CA 94987

HYPERBOLIC RESISTANCE

In "Bi-Amping the Sapphire II Sub-I System" (*SB* 3/92, p. 24), Gary Galo does a good job of explaining the issues of damping factor as it relates to cable resistance. Unfortunately, he unwittingly propagates an ongoing myth regarding cable resistance. That is the idea that the single largest contributor to series resistance is not the amplifier output, cable, or crossover series resistances, but simply the voice coil's DC resistance, which is often orders of magnitude greater than all the other losses combined. (In fact, it represents the most significant source of losses of any kind in most speaker systems, whether electrical, mechanical or acoustical.)

The damping factor issue implies that lowering damping factor by lowering the series resistance (from 0.1Ω to 0.01Ω, for example) will result in a related qualitative improvement in the sound, specifically in better controlled, tighter bass. The example Gary describes results in reducing an amplifier's damping factor from some theoretical of 400 to 56 with the addition of about 0.12Ω of cable resistance, thus "reducing a high performance amplifier to rubble."

Enthusiastic hyperbole aside (and, for the record, they are not Gary's assertions alone, but have been around for decades), the assertions make predictions which are testable, either in theory or by experimentation. Let's begin with the theory.

The assertion is made that reduced damping factor results in looser, more poorly controlled bass response from dynamic, direct radiator loudspeakers. The measure of bass response "looseness" is its total Q at resonance: Q_{TS}. The system's Q_{TS} is the result of the parallel mechanical and electrical losses. As I stated above (and which can be demonstrated by reviewing the vast majority of driver and system specifications), the predominating loss is electrical in nature and is represented by the electrical Q at resonance: Q_{ES}. Relatively small changes in it will affect the Q_{TS} more than similar changes in the Q_{MS}, which represents the mechanical losses. This is good for the damping factor proponents.

Q_{ES} for a closed box system is calculated as follows:[1]

$$Q_{EC} = \frac{2\pi F_C R_E M_{MS}}{B^2l^2}$$

where:
F_C is the system resonance
M_{MS} is the effective moving mass of the driver
Bl is magnet/voice coil transduction

The most important parameter is R_E, the DC resistance. Normally, this symbol is taken to mean the voice coil's DC resistance. Small very explicitly points out, however, that this term must also include "any significant resistance present in connecting leads and crossover inductors."

Without going through the relatively simple algebraic reduction needed, we can separate the source resistance (R_G) and the voice coil resistance (R_E) and look at their separate effects on the system's electrical Q. Again from Small:

$$Q_E = Q_{EC} \frac{R_G + R_E}{R_E}$$

And the total Q is:

World Radio History

$$Q_{TC} = \frac{Q_{MC} \, Q_E}{Q_{MC} + Q_E}$$

We now have a quantitative basis for analyzing the effect of cable and crossover source resistance on the system response.

Let's look at a typical sealed-box system with a Q_{TC} of about 0.707 (giving maximally flat response, with no peak in the low frequency response curve) and a voice coil resistance of 7Ω. This is based on a Q_{EC} of 0.85 and a Q_{MC} of 4.2, which are typical values for rubber surround, well-dampened drivers that might be used in a high quality closed-box system. We will get Q_{TC} with perfect cables, and our amplifier with its damping factor of 400. When we add our 0.12Ω of cable resistance, we get:

$$Q_E = 0.85 \, \frac{0.12 + 7}{7}$$

We have raised the electrical Q from 0.85 to 0.865; the resulting system Q is raised from 0.707 to 0.717. The response consequences of this are also easily predictable. Our original system, as stated above, was maximally flat. Now, with its elevated Q, the bass exhibits a peak described by the following relation:

$$|X(jw)|_{MAX} = \left[\frac{Q_{TC}^4}{Q_{TC}^2 - 0.25} \right]^{1/2}$$

The result is a peak at resonance about 0.004dB high. I submit that such a peak might be relegated to the realm of the insignificant without much argument.

We can counter with several rebuttals, though. First, not all systems are closed-box; reflex systems, being more complex, are more sensitive to these sorts of parameter variations. The effect will be more complex than a simple increase in the peak amplitude at resonance. A shift in the driver Q in the range of about 2% due to changes in source resistance (or damping factor) is far less than the normal production tolerances for other factors such as mass, compliance, and the like.

Even if we select our drivers to have precisely the right values (and I challenge anyone to realistically measure these quantities to better tolerances than 2%), the value changes due to normal fluctuations in temperature, humidity, and aging overshadow those due to the source resistance values of Gary's range. (Paper cone drivers, for example, can readily change their mass by 10% simply by absorbing and releasing moisture over the normal humidity ranges found in typical American homes with central heating.) Even the normal manufacturing variations in voice coil resistance are greater than the values discussed here.

