A SPEAKER PILGRIM'S EPIC: FROM HORNS TO DIPOLES

THREE: 1996

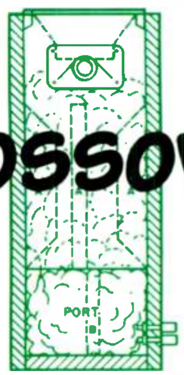
US$7.00

CANADA $8.00

Speaker Builder

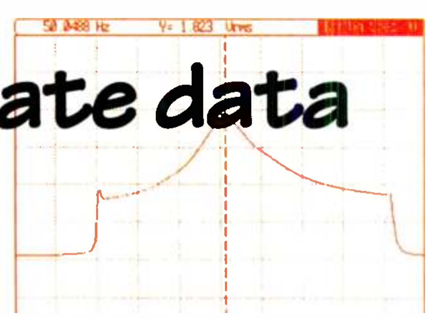
THE LOUDSPEAKER JOURNAL

Build this Satellite-Sub Combo



Crossovering the Squatline

All you ever wanted to know about Capacitors



Getting more accurate data on those drivers

BOXES: BETTER ASSEMBLY METHODS

Critics Judge InfiniCap

(bulletin posted on The Audiophile Network, to one and all)

Note: Mr. Blackburn's credentials as a sober critic are impressive. An engineer for a worldwide company, he is involved in the development and ongoing support of advanced digital imaging and storage systems. His articles have been published by Stereophile (he satirized pseudo-physics in high end audio), The Audiophile Voice (equipment and music reviews), and The Sensible Sound (music reviews). He is a regular contributor to Positive Feedback.

Msg#:19460 09-11-95 08:46:01 From: Doug Blackburn

I found a great sounding new cap — unbelievable sounding actually. I used to think [a highly regarded multiple section film and foil capacitor*] sounded pretty good, but ***these*** caps are unreal. I tried these caps out in various locations in some of my equipment — power supply bypasses, in the audio signal path, etc. ***Unreal*** sound quality. These make [a highly regarded multiple section film and foil capacitor] sound ***broken!*** I'm ***not kidding!*** The difference is ***very*** large.

These are called InfiniCap. They are from the same people who came up with WonderCaps quite a few years back. These sound ***nothing*** like WonderCaps — far far far better. They aren't cheap, but they don't set new record high prices either.

These caps are well worth the price/performance. I look forward to many months of happy experimenting with these caps in other components.

* The original posting explicitly states this capacitor's name. The above excerpt quotes the first, second, and last paragraphs in their entirety.

"The Audiophile Network is the granddaddy of cyberspace meeting places for audiophiles, and remains the insider's choice for audiophile information. Dataline phone #818-988-0452." — Stereophile, July 1995

Here's what high end audio manufacturers have said:

- A high end speaker manufacturer:

"InfiniCap does amazing things for our speaker! It's far better than all other audiophile capacitors. For example, compared to Hovland MusiCap, InfiniCap is more transparent, faster, more dynamic, and more open, with better separation of instruments and their harmonics, better inner detail, better stereo imaging with a wider stage — and bass that's richer with more weight, yet also tighter, faster, and better defined."

- A leading high end mfr of tube and solid state electronics:

"The difference compared to MultiCap is astounding! Just amazing! Night and day!"

New Wonder Solder UltraClear

For years, Wonder Solder has been the standard of the world:

"The best-known silver solder in the high-end audio community is Wonder Solder. Suffice to say, many manufacturers of high-end audio equipment use Wonder Solder." — Gary Galo, The Audio Amateur 3/94

"An audibly superior solder with superb working properties and a pleasure to use. Several audio manufacturers have reported, after listening tests using Wonder Solder, significant sonic improvements over identical components assembled with their favorite solders. Use of Wonder Solder will provide greater transparency without the glare and brightness often associated with silver bearing solders." — Michael Percy, Audio Consultant

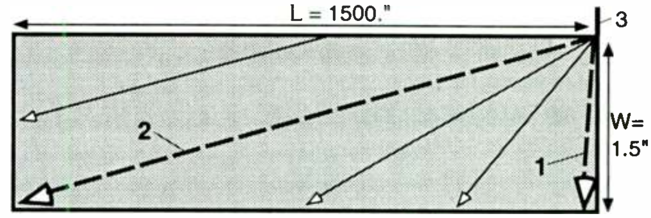
Now there's *new Wonder Solder UltraClear*™

Stunning Ultra Transparency • Clean Purity • Natural Musicality

You won't believe the sonic difference a solder can make, until you try new Wonder Solder UltraClear. For mere pennies you can solder (or reflow) a whole amp or speaker, and make it sound like one twice as expensive. Available with rosin or water soluble flux core, and in bars for tanks (we'll send rosin as standard sample).

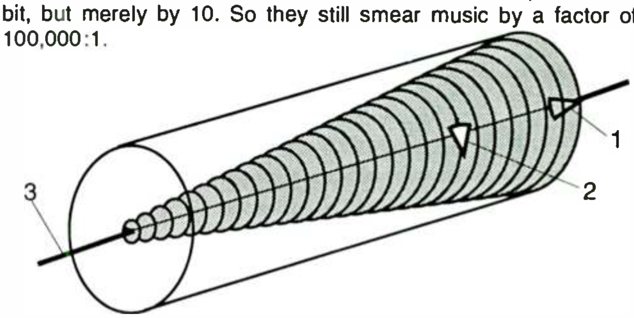
What's Wrong with Your Capacitors?

For any capacitor to work, electric charge must get from the terminal (3) to all parts of the plate. It fans out over your capacitor's plate, following the diagonal paths shown. This creates a bad problem. Path 2 can be 1000 times longer than path 1. So your music doesn't all get through your capacitor at the same time. Some music gets through quickly, via path 1, but some of the same music signal takes 1000 times longer, via path 2. This time smears your music, so it sounds fuzzy, defocussed, and veiled, and perhaps muddy, clogged, honky, or glary.



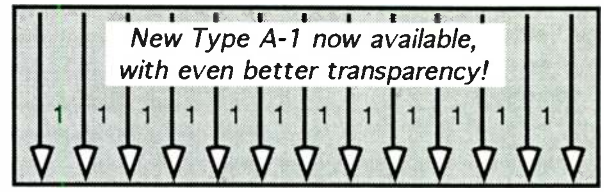
Your capacitors have another problem that's even worse. They roll up signal path 2 into a tight corkscrew coil (below). The inductance of any coil is multiplied by the number of turns squared, and there can be 1000 turns in an audio capacitor. So the inductance of path 2 can be a million times higher than straight path 1, delaying music a million times worse for some paths through the capacitor than for other paths. This capacitor actually smears music by a factor of 1,000,000:1.

Multiple capacitors with 10 sections reduce these problems a bit, but merely by 10. So they still smear music by a factor of 100,000:1.



InfiniCap *is Different!*

Only the Wonder **InfiniCap®** capacitor cures all these problems. InfiniCap's unique design (patents pend) with metal ends eliminates long, diagonal, corkscrew signal paths like path 2. InfiniCap has an **infinite number of parallel paths**, which are all like path 1, as shown below.