A second rebuttal is found in the statement, "but I can hear a clear and obvious difference." The answer is simply that

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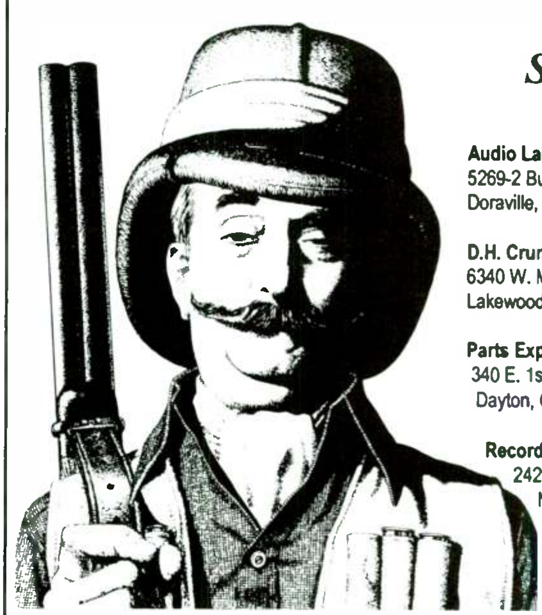

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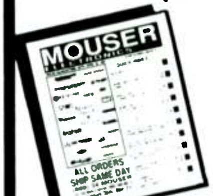

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if the assertion is true, it is not due to the mechanism claimed (damping factor), because it does not have the effect claimed. The assertion is flawed in that the effect heard, if real, occurs among a noisy background of myriad other possible causative agents, few if any of which are sufficiently controlled (or even understood) to be eliminated.

I do not believe the damping factor issue is as important as Gary and others claim it to be, at least not for the reasons asserted, as the predictions of these assertions do not support the original premise. There may be audible consequences to changes in cable resistance; that assertion remains unproven and, to a degree, unchallenged. If the effects are real, we must search for another explanation.

Dick Pierce
Pepperell, MA 01463

REFERENCES

Small, R.H., "Direct Radiator Loudspeaker System Analysis," *JAES*, Vol. 20, No. 5, June 1972; "Closed Box Loudspeaker Systems, Part I: Analysis," Vol. 20, No. 10, December 1972; "Closed Box Loudspeaker Systems, Part II: Synthesis," Vol. 21, No. 1, January 1973.

A VISIT FROM DR. WHO

On page 59 of *SB* 2/92, Music Interface Technologies claims to be making a "power line treatment" device. Instead, they appear to have stumbled upon a *time machine*! Examine the "not this" graph: if this graph is from a conventional oscilloscope CRT (voltage versus time), there are numerous points where time is moving *backward*!

Think of the astounding implications: time travel, reversal of the aging process, being able to see Paul Klipsch as a boy, building his first speaker system. Actually, considering the claims made by some advertisers about their products, this is rather mundane.

John W. Hardy
Evanston, IL 60202

Sallie Reynolds of MIT replies:

We weren't aiming at the redoubtable Mr. Klipsch, but at the great Edison himself. Think what we might learn from him!

Actually, of course, the graph in that ad is just an artist's rendition of a noisy power line. Our new ads will give real performance graphs, which we probably should have used to begin with, particularly for *SB*'s technically sophisticated readers. While the MIT Z-Stabilizer won't take you back in time, it will certainly transport you closer to the original musical event.

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Dipole Woofer

continued from page 13

attributed to Sumo in "Technology Watch" by Peter Muxlow. I ran to the *Stereophile* show in L.A. to confer with the nice folks at Sumo, only to find out that the Sumo Aria is no longer in production. Furthermore, the patent is actually owned by Museatex in Calgary, Canada. I quickly contacted Kurien Jacob, president of Museatex, who graciously consented to the publication of this article (although any commercial production of the "Spandex woofer" will require a lawyer). Their design is different, though, in that it is a traveling wave driver (such as a Walsh) while mine is more a soft piston.

Hi-Fi Room

continued from page 52

I achieved my primary objectives. I constructed a traditional rectangular listening room sized for maximum diffusion and minimum resonances. I treated the room's surfaces to control diffusion, RT_{60}, and ITDG. I also built the proposed equipment storage room adjacent to the listening area.

The amount of time and effort may not have been justified had I not noted a dramatic difference in the room's sonic character. The sound was more spacious, and the illusion of a much larger listening space was stunning. Inner details and low-level resolution were clearly audible. Stereo imaging took on a new quality. Instruments were pinpointed in space without any wavering. I was no longer confined to the "X marks the spot" listening position, and as I moved about, I noticed little difference in stereo imaging. Was it worth it? You bet it was!

Black Dahlia

continued from page 63

cle Dick stated that damping the tweeter resonances didn't change the measured frequency response.

My complaints about the upper midrange seem to parallel Dick's reactions to the first prototype, before final voicing. Beginning on page 119 of the *Stereophile* article, he stated that he was "still bothered by an imbalance between the lower and upper mids. The presentation was too polite. Lesley's voice via the Lesley test was slanted toward the lower registers; a little dark and lackluster compared with the real thing." As my review points out, I tried various loudspeaker angles, including Dick's recommended one, but none of them solved the tonal balance problem. I still believe that the substitution of the unmodified MB tweeter is at least partly responsible for the tonal balance problems.

Thunder Box

continued from page 69

what program doesn't? It is an excellent place to catalog driver parameters. The color graphics are attractive and easy to read. I especially like the SPL/Excursion graph feature, as I don't presently have the equations to put them on my spreadsheets. Also, I learned some things from these graphs that I had not considered in past designs. The program takes up only 300K of RAM, so it ought to run on just about any PC. If you are just getting started as a speaker builder, you may want to consider it.

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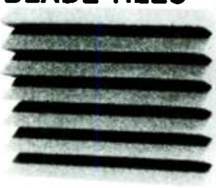

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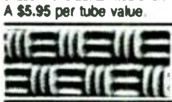

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New fiberglass horns, famous maker copies from the 70s, 1" and 2" throats, 300Hz, 500Hz, 800Hz, and 1200Hz cutoffs, threaded and bolt on driver mounts, $15 to $40 each. Jim Sanford, PO Box 222, LaConner, WA 98257, (206) 466-5161.

Dynaudio 21W54, $130/pair plus shipping; Shadow electronics crossover, 150Hz, $200 plus shipping. Carl, (916) 967-1065, CA.

HP5450A digital oscilloscope, 100mHz, bandwith, 10M samples/second, 2+2 channels, IEEE-488, fully programmable, includes Thinkjet printer for one button hard copy, like new with all probes, cables, manuals, front cover, pouch, list $3,990, sell $2,990/BO. Doug Pocius, (408) 338-9113.

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Tektronics type 130 L-C meter with manual, $60; Hewlett Packard 5325B universal counter, $100/pair; EV X36 crossovers, $20/pair; PR.8Ω, EV sentry IV B horn system, three-way crossovers, $50; Audax PR17HR37TSM 8Ω mid, new, $20; Focal 7N313 mids, $100/pair; D28-AF, $50/pair; REK-O-Cut R-320A auto turntable, S-220 tonearm, $75. Jim, (708) 425-6719.

Apature Digital interconnects, 3' and 6', retail $200, $85; Phase Linear 4000 series II preamp, $175; Earthquake MD-5, cast frame, 5" mids, never used, $75/pair; one Phillips AD0162/T8 tweeter $10 or one 5060/SQ8 mid in trade. Andy, (414) 458-2057, 5-8 p.m. CST.

Free 10" woofers; Dynaudio 21W54, 9" woofers, needs work, B/O; D21, $15; D52, $25; Chassis, aluminum BUD 17" × 10" × 3", $20; Caps, 100W v dc, 12,000μF, 2/$15; motherboard, 486d × 33, B/N, $175. Harold, (716) 624-9159

Altec 604 coaxial speakers, ferrite with Mantaray horn, $500/pair; Yamaha EQ stereo, 31-band, balanced rackmount, $300; Pioneer EQ stereo, 10-band, $125; Pioneer dynamic range expander, $75; Akai AM-FM, $60; JBL control 1 monitor speakers, $150/pair; wooden sectoral horns for JBL 1" drivers, $125/pair. David, (914) 688-5024.