These signal paths are all **short**, so InfiniCap is fast. These paths are all the **same length**, so all of your music signal gets through the capacitor at the same time. These paths don't make coil turns, so they don't have drastically differing inductances.

It's like an infinity of capacitors in parallel – **InfiniCap**! That's why **InfiniCap** sounds:

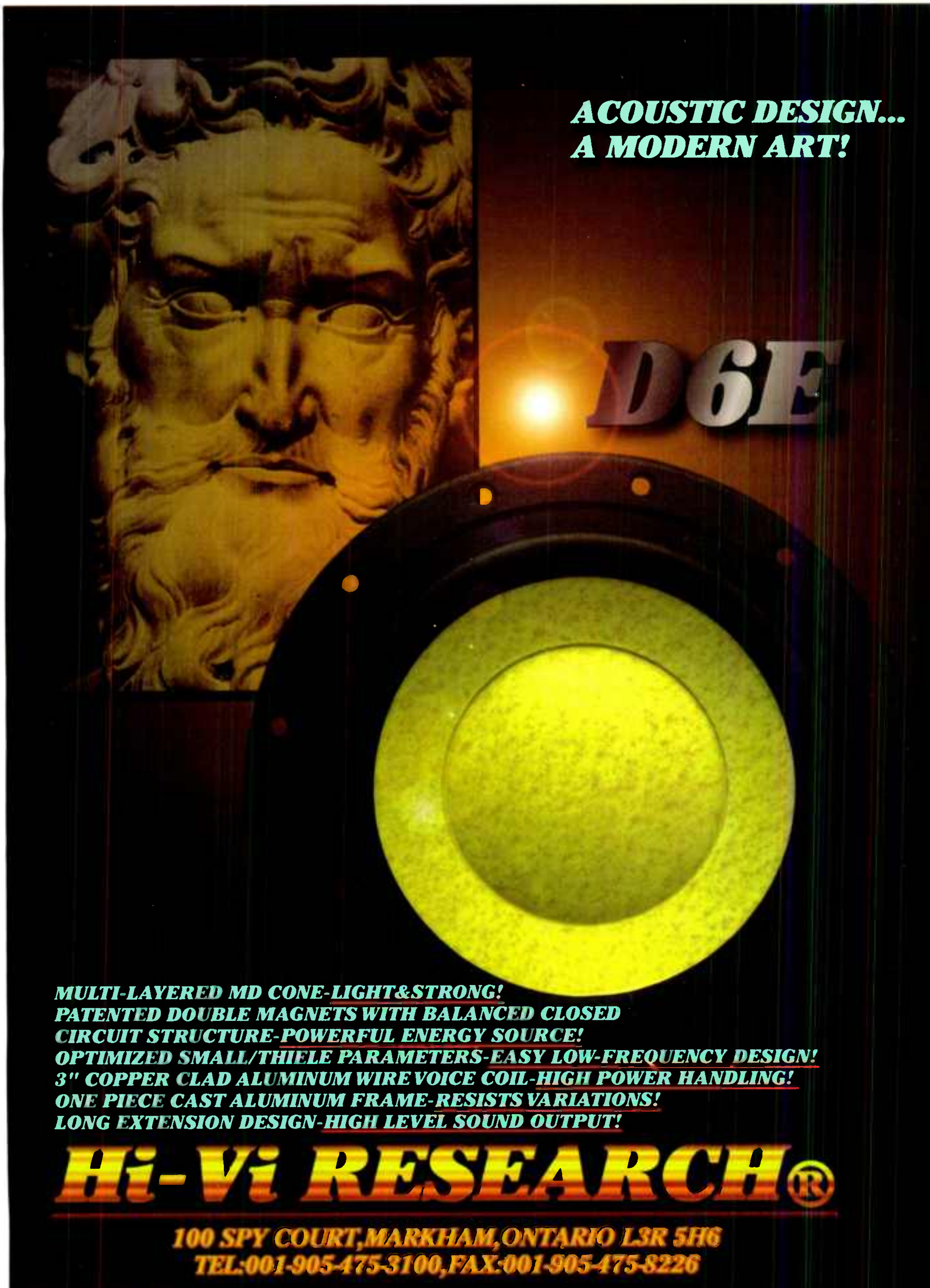
- transparent, open, and airy — instead of veiled or clogged;
- clean and pure — instead of smeared or dirty;
- clearly focussed, coherent — instead of defocussed or fuzzy;
- fast and delicate — instead of sluggish, hard, or splattered.

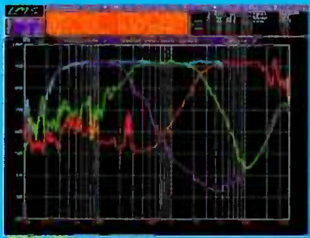
InfiniCap gives you all the music at the same time. InfiniCap reveals the subtle inner details, the magic that makes music sound real. Hear the amazing sonic difference yourself.

Free sample InfiniCap! Write: ***TRT***, 408-b Mason, Vista CA 92084

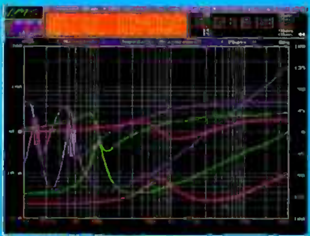
Reader Service #54

Reader Service #35 →

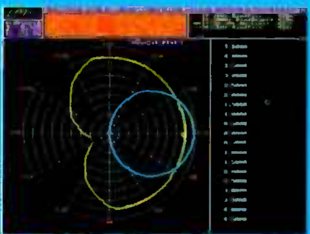

ACOUSTIC DESIGN...
A MODERN ART!
D6E
MULTI-LAYERED MD CONE-LIGHT&STRONG!
PATENTED DOUBLE MAGNETS WITH BALANCED CLOSED
CIRCUIT STRUCTURE-POWERFUL ENERGY SOURCE!
OPTIMIZED SMALL/THIELE PARAMETERS-EASY LOW-FREQUENCY DESIGN!
3" COPPER CLAD ALUMINUM WIRE VOICE COIL-HIGH POWER HANDLING!
ONE PIECE CAST ALUMINUM FRAME-RESISTS VARIATIONS!
LONG EXTENSION DESIGN-HIGH LEVEL SOUND OUTPUT!
Hi-Vi RESEARCH®
100 SPY COURT,MARKHAM,ONTARIO L3R 5H6
TEL:001-905-475-3100,FAX:001-905-475-8226



SPL Response

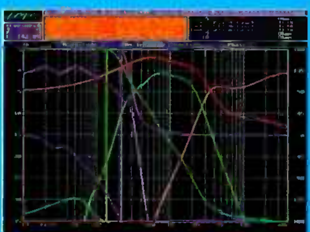


Impedance Curves

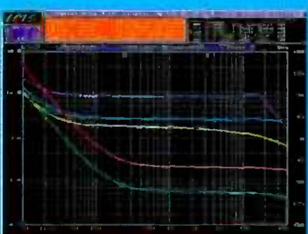


Nyquist Real/Imaginary

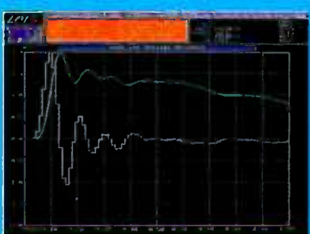
Polar SPL Response



Network Transfer Functions



Inductance/Capacitance



Impulse/Step Response

LMS Loudspeaker Measurement ~~System~~ Solution!