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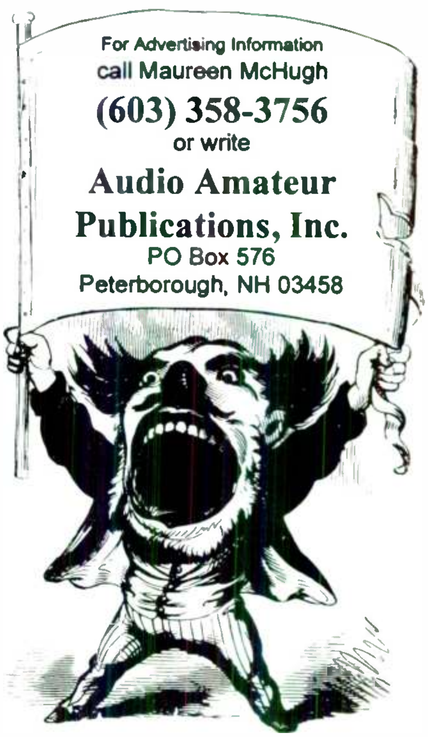
Hewlett Packard 300C distortion analyzer, $150; SpeakerLab three-way K-Horn, $250; AR1W, $105; EV Aristocrat copy with EV 12TRXB coaxial, $105; KLH model 7, $105; Cerwin-Vega eight channel mixer, $290; DBX 3BX, $150; Dynaco PAT4, $75; FM3, $75. Marshall, (310) 559-3947, FAX (310) 836-3763.

30" subwoofer EV-30W; free air res. 18Hz; biggest most efficient woofer ever made; ask for published article on enclosure and EV data; $250 plus shipping including freight panel. Audio Monster, Charles Graham, 4 Fieldwood Dr., Bedford Hills, NY 10507, (914) 666-4523.

Gold Ribbons 3.0, $275/pair; Dynaudio D21AF tweeters, $45/pair; Dynaudio D52 dome midrange, $60/pair; Dynaudio 30W-54 woofer, $125/pair; Peerless TP1-65F/8 6" mid/woofer, $10/pair. John, (901) 756-6831.

Audio Research (Magnapan) Magnaplanar Tympani 1-D loudspeakers, $699/pair; Audio Concepts (Shadow Engineering) two-way electronics crossover, $199; Ribbon speaker system oak (three Strathearns per side), $999/pair; ADS 2002 bi-amplified speaker system, needs one woofer repaired, $179; 2001 speaker system cases, no grilles, 1" dome tweeters, model 314, 4", 4Ω replacement woofers, $39/each. Michael Marks, 2334 Morgan Lane, Dunn Loring, VA 22027, (703) 641-5824.

DBX model DX5 compact disc player includes impact restoration and ambience circuitry and variable compressor, excellent condition, $300. David Schmidt, 2601 W. Monterey Way, Phoenix, AZ 85017, (602) 252-3210.



World Radio History

Focal Aria 10 subs with Vieta L-100Y and crossovers, $300/pair plus freight; Focal 6V013L, four, mid bass, $75/pair; Focal T90T102 tweeters, $60/pair. Ed Nichols, (817) 244-5763.

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Need owner's manual, schematics, and service info for Pioneer SX-1980 receiver. Also, to buy Advent speakers known as *Large Advent*, walnut. David Honeycutt, 908 Applewood Ave., Kannapolis, NC 28081, (704) 933-4396.

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

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

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

THE 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! Toobers, Tranzzeestors, vinyl canyons or digital dots. No matter what your level of interest, experience, or preferences, you are welcome. Contact CAAS at (518) 756-9894 (leave message), or write CAAS, PO Box 144, Hannacroix, NY 12087. See you soon!

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

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

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

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.

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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 bi-annual 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.

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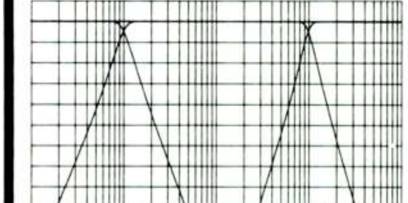

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World Radio History

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

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

THE HI-FI CLUB of Cape Town in South Africa sends a monthly-newsletter to its members and world-wide subscribers. To receive an evaluation copy of our current newsletter, write to: PO Box 18262, Wynberg 7824, South Africa. We'll be very pleased to hear from you.

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

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

SPEAKER BUILDERS/AUDIOPHILES in the Milwaukee, WI area. I am a speaker builder with test gear looking to join or form an audio club. Anyone interested contact, Kirk Rontti, (414) 355-7509 leave message.

LOS ANGELES AREA ARIA AND SWAN Loudspeakers Users Group. If you have built or plan to build any of the Aria or Swan loudspeakers and would like to meet for listening sessions or have any questions or modifications that you would like to share, please call Geoffrey, (213) 965-9173 or Edward, (310) 395-5196.

THE PRAIRIE STATE AUDIO CONSTRUCTION SOCIETY. (PSACS) meets every other month. Meetings feature audio construction, design, and analyses, blind listening tests, equipment clinics, auto-sound, lectures from manufacturers and reviewers. PSACS, PO Box 482, Cary, IL 60013, call Tom, (708) 248-3377 days, (708) 516-0170 eves.

HI-FI COLLECTOR/HOBBYIST seeks "living letters"/ audio penpals from other states to correspond via reel-to-reel tape. Non-commercial strictly; make up short monologues on subjects from vintage technology, with regional FM excerpts for background or equipment samples, from personal tales of yard sales scavaging success, repair/restoration tactics and strategies, favorite service centers, general ways to handle the burgeoning obsession with arcane hi-fi gear. All correspondence on 3", 5", 7" reels (¼" tape) will be cheerfully answered and tapes returned via parcel post. James Addison, 171 Hartford Rd., Apt. #7, New Britain, CT 06053.

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.

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THE WESTERN NEW YORK Audio Society is an active, long established club located in the Buffalo area. We issue a newsletter and hold meetings the first Tuesday of every month. Our meetings attract many prominent manufacturers of audio related equipment. We are involved in all facets of audio—from building/ modifying to exposure to the newest high-end gear, and the chance to hear more types of music. For information regarding our society, please write to WNY Audio Society, PO Box 312, N. Tonawanda, NY 14120.

Ad Index

World Radio History

Moran in the Market

OLD ENCOUNTERS

By David R. Moran

In the Beginning

The consumer hi-fi industry began, as most loudspeaker mavens know, in the early '50s, on the night when adult-education audio teacher Edgar Villchur explained his theory of sealed-box woofer mechanics to a student who happened to be a woodworker/cabinetmaker named Henry Kloss. When designed in this fashion, loudspeakers no longer had to be the size of walk-in closets, as was the case then. They could be small and would still deliver accurate bass.

"Henry's smart, so of course he immediately got it," as Villchur stated in an interview with me a few years ago. The two young men founded Acoustic Research; soon enough, Kloss set out on his own to found KLH ("he was clearly more presidential than vice-presidential material," Villchur points out); an industry of feasible-size home systems was born; and the rest is— well, you know what the rest is.

Litany

There were Advent, Kloss's success after KLH and before today's Cambridge SoundWorks; Allison Acoustics, founded by Villchur's junior colleague Roy Allison; Boston Acoustics, founded by Kloss junior colleague Andy Petite. Peripherally there was Snell Acoustics, and more peripherally Scott, EPI, Cizek, dbx, Apogee, Atlantic, and on and on. Hardly at the periphery, of course, there was, finally, Bose, founded by Amar Bose.

Acoustical and speaker designs aside, each of these companies had or has its own marketing philosophy and style, and its own attitudes toward consumers and targeted group(s). Most of these companies had their moments of success in the frequently nonmeritocratic loudspeaker world, but only two can be said to have prevailed (about which more below).

The old AR, and Allison likewise in the recent decades, aimed foremost to please the end-user consumer. Ads were scholarly, and the companies relied in part on high ratings from *Consumer Reports* (e.g.) to pull the serious customer into stores. KLH and Advent were rather more dealer-oriented—dealers being a company's first customers—and relied on good profit margins and the salesman to help push the product out the door.

With equally high-quality product but less emphasis on sheer value, Snell went high-end. Adhering closely to the high-value solid-product philosophy, Cambridge SoundWorks has successfully capitalized on the strong and widespread (and seriously underappreciated) consumer dislike and distrust of audio retailers by selling direct to its market.

Boston Acoustics, these days the last of the successful independents, decided from the outset to run itself like a real business, and used a combination of some of the above corporate styles (except for going direct). This discipline of BA's represents quite a savvy—and utterly novel—idea for the nonJapanese audio world.

In a positively shocking, even revolutionary idea for nonJapanese audio, Bose Corporation decided from the outset to run itself like a hard big business, and consequently the company has had unprecedentedly large, and continuing, commercial success, perhaps an order of magnitude larger in sales than any of these other Boston-area companies, and also larger than all of them combined.

Keeping On Going

Is the elder generation in these companies done with us yet? Evidently not. Although near or even past what used to be considered retirement age, all of these venerable founders persevere. All think up products and product lines, but all are active at the detail level as well. Bose stays directly involved, down to reviewing manuals, ads, and product literature. Kloss still does driver selection and crossover design. Allison does that and more: he designs his own drivers, too, and sometimes finds time to publish research articles. A few months ago he had to fold his eponymous company, after financial dealings with new Korean backers proved unsuccessful in those straitening economic times.