New! Version 3.6

At last, there is a complete and affordable analyzer system that provides quality data suitable for real electro-acoustic engineering purposes. The LMS system provides a vast array of powerful computer based features which are specifically focused on the unique requirements of loudspeaker development and QC production testing.

Whether your application is professional audio, consumer stereo, car stereo, or contract installation, LMS is the perfect tool for development and testing of loudspeaker systems.

No other measurement package today provides as many outstanding features and capabilities at such an incredible price!

System Utilities and Features

The system software provides a host of powerful utilities and processing features which enable the user to perform many complex and tedious tasks easier than ever before. Unlike most other analyzer software which is oriented towards single curve use, LMS handles multiple curve display and operations with a versatile 20 entry library database.

- ✔ Curve library system for multi-curve operations
- ✔ Macro programming of operation for QC testing
- ✔ Standard and user selectable Frequency Ranges
- ✔ Relative and Absolute PASS/FAIL Compare
- ✔ Import and Export Data to ASCII files
- ✔ Speaker Parameter Generation
- ✔ SPL/Z Combo Conversion
- ✔ Nyquist Plot Conversion
- ✔ Polar Plot Conversion
- ✔ Tail Slope Correction
- ✔ Multi-Curve Averager
- ✔ RLC Meter

Analyzer System Specifications

- ✔ Full Length IBM PC Slot Card, 8 Bit PC Slot
- ✔ Oscillator: Continuous or Gated Swept Sine Wave
- ✔ Osc Maximum Output: +16dBm (5Vrms)
- ✔ THD: 0.015%, 20Hz-20kHz
- ✔ Frequency Resolution: 200 steps/decade, Log
- ✔ Filters can track Osc frequency by any ratio
- ✔ SPL Measurement Range: 35-125 dB-SPL
- ✔ Video graphics support: VGA, EGA, CGA, HGA
- ✔ Calibrated 8mm Electret Mic with Preamp
- ✔ Mic Frequency Range: 10Hz-40kHz
- ✔ Osc Attenuator Range: 60dB in 0.25 dB Steps
- ✔ Osc Frequency Range: 10Hz-100kHz
- ✔ Dual State-Variable Filters, LP/HP/BP/BR
- ✔ System Signal to Noise Ratio: 90dB
- ✔ XLR Interface: Osc out, Bal Input, Mic Input
- ✔ 360 Page Manual with Application Notes

Processing Operations

The LMS software provides a host of powerful post processing features which enable the user to perform complex mathematical operations on curve data quickly and easily.

- ✔ Scaling, Smoothing Curves
- ✔ Minimum Phase Transform
- ✔ Group Delay Transform
- ✔ Addition, Subtraction
- ✔ Multiplication, Division
- ✔ Frequency Div/Mul
- ✔ Invert, Square-Root
- ✔ dB to Linear Conversion
- ✔ Inverse FFT

Call Today for a free Demo Disk! *Tel: (503) 620-3044*

International Dealers: **Agentina**:Interface SRL (54-1)741-1389/ **Australia**:ME Technologies 61(0)65-50-2254/ **Austria**:Audiomax 49(0)71-31-162225/ **Belgium**:Belram 32(0)2-736-50-00/ **Brazil**:SDS Equipamentos 55(0)11-887-7597/ **Canada**:Gerraudio 416-696-2779/ **China**:HiVi Research (852)2-556-9619/ **Denmark,Finland**:A&T Ljudproduktion 46(0)8-623-08-70/ **France**:Belram 32(0)2-736-50-00/ **Germany**:Audiomax 49-71-31-162225/ **Indonesia**:Ken's Audio 62(0)21-639-5806/ **Italy**:Outline snc 39-30-3581341/ **Korea**: Sammi Sound:82(02)463-0394/ **Luxembourg**:Belram 32(0)2-736-50-00/ **Malaysia**:AUVI 65-283-2544/ **New Zealand**:ME Technologies 61-65-50-2254/ **Norway**:A&T Ljudproduktion 46(0)8-623-08-70/ **Phillipines**:Dai-Ichi 632-631-6276/ **Poland**:Inter-Americom 48(22)43-23-34/ **Singapore**: AUVI 65-283-2544/ **Spain**:Audio Stage Design 34(94)620-27-47/ **Sweden**:A&T Ljudproduction 46(0)8-623-08-70/ **Switzerland**:Good Vibes Ltd. 41-56-82-5020/ **Taiwan**:Gestion Taycan Intl 886-2-562-3883/ **Thailand**:AUVI 65-283-2544/ **The Netherlands**:Duran Audio 31-41-80-15583/ **UK(England)**:Munro Assoc 44(0)171-403-3808.

LINEAR X

LinearX Systems Inc/7556 SW Bridgeport Rd/Portland, OR 97224 USA/TEL: (503)620-3044/FAX: (503)598-9258

About This Issue

Author and teacher **Daniel Coyle** continues his quest for the perfect speakers in "A Pilgrim's Progress" (p. 10). He shares with *SB* readers his exploits in building three speakers and examines the relative merits of each topology.

John Cockroft resurrects one of his speaker systems—after dusting it off and dragging it out of the closet—with a new woofer, tweeter, and crossover ("The Squatline, HDOLLP & All," p. 16). The author, always exploring new possibilities for improvement, also examines at length a new crossover design for future systems.

Also in this issue you'll meet Adria, a three-way system that uses PVC piping for the acoustic volume of the satellites, and includes some unique stands. **Michael Hildebrand** includes many design and construction tricks to help you build this attractive system ("The Adria: A Satellite Subwoofer System," p. 24).

Capacitors come in various shapes, sizes, and characteristics. Which one you choose can greatly affect the sound quality of your system. "Capacitors: Why They Matter" (p. 40) outlines the differences among capacitor types and helps you choose good-quality components for a loudspeaker crossover.

Don Jenkins shares the results of his extensive work on a computer model for driver dynamics in "Measuring Driver Flux Density" (p. 46). His performance data is significant for its direct-measurement techniques of critical parameters.

Attention to detail is the key to successful assembly of your speaker enclosure, as we discover on our visit to **Bob Wayland**'s workshop ("Wayland's Wood World," p. 52).

We also encounter a PC program designed to assist with speaker placement and room effects and dimensions ("Software Review," p. 56).

Speaker Builder (US USSN 0199-7929) is published every six weeks (eight times a year), at $32 per year, $58 for two years; Canada add $8 per year; overseas rates $50 one year, $90 two years; by Audio Amateur Publications, Inc., Edward T. Dell, Jr., President, at 305 Union Street, PO Box 494, Peterborough, NH 03458-0494. Second-class postage paid at Peterborough, NH and an additional mailing office.

POSTMASTER:
Send address change to:
Speaker Builder, PO Box 494
Peterborough, NH 03458-0494

Speaker Builder®

The Staff

Editor and Publisher
Edward T. Dell, Jr.

Contributing Editors
Joseph D'Appolito, Robert Bullock, Richard Campbell, John Cockroft, David Davenport, Vance Dickason, Bruce Edgar, Gary Galo, G.R. Koonce, Richard Pierce, Bill Waslo

Assistant Publisher
Karen Hebert

Dennis Brisson Managing Editor
Swain Pratt Associate Editor
Courtney Howard Editorial Assistant
Suzanne Coté Graphics Director
Diane Luopa Assistant Graphics Director
Joan Ahern Production Assistant
Laurel Humphrey Marketing Director
Robyn Lasanen Circulation Manager
Doris Hamberg Administrative Assistant

Advertising Rates & Schedules
Peter B. Wostrel National Advertising Director
Linda M. Guyette Advertising Sales
Laura Brown Advertising Assistant
(603) 924-7292 FAX (603) 924-6230

The peculiar evil of silencing the expression of an opinion is, that it is robbing the human race; posterity as well as the existing generation; those who dissent from the opinion, still more than those who hold it.
JOHN STUART MILL

Speaker Builder is published eight times a year in the interest of high-quality audio reproduction.

Legal Notice
Each design published in Speaker Builder is the intellectual property of its author and is offered to readers for their personal use only. Any commercial use of such ideas or designs without prior written permission is an infringement of the copyright protection of the work of each contributing author.

Subscription Inquiries
A one year subscription costs $32. Canada please add $8. Overseas rate is $50 per year.

To subscribe, renew or change address write to the Circulation Department (PO Box 494, Peterborough, NH 03458-0494) or telephone (603) 924-9464 or FAX (603) 924-9467 for MC/Visa/Discover charge card orders. **E-mail: audiotech@top.monad.net.**

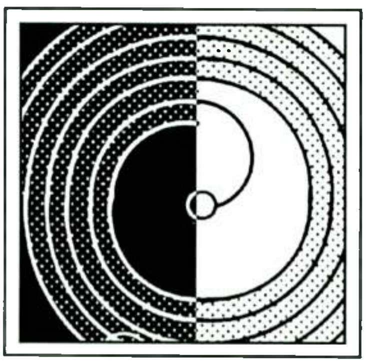
For gift subscriptions please include gift recipient's name and your own, with remittance. A gift card will be sent.

Editorial Inquiries
Send editorial correspondence and manuscripts to *Speaker Builder*, Editorial Dept., PO Box 494, Peterborough, NH 03458-0494. **E-mail: audiodiy@top.monad.net.** No responsibility is assumed for unsolicited manuscripts. Include a self-addressed envelope with return postage. The staff ***will not*** answer technical queries by telephone.

← *Reader Service #36*

Speaker Builder
THE LOUDSPEAKER JOURNAL
VOLUME 17 NUMBER 3 MAY 1996


24


40

DEPARTMENTS

KEEP IN TOUCH

EDITORIAL — Send letters, questions, and comments to: Speaker Builder, Editorial Dept., PO Box 494, Peterborough, NH 03458 USA, FAX (603) 924-9467, E-mail: audiodiy@top.monad.net.

Be sure to reference the issue, title, author, and page number of the article or letter in question; and if you request an answer from an author, please include a self-addressed envelope (and your FAX number and/or E-mail address, if applicable), with a loose stamp or postal coupon.

Due to the volume of correspondence, we cannot personally acknowledge or respond to each letter or query. All letters to the editor will be considered for publication unless you indicate otherwise. *Speaker Builder* reserves the right to edit your letters or technical queries for length and clarity.

Author guidelines are available by sending a self-addressed envelope with loose postage to the above address.

CIRCULATION — For subscriptions, renewals, back issues, or address changes, write to the Circulation Department (PO Box 494, Peterborough, NH 03458) or call (603) 924-9464 or FAX (603) 924-9467. E-mail: audiotech@top.monad.net.

ADVERTISING — Address advertising inquiries and information requests to the Advertising Department, Audio Amateur Publications, Inc., PO Box 494, Peterborough, NH 03458-0576, voice (603) 924-7292 or 1-800-524-9464, FAX (603) 924-6230.

OLD COLONY SOUND LAB — For product information and ordering, contact Old Colony Sound Laboratory, PO Box 243, Peterborough, NH 03458-0243, voice (603) 924-6371 and (603) 924-6526, FAX (603) 924-9467.

■ TWO NEW KLIPSCH SPEAKERS

Klipsch Professional, makers of loudspeaker systems and components, updated Paul Klipsch's "Heresy" speaker with the new KP-250 II. New features include a high-frequency unit tweeter phase plug, 19mm birch plywood enclosure, and midrange driver using a 2″-diameter titanium dome tweeter. The manufacturer also unveiled the KPT-250 cinema surround loudspeaker system, available in either 15° or 30° down-facing angles. Both new products feature Tractrix Wave™ midrange/tweeter horns, 300W performance, and directivity in a 90° × 40° pattern. Klipsch Professional, 149 N. Industrial Park Rd., Hope, AR 71801, (616) 695-5948, FAX (616) 695-7623.

Reader Service #111

■ NEW CAP DISTRIBUTOR

The MultiCap capacitor, formerly distributed by MIT, is now available directly from Rel Cap. Conceived by Richard Marsh at the Lawrence Livermore National Laboratory, this unique internal by-pass capacitor has been increasingly appearing in the industry's finest electronic products. Rel Cap intends to introduce new lines of MultiCap and other exciting capacitor products for audio use, and will continue to provide its marketing expertise to ensure the MultiCap's continued growth. Reliable Capacitors, 12931 E. Sunnyside Pl., Santa Fe Springs, CA 90670, (310) 947-8577, FAX (310) 944-7494.

■ AUTO SERVO-SUBS

Velodyne Acoustics announces the manufacture of new automobile subwoofers in 10-, 12-, and 15-inch versions, each with a dual-accelerometer control system. One accelerometer is mounted on the speaker's voice coil, measuring the motion of the spun-aluminum cone, and another on the die-cast basket to gauge the car's movement. Boasting a 4Ω nominal impedance and <1% total harmonic distortion, each new subwoofer sports a low-pass crossover, subsonic filter, voice coil temperature-sensitive and gain-compression circuits, phase adjustment, remote digital volume control, and enclosure type selection. Velodyne Acoustics, Inc., 1070 Commercial St. #101, San Jose, CA 95112, (408) 436-7270, FAX (408) 383-7856.