The real news story in this development was that, hearing of the failure and dismayed that such worthy loudspeaker-design philosophies and attitudes were in such jeopardy, Edgar Villchur, out of the business for over 25 years and himself a decade and more on the other side of the retirement milestone, immediately offered to help, both financially and in advisory ways. So now is born RDL Acoustics (Room-Designed Loudspeakers, 26 Pearl St. #15, Bellingham, MA 02019, (800) 227-0390, (508) 966-2200), the Boston area's brand-newest loudspeaker company even as it includes the most senior player. And RDL is also going to go direct—mail order, no dealers.

As one who championed several of the Allison designs over the years, in particular their solid upper bass (the rock 'n' roll octaves) and their spacious treble (the violin octaves), I wish RDL well and, for once, success.

Archaeology

This brief history of local audio time has not been prompted (to tell the whole truth) by the birth of RDL, or not only by it. A while ago a friend called to say he had come across a pair of brand-new, unused, unpacked KLH 6 loudspeakers, and asked whether I wanted to take a look at them. For an audio historian and speaker reviewer, it was an irresistible offer to glimpse the influential past. Indeed, for a while in my college days I had owned a pair.

The Model 6 was KLH's first large success, the first to take goodly market share from AR, the product that widely established the company's name among dealers and customers. With a nominally 10″ woofer crossed over around 1.5–2kHz to Kloss's first ringed-dome tweeter (doughnutlike, but with the hole filled with a doughnut hole) in a slightly less than 1′ × 1′ × 2′ cabinet, the KLH 6 retailed in the low $100s ($134 in walnut, Kloss

Continued on page 86

PREVIEW
Glass Audio

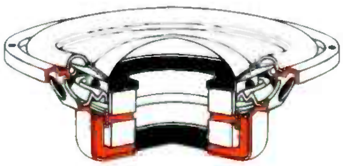
Issue 1, 1993

- 40W Class A Triode Amp
- Overlooked Tube Bargains
- Tubesaurus Rex

World Radio History

MW142

DPC Cone Double Magnet 5″ Woofer



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

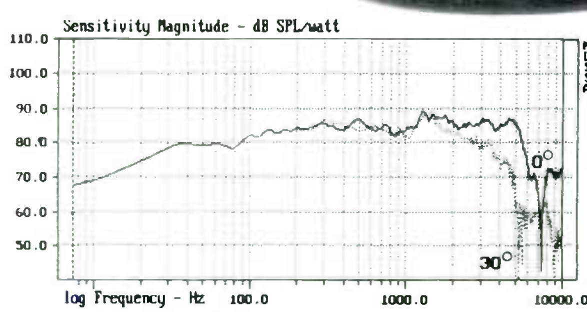
Vented double magnet system with steel chassis — damped polymer composite cone — rubber surround — smooth response to upper limit of 5 Khz with excellent on and off axis response and good roll off.

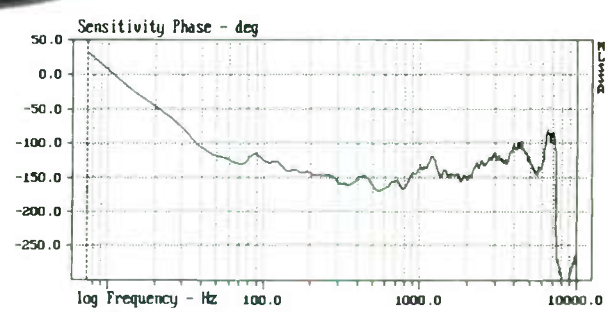
High power handling emanates from this unique design, resulting in a very impressive small bass/mid or mid range unit.

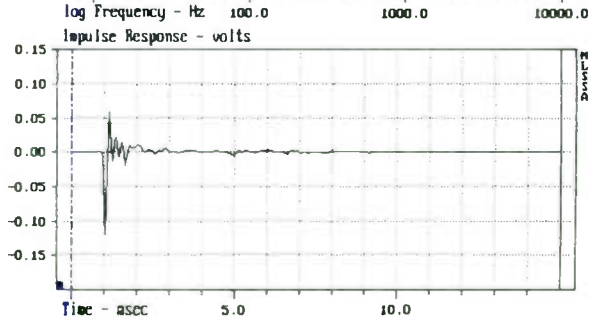
Specification

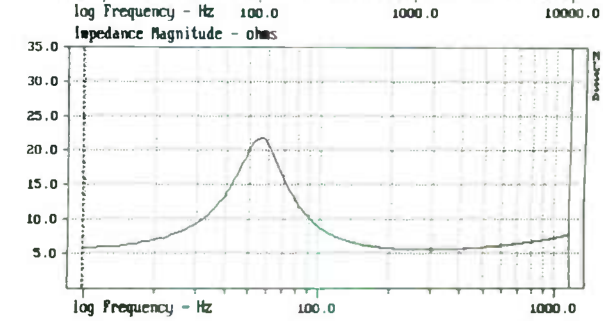
Overall Dimensions	Ø 142mm(5.5″) x 52mm(2″)
Nominal Power Handling (Din)	150 W
Transient Power — 10ms	1000 W
Voice Coil Diameter	75mm(3″)
Voice Coil Type / Former	Hexatech Aluminium
Frequency Response	48-5000 Hz
FS — Resonant Frequency	52 Hz
Sensitivity 1W/1M	86 dB
Z — Nominal Impedance	8 ohms
RE — DC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