Reader Service #115

∩ AS SOLID AS A ROCK

DD-Audio introduces three new speakers encased within green and gray soapstone, extracted from the Tulikivi quarries of Finland. The DD-Stone Monument consists of two mid-range units and one bass unit, composed of four 5″ high-bass and two 5″ mid-range elements with one soft-dome tweeter. The dipole speaker DD-Stone Dimension comprises one dome tweeter, one 5″ mid-range unit, and six 5″ woofers, whereas the DD-Stone Exquisite has a stiff Kevlar cone, 1″ hard-dome tweeter, one 5″ mid-range, and one 6½″ woofer in a reflex box. Rexxell Corporation, 1300 W. Belmont, Ste. 207, Chicago, IL 60657, (312) 880-8825, FAX (312) 880-2233.

Reader Service #104

■ SPEAKER MINIATURES

Bandor Loudspeakers announces its line of miniature two-, four-, six-, and twelve-inch drivers. The smallest, a high-fidelity unit with 2″ aluminum cone and 0.75″ voice coil, offers a frequency range of 100Hz–20kHz and voice-coil impedance options of 4, 8, and 16Ω. The 4″ bass driver is designed for specialist applications, with an impedance of 4 or 8Ω and free air cone resonance of 32Hz. A general-purpose bass driver, the 6″ model boasts a maximum continuous RMS power rating of 100W, whereas the 12″ unit is intended for high-power operations with a maximum rating of 200W. Bandor Loudspeakers, 11 Penfold Cottages, Penfold Lane, Holmer Green, BUCKS, UK HP15 6XR, phone/FAX (+44) 1494-714058.

Reader Service #102

■ WELCOME, JUNIOR

Newly released from LinearX is a PC-based, one-third octave real-time analyzer, the RTAjr. With a choice of one of four calibrated microphones, the RTAjr comes complete with an ISA half-length PC slot card, a 3.5mm to XLR mike adaptor cable, and Windows™-based operating software. The package offers scoring systems for IASCA and USAC, post processing ability, and weighting filters, and it is capable of measuring impedance, maximum SPL, and octave RTA response. LinearX Systems, Inc., 7556 SW Bridgeport Rd., Portland, OR 97224, (503) 620-3044, FAX (503) 598-9258.

Reader Service #108

■ GOOD THINGS IN SMALL PACKAGES

B & W announces the DM302 compact loudspeaker featuring a one-inch soft-dome tweeter and a five-inch bass/midrange unit. The DM302's Prism enclosure system employs a slot-ported vented design, six crossbraces, a paper diaphragm, a Nitrile-rubber "hooded" surround, and injection-molded front and rear baffles. The compact unit, offering an 8Ω nominal impedance and 91dB SPL in 1W/1m, is housed within a steel enclosure finished in black-ash vinyl with black grille cloth. B & W Loudspeakers of America, 54 Concord St., North Reading, MA 01864-2699, (800) 370-3740, FAX (508) 664-4109.

Reader Service #110

∩ POWERED SUBS

AudioSource offers two new subwoofers with built-in power amplifiers, the SW 8 and SW 10, ideal for home-theater surround-sound systems. The SW 8 forward-firing subwoofer sports an 8″ driver for deep, clear bass and an integrated 50W power amplifier. The SW 10 promises a full 100W power amp, and features a downward-firing 10″ driver. Complete within black, wood-grained cabinets, both subwoofers feature controls for phase reverse, crossover frequency, subwoofer level, and power; gold-plated line-level RCA inputs and outputs; and a wide range of crossover adjustment. AudioSource, Inc., 1327 N. Carolan Ave., Burlingame, CA 94010, (415) 348-8114, FAX (415) 348-8083.

Reader Service #103

■ BOSTWICK NEWS

Bostwick introduces the MA250xz, the first in a new amplifier product line. The MA250xz boasts one-, two-, or three-channel operation with 2 × 50W at 4Ω, 2 × 75W at 2Ω, or a 150W mono. Operating at 18dB per octave at 80Hz lowpass or 110Hz highpass, the unit further offers gold-plated terminals as well as a discrete heat sink and outputs. The two-year warranty furnishes thermal, overload, and short-circuit protection. Bostwick, 125 Old Monroe Rd., PO Box 327, Bogart, GA 30622, (706) 543-9494, FAX (706) 369-9519.

Reader Service #106

■ THE IMPROVED HOVR-6

Driver Design Ltd. has improved its HOVR-6 professional midrange driver. With a reduction in moving mass from 8.25 to 6.75 grams, the driver's nominal efficiency raised from 94.5 to 96dB at 1W/1m. Conversely, a drop in nominal impedance from 8Ω to 6Ω raised the voltage sensitivity. The HOVR-6's lower resonant frequency of 70Hz enables a rated power handling of 50W at 140Hz, or 100W with a 400Hz crosspoint. Driver Design Limited, 1018 Maywood Dr., Martinez, CA 94553, phone/FAX (510) 370-1941.

Reader Service #107

■ BOX THAT WOOFER

Fultron's BP10 bandpass woofer box, available in 4Ω or 8Ω versions, boasts a 4dB gain and 40–125Hz frequency response. Able to function with as few as 50W, the box comes equipped with the company's main line 10″ ProSeries woofer. The 22½″ × 12½″ × 13″ construction includes a carpeted exterior, fully finished interior, and a plexiglass window which protects and showcases the woofer. For a retailer near you, call Fultron at 1-800-467-2400.

■ BIWIRING DESIGN

Wireworld's Atlantis II and Oasis II speaker cables, each combining two symmetrical and completely isolated coaxial speaker cables, improve fidelity by reducing interaction between amplifier, cable, and speaker. The full benefit of biwiring, Discrete Biwiring™, is achieved through the isolation of the magnetic fields of both high- and low-range conductors. The coaxial design minimizes resistance, inductance, capacitance, skin effect, mechanical instability, and external interference. Wireworld, Inc., 3320 Griffin Road, Ft. Lauderdale, FL 33312, (954) 962-2650, FAX (954) 962-2603.

Reader Service #101

A PILGRIM'S PROGRESS

By Daniel Patrick Coyle

It's difficult to determine much about audio state-of-the-art. While scientists publish their findings, much engineering wisdom is guarded, "proprietary" knowledge. I tried to make "perfect" speakers based on papers and articles, but many issues are not described, let alone settled.

Time and money are required to develop knowledge and preferences about speakers. Dick Heyser, father of time-delay spectrometry,[1] modified the first imperative of loudspeaker design—"Get the frequency/amplitude right"—to read "but not at the expense of impulse response." After that, it becomes murky: line source, omni, or point source; monopole or dipole; high-order crossovers or first-order; big baffles or minimum size?

The only solution is experience. I found I could rely on others for information about how components behave, but there is no substitute for listening to evaluate the merits of a device. The clearer, more truthful speaker is always much more interesting than our pallid imaginings, Horatio.

ROCK MONITORS

In the '80s, I had eight Dynaudio 12″ drivers in two reflex 18-ft^3 bins, biamped with JBL's best biradial monitor horn (*Photo 1*). The concept of horns as acoustic transformers intrigued me. My previous speakers were a pair of Strathearns with an iron transformer to load the amp. I thought it might be more linear to dump the hysteresis of the iron and use the acoustic shape of the baffle to load a dome driver. A horn's efficiency comes from its shape. The radiation impedance of the acoustic transformer varies with frequency, so it can't be as linear as a flat or nonexistent baffle.