Specifications given are as after 24 hours of running.









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Continued from page 84
recalls, and just over $100 in smooth unfinished birch, as my friend's units were).

While for its time it sounded pretty good, today most of us would find it dull and unextended up top (albeit smooth), and with a rough upper midrange too. But sited within a bookcase it produced very solid and extended bass and lower midrange. On the floor it could turn boomy, yet if you tried to fix that by putting it on a low stand, the upper bass and lower midrange typically would exhibit—guess what?—a thinning dip due to suboptimal boundary augmentation. (Some things never change.)

The KLH 6 was the direct ancestor of the hugely popular Large Advent loudspeaker, a half-dozen or so years later, which was another two-way design from Kloss, this time with a nominally 9″ woofer and his second ringed-dome tweeter. To my ear that system was quite a bit better than the KLH 6. If I can find an Advent in good condition (and I think I know where I can), I will give a follow-up report in a future column.

Measurement Time

My friend was about to sell his units to a happy buyer who was not a little surprised to find a brand-new, quarter-century-old, semi-famous loudspeaker in almost like-new condition. So I was not permitted time to do a range of measurements, either in-room, or outdoors to look at its horizontal radiation, and even less time to listen. What I did, then, was just close-mike it for 30 seconds, as usual using pink noise, a corrected AKG mike, with the results continuously averaged, ⅓-octave-analyzed and displayed on my dbx RTA-1.

Figure 1 shows the respectable results with one of the units. The other had a malfunctioning tweeter (possibly the crossover was dried out and kaput, too, but we did not investigate); the two woofers however were still a match within a decibel. Care is required in interpretation of these responses, since close-miking tells absolutely nothing about radiation pattern above a few hundred hertz and nothing about driver blending at any listening distance.

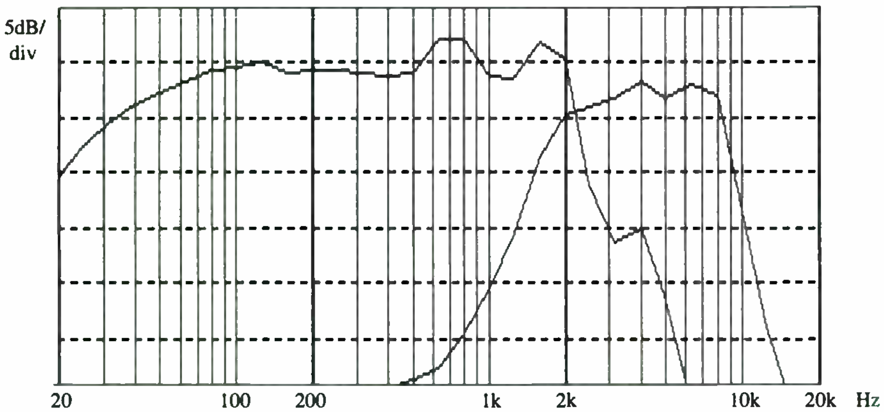

FIGURE 1: Close-miked measurements of a good-condition KLH model 6 two-way loudspeaker, manufactured over a quarter-century ago. Observe the relative lower tweeter level, along with its top-octave sharp dive; the unusually gradual (i.e., nontextbook) woofer roll-off; and the incipient but rather well-behaved roughness of the woofer in the two 500–2kHz octaves. (Note also that such miking as this tells nothing about a system's radiation pattern and thus little about its sound in a room.)

First, observe the fine pistonic behavior (flatness) of the woofer from below 80Hz to above 500Hz, crucial octaves. This is completely typical today but was not always the case then. (AR and KLH really defined how most of the world learned to hear proper, accurate midrange and below—assuming smooth boundary augmentation, that is, as in a bookcase surrounded by books.) The roll-off below 80Hz is oddly and strikingly gradual, nothing like the textbook curve for sealed boxes. Of course, Villchur and Kloss were the first to quantify bass performance as a function of the relationships among enclosure size, magnet strength, woofer diameter, and efficiency (the KLH 6 did not sound as though it had high sensitivity).

Some ripple and breakup appear at the top of the woofer range, nothing too terrible, and its response is extended. The off-axis output is going to be notably and audibly reduced as the wide-diameter driver beams, which will likely mean a valley in the total power heard in the room in the increasingly ear-sensitive octaves above 500Hz and on to 2kHz.

Certainly the KLH 6 was (and still is, as evinced at my brief listening session) capable of sounding somewhat hollow, like many full-range two-ways unless you use them as desktop monitors. Worse, the upper-midrange portion of sonic images, formed in part by the rolled off reflections, will likely tend to be narrower than the portions just below (midrange and lower midrange, which are more "equi-omni") and just above (where the tweeter likely comes flaring in).

Tweeter Talk

Some goals of that Kloss tweeter design were for it to be big enough to reach down below 2kHz and handle all the musical power that's there, and also for the outer doughnut ring to "decouple" somewhat from the smaller-diameter (approximately ¾″ or so) inner dome, letting the latter achieve good dispersion up high. I cannot say what the radiation pattern of this tweeter might be; it certainly doesn't (and didn't) sound as though it had great dispersion and airiness.

It has nothing on the Allison tweeter (but then almost no other tweeter is comparable either). How it might do against today's ubiquitous 1″ domes (a Villchur invention) is hard to predict, and I find that they too sound uniformly constricted and airless, unless they're mounted on a very small baffle, B&W-style. (See *SB* 5/92, *Fig. 2*, p. 75, and *Fig. 4*, p. 76.)

The KLH 6 tweeter is mounted on a rather wide baffle, furthermore, which won't do any favors for any inherent spaciousness it might have in any case. Kloss's old Advent filled-doughnut-style tweeter, successor to this one, sounded to me as though it yielded fairly impressive dispersion, so perhaps it did achieve some inner-dome decoupling. Otherwise I am generally skeptical of the claim. My measurements of the similarly designed (large-diameter, "double-ring") OEM tweeter used in the Cambridge SoundWorks Ensemble small-baffle satellite, and its sound, lead me to think no decoupling whatsoever is involved (*SB* 5/91, *Fig. 3*, p. 92).

In any event, this particular KLH 6 tweeter dives above 8kHz, as shown, and appears furthermore to be run some 3dB lower in level than the woofer. (So maybe its off-axis flare-in is not so bad after all.) Their radiation pattern and general smoothness apart, today's tweeters are run much hotter than this by loudspeaker designers. No one would currently design a modern speaker with the downward-sloping overall spectral timbre of this generation of loudspeakers: octave-to-octave tonal balance, Kloss liked to call it in ads.

Everything is much brighter these days. I am not necessarily clucking about this; I enjoy playback clarity, especially when it also is spacious and smooth. But it's no wonder that typical closely and brightly miked recordings were deemed harsh (and the digital technology was and still is wrongly blamed) when heard through the transparent window of the CD record/play chain over modern speakers a decade ago. It was a sudden, upward-treble imbalance: no more LP roll-off, and—for better or worse—no more KLH 6-type loudspeakers.

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heavy gauge ribbon wire and
ented pole piece allows
ximum heat dispersion to keep
voice coil cool and increase
ver handling. The special
ble reinforced steel basket
forms as well a die cast, but at a fraction of the cost. Power handling: 250
ts RMS, 350 watts maximum. Resonant frequency: 48.5 Hz. Frequency
ponse: 30-3,000 Hz. SPL= 88 dB 1W/1M. 2" voice coil. 50 oz. magnet.
hm impedance. VAS= .5 cu ft. QTS= .39, QMS= 13.4, QES= .41.
ensions: A= 8-1/8", B= 5-1/2", C= 2-3/4", D= 1-1/2". Net weight: 9 lbs.

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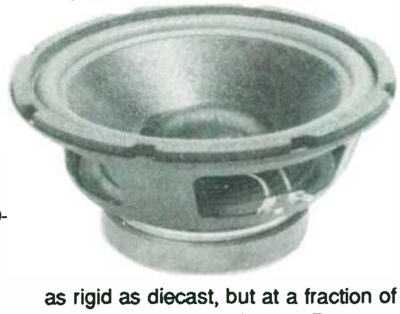

High power woofer featuring a Kevlar reinforced paper cone and coated with a polymer resin for added stiffness. A Kapton voice coil former is edgewound with heavy gauge ribbon wire and a vented pole piece allows for maximum heat dispersion to keep the voice coil cool and increase power handling. The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

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