You can observe a crude instance of this by listening to an unloaded (driverless) horn when put over someone's mouth. I spent some time making an electronic EQ to correct for the horn throat's unloading at high frequencies. I had a killer rock monitor.

Then, I fell in with a bad crowd and encountered Shiva, destroyer of worlds, in the visage of Ron Cox, well-known to *Stereophile* readers as an amp constructor. He has a pretty good ear, and made comments about my speakers, and I realized I preferred detail and linearity more than the dynamics of the biradials. The bare dome is more linear through its range. I also came to fear that speakers which played so loudly and effortlessly would damage my hearing. I don't like horns for hi-fi. (Ron has now become a single-ended amp fan and is building horns.)

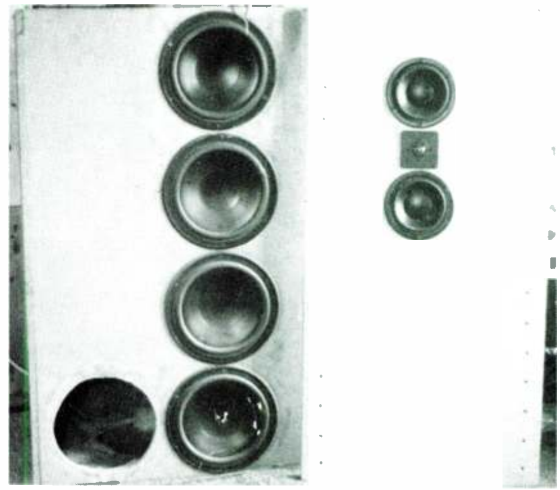


PHOTO 1: First dipole, horizontally displaced. Notice disabled downward-firing 15″, seen through port.

While the bass bins extended to 30Hz, they were not tight. Hearing B&W Matrix and Duntech Sovereign speakers convinced me that flex in big-panel walls perceptibly degrades clarity. I resigned myself to adding a second layer of ¾″ particleboard to my bass enclosures.

It took much of my vacation to reinforce one of the boxes, and while it sounded better, I found I couldn't move the speaker alone. This was no longer tolerable, let alone fun. I needed a change of approach. It was wasteful to build pairs before I learned what sounded best, so I decided to experiment with single loudspeakers.

ISOBARIK

I cut down the sacred bass bins to a less visually oppressive size for my living room. Isobarik theory stated a smaller box should provide better low-frequency loading, allowing me to mount drivers two deep, which reduced the total size of the four-driver sound source. Unfortunately, when I tried it, the twelves audibly ran out excursion far too soon.

I have heard other Isobariks suffer from a lack of clarity above deepest bass, possibly because of the interdriver coupling. My experience with slot-loaded and chamber-loaded speakers is that they trade limited range for higher efficiency and are quite colored. The increase in radiation resistance is not worth the rise in resonant frequency and the decreased clarity that accompanies the front chamber.

PHOTO 2: Coaxial dipoles. Note position out in room, with sound absorption. Behind open 1″ × 4″ wall is bass trap.

DIPOLE BASS

Isobarik was a failure for me, but I did construct a rigid plate for mounting the four 12″ drivers. In trying to determine the source of a rattling noise, I realized the drivers sounded much less colored when out of the box, and the bass wasn't so bad.

I was intrigued by the dipoles' lack of enclosure resonance and that they have a similar sound-dispersion pattern at all frequencies—like the biradial horns. Is the best radiation pattern for a speaker omni or directional? I find the imaging specificity of point sources more compelling than the indistinct but enveloping omni dispersion. Others have pointed out the benefits of not sending energy out to the side, where late wall returns decrease clarity. I have noticed that speakers with similar dispersion patterns at all frequencies are truer in the room.

The phase shifts in bass alignments produce audible effects. Reflex speakers seem extended in the bass, but lack clarity in comparison to sealed boxes. A ported enclosure has a natural fourth-order rolloff, while a sealed box has a second-order rolloff below its resonant frequency. A dipole's rolloff is only first order, albeit usually starting at too high a frequency. The sound reflections returned from the cabinet are nil. The radiation resistance load on the drivers is symmetric. This is the good news.

I had read the bad news about dipole bass in AES reports, but had not listened to examples. Beranek,[2] Olsen,[3] and Newman[4] had shown the amplitude response of dipole bass to be hopeless in the lowest octave, but in listening to it, I found its clarity very attractive. (We need to pay more attention to the data and less to the conclusions, even in AES papers. If their criteria are not the same as yours, even authoritative conclusions may lead you astray.)

In the past ten years, several panel speakers have shown what can be done with sufficient driver size and excursion. Several alignments have interesting, if incomplete, charms. Hearing the Apogee ribbons driven by big Krell amps convinced me that it was possible, if expensive, to achieve definition and extension from dipoles.

In a fit of wild abandon, I cut the sides and back off a bass bin and mounted the speakers all facing forward. This sounded pretty good, considering that my expectations were low. There was little bass, but it was tight and had pitch.

BAFFLE SIZE

One theory states all is well if the distance between drivers is small compared to the wavelengths of radiated sound. My experience has been that the different path lengths and transit times for bass (or worse yet, treble) signals from displaced speakers cause problems. It is best to have one driver for hi-fi. In large rooms requiring multiples, all the drivers must be in close proximity.

You may choose a large baffle or enclosure for its greater radiation resistance, but, like the horn, the baffle never provides the same load over many octaves or at all angles. World-class speakers, such as the Infinity IRS, have large baffles, yet minimonitors derive their image specificity from their small baffle size. A small baffle is less colored, which is more important than baffle reinforcement.

At first glance, it may seem that large baffles make drivers more efficient because they then have to push energy into only a small space. But except for true infinite-baffle situations (mounted on the wall), it is the energy delivered to the sound field, not the baffle, that creates the illusion of an event. Even a flat baffle returns some time-delayed sound to interact with the new sound. The additive and destructive cancellation of the wavefronts then produces a comb filter.

PHOTO 3: Close-up of minidipole monitors. (Photo by Ron Kay.)

A speaker without a back chamber is less efficient, but it has practically the same dipolar response at all frequencies, and if its baffle is not much larger than the driver, it will lack edge-diffraction returns, which is very attractive. Foam is great to absorb upper-mid and high-frequency returns, but no baffle is better.

REBUILDING

After Shiva's visit, I started to rebuild my audio world with a dome setup. I hoped to retain the detail of the titanium dome while losing the unwanted sonic signature of the horn baffle. So much for acoustic transformation. I preferred fewer poles in my transfer function.

I first tried a dipole D'Appolito configuration (*Photo 2*). At a given sound level, a single driver must make a greater excursion than a pair. Coming from the biradial horns, I felt it would take at least two 7″ drivers to cover the midrange with authority. It didn't.

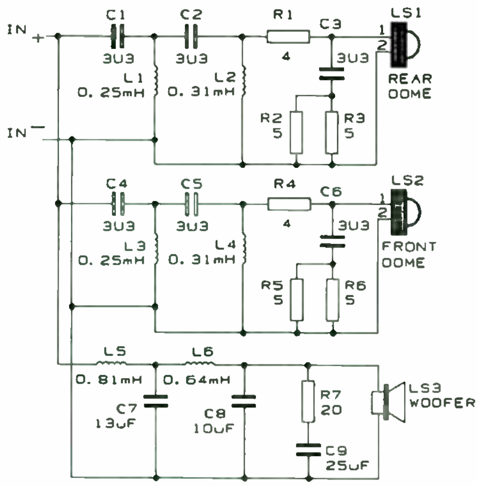


FIGURE 1: Crossover diagram, minidipole.

When working up through 3kHz, a single 7″ driver images better and has less coloration. To my ear, this was more audible than any lobing errors in the crossover range, which the D'Appolito addresses.

Dynaudio always recommends first-order parallel crossovers for its drivers, while I was a fan of first-order *series* crossovers ("Custom Wound Inductors," *SB* 3/82). I now noticed that while the sound was better with fewer, smaller drivers, they sounded strained at full volume. The drivers were distorting out-of-range, which was degrading clarity. I tried a third-order crossover and found it an improvement.

First-order crossovers are championed in several AES articles, oscilloscope photos, the Vandersteens, and Thieles, but my experience indicated that stopping out-of-band distortion was even more important. The third-order sounded so good that I tried the fourth-order Legendere crossover[5] of the Black Dahlia, noted critic Dick Olsher's public-domain speaker. Better yet! I showed the highest engineering judgment and adopted Olsher's alignment for these two drivers.

MINIDIPOLE MONITORS

Although intrigued by the properties of boxless speakers, I had only low Q_{TS} drivers on hand. The speaker design in *Photo 3* is the result of seeking imaging over ultimate volume and bass. My room is midsized and will accommodate panels. These speakers are nonresonant and throw an image well, but won't play loudly or deeply. On sturdy stands or hung from the ceiling, they make an interesting, if large and expensive, minimonitor.

The upper range of the Black Dahlia alignment uses the 1″ M.B. titanium tweeter, and the 17W75 Dynaudio 6.5″ is the midbass driver. The *Stereophile* reviews of the Black Dahlia warn of box-resonance problems. An open baffle trades box problems for the reduced bass of an open-back speaker.

To extend bass response, I added a biamped coaxial array of four twelves below 160Hz. Dynamic drivers are seldom used without an enclosure, because at low frequencies the destructive interference between the front and back sound waves ruins efficiency. If you care to try this, I recommend getting the cheapest speakers you can find with a low resonant frequency and large excursion. The 12″ Peerless 305 used in the Swan ("The Swan IV Speaker System," *SB* 4/88, p. 9) is a good candidate, and if it turns out you don't like dipole, they work quite well in ported enclosures.

The midrange and bass speakers radiate in both directions on an open panel, but the tweeter is a monopole. I added a second, rear-facing tweeter on the back of the baffle to maintain the dipole radiation characteristic. It is wired in reverse polarity and fed by its own Black Dahlia high-pass crossover. While praising the Black Dahlia's resolution, almost everyone but Mr. Olsher considers its balance to be rolled off in the high end. I lessened the pad on the tweeter (*Fig. 1*).

COAXIAL OR VERTICAL

Shiva, destroyer of worlds, came over again and brought his Stax electrostatic headphones and their dedicated tube amp that he had built. I was invited to compare their sound to that of my speakers. Thanks.

This listen convinced me there was some snap missing, and maybe a coloration in my coaxial system. That same day, we visited the Eminent Technology dealer, whose drivers feature ribbon voice coils suspended on thin film, with no baffle, but only a metal support frame. Their open sound suggested a further reduction in coloration. If the low-frequency drivers could operate without baffle augmentation, why not all the drivers?

Positioning the mid and treble drivers in free space required that I abandon the coaxial array for a vertically displaced point source. The 6.5″ driver and the dome sit in a small board projecting above a cluster of bass drivers in *Photo 5*. The reduction in baffle signature was very nice. Again, I tried a second Dynaudio 6.5″ in a D'Appolito, but discarded it in favor of a single driver.

Sounds of different frequencies needn't necessarily be reproduced by different drivers—witness full-range electrostatics. But if separate drivers *are* used, as with dynamic drivers, vertical arrays are less offensive than horizontal displacement. (*Audio* published an article suggesting we naturally expect high frequencies from above and low frequencies from a position nearer the ground.) Vertically displaced drivers also deliver sound to the room in a way that gives a minimum of ambiguity of left-right clues, which is what much of stereo is about.

EXPERIMENTAL FINE-TUNING

It is rewarding to adjust fore and aft driver displacement to achieve time alignment, à la Ed Long (holder of the registered trademark, "Time Aligned"). Because the acoustic center varies with frequency, aligning voice

PHOTO 4: Vertical dipoles. (Ron Kay photo.)

PHOTO 5: Monopoles. Note the offset and the foam.

Reader Service #31

coils won't work. You must align them empirically.

Build separate baffles or enclosures for each driver and hook up the crossover. Test with a Wittenbreder impulse generator (*SB* 2/83, p. 14)—or a square-wave generator set at the crossover frequency—feeding the speakers through an amp, with a flat mike going into an oscilloscope. Set the midrange driver back from the woofer and align for maximum impulse height. The movement of drivers by only millimeters fore and aft has an acoustic effect.

The coaxial had "flown" from my ceiling, but the new woofer panel rested on the floor, which reinforced the bass. Seeing that coaxial symmetry was broken, I decided to replace two of the 12″ Dynaudios with two 15″ drivers from Itone Audio to increase radiating surface. They have a lower f_S (17Hz, versus the Dynaudio's 22Hz) and much higher Q at 0.7, which is preferable for an open baffle. But they were only marginally better.

The domes and the 6.5s are not hard to drive. I used a Curcio driver card and Sovtek 5881s in a triode AB amp. The amp driving dipole bass matters, as does the driver wiring configuration. Series wiring is not good for woofers. There is a perceptible improvement with paralleled drivers, but this requires amps that will work into low impedances. Powerful solid-state amps provide control of the high-inertia bass cones. I biamped at 160Hz.

When I completed the Waldron tube crossover (*TAA* 3/79, p. 6), I played it for a week before adding a Curcio high-voltage quad regulator card. The regulation improved image specificity and tightened the bass. Regulation is pleasantly audible on dipole bass power supplies.

CODA

Eventually I came to realize that, like me, dipole bass has its charm, but is severely limited. While the best baffle is no baffle, and the best enclosure no enclosure, the dipole runs out of steam in the lowest octaves. It has no-impact bass. For me, the resonance-free qualities of an enclosureless driver are not enough to compensate for the missing punch of the enclosure. In this case, I spent a lot of energy concurring with Beranek, Olsen, and Newman.

The best sound comes from fewer drivers, closely spaced, empirically staggered fore and aft, with a well-controlled radiation pattern, high-order crossovers if need be, and either no enclosure or very rigid walls and dead interiors. Electronic EQs are not my first choice, and electronic time delays are worse.

A large nonresonant room is the biggest luxury you can have in the pursuit of good sound, but removing walls is only for serious home-owning audiophiles. Room symmetry is the frosting on the cake that enhances sound stage. That old fastidiousness that manifested itself in phono-cartridge alignment should now be directed to speaker placement, toe-in, and sound absorption and dispersion devices. The Chesky test CD is quite useful for this (from cut 10, and beyond).

The dipole minimonitors whetted my desire for better dipoles, so I built electrostats following the Sanders articles (*SB* 1, 2, 3/90). They are wonderfully transparent, but even with the voltage swing of Ron Cox's 211 Ongaku clone, they were very hard to drive above 8kHz because of the capacitive reactance. (I measured 2000pF per panel.) The electrostatic principle gives the least colored transducer, if you have the amp that can drive it. I believe my personal salvation lies with an Estat panel—8″ wide and 48″ tall, with 0.125″ spacing and 0.125″ thick stators—which needs a direct-drive 2.5kV amp. I'm collecting surplus parts.

MONOPOLES

In '93, I heard two Audax HD-A 8″ with a 5.25″ HD-A mid and a dome in Dick Olsher's Poly Natalia alignment. The 8s and the 5 blended seamlessly, sounding better than the bottom end of the electrostats and the two 12s and two 15s in a dipole baffle. I decided dipoles weren't necessarily better than monopoles.

I tried a single HD-A 8″ and the HD-A 4″ mid (with a cloth dome) that had the best time response in the '94 Audax catalog, the TWO25MO. This is a transparent and dynamic system, with the frequency extension the electrostat never had. In a biamped system, the sensitivity of the 4″ and the dome is suitable for a low-efficiency single-ended amp, and less colored than a horn.

The bass enclosure has an internal volume of $2.1ft^3$ and must be rigid. Minimum wall thickness is 1.5″, and 2.0″ is perceptibly better. Two layers of 1.125″ particleboard, available for counter tops, work well. Line the inside with 3″-thick foam waffle and stuff with your favorite acoustic batting. Use

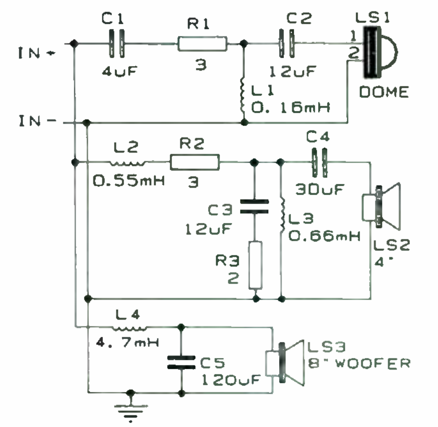


FIGURE 2: Wiring diagram for monopole speaker. All capacitors are film. Dome driver is mounted 2¼″ to the rear of the mid-driver, which is mounted 3 7/8″ to the rear of the woofer.

10-gauge wiring for the woofer. Silicone the midrange and tweeter structures together to make a breakable bond. The bottom enclosure sounds better when supported on metal cones. A&S Speakers sells inexpensive brass cones that work well.

The mid enclosure can be one layer of 1.125″ particleboard, $0.2ft^3$ or larger. It should have a large vent in the rear. Make the face as narrow, short, and nonresonant as possible. The edges are canted back at 45°, which is useful, but I blew it with too tall a face. Because of the existing 8″ box, I didn't want a deep enclosure, so I foolishly compromised sound for visuals. Minimal vertical spacing should not be compromised for anything except box rigidity.

A plate siliconed to the mid enclosure supports the dome, which is as acoustically free-standing as possible. I used a felt ring from Madisound and foam to diminish sound return. If you are willing to mold wood, fiberglass, or plaster, you may come up with a far better enclosure than mine. Everything needs to be solid and well damped.

I scaled crossover values from Audax literature for a similar project (*Fig. 2*). Keep the inductors at least 6″ apart and firmly mounted. Don't use electrolytics—Madisound has big, inexpensive film caps. I used braided conductors for speaker hookup, but I have no recommendations other than to listen.

Wire topology *does* matter. Inductance is the enemy of bass, and capacitance is the enemy of treble response. Closely spaced conductors are high capacitance, and widely separated wires are high inductance. Drivers having a voice coil are quite inductive.

I have found my way by experimentation, but this "truth" is for you only in the unlikely instance that we share the same aesthetic tastes. Follow your own ears.

REFERENCES

1. "Loudspeaker Phase Characteristics and Time-Delay Distortion," *JAES*, January and April, 1969.

2. *Acoustics*, McGraw-Hill, 1954, p. 210.

3. *Elements of Acoustic Engineering, 2nd Ed.*, Van Nostrand, 1947, p. 146.

4. "Dipole Radiator Systems," *JAES*, Vol. 28, # 1/2, Jan/Feb 1980.

5. For further information and parts, contact Madisound Speakers.

THE SQUATLINE, HDOLLP & ALL

By John Cockroft

Ever since I mentioned the Squatline in my Simpline Sidewinder article (*SB* 4/95), I've been in a bit of trouble. For years, the Squatline has been sulking in a dark closet corner. I made a big mistake in bringing him out. (Not that he didn't do his job when he came out. He did. Admirably.)

Squatline started out as the shorter brother of the Shortline (*SB* 1/88). Unlike his sibling, the Microline (*SB* 5/89), who was tall and slim, Squatline was fat and dumpy. When it came to crossovers, Shortline got a Linkwitz/Riley, but because I ran out of the right size coils, Squatline had to make do with a Butterworth.

Bravely, he didn't complain. He just made the best of it and sang forth. In stereo duets with Shortline, he held up his end with vigor. However, it just seemed that Squatline was cast in Shortline's shadow. But he came through, when needed, as a stand-in for the Simpline Sidewinder, and it's time to bring him from the mid-'80s to the mid-'90s.

EXTRA PUSH

The Squatline has been passively Butterworthed long enough. He is now passively Linkwitz/Rileyed at the line level. This means he gets an extra amplifier to push the wind through his lungs. He proved he could do it low down when he was a surrogate Sidewinder, and he proved he could do it high up when I gave him the chance.

Now, I've given the Squatline a new woofer—one I eventually found did the best job in the Sidewinder and at the least cost. The Dayton 8″ treated-paper cone woofer #295-240 is available for only $21.50 from Parts Express. This speaker has a rubber surround, a vented pole piece, and very impressive workmanship. Best of all, it sounds good.

A few years ago, one of my supervisors borrowed the Squatline and blew out its Peerless tweeter. I replaced it with a similar item I purchased in the early '70s. It eventually ended up in a system that I traded to a friend. Years later it found its way to my son, Paul, who returned the system to me. It appeared to have spent some months outside—the midrange surround had almost totally rotted away and tears of the mistreated tweeter had rusted the heads of the assembly screws. But the little tweeter has guts. A couple of years later it still sounds like new. It is singing to me now, and I wouldn't trade it for anything. (Maybe it's finally broken in.)

PROTECTED CROSSOVER

Other tweeters could probably be used, and other woofers as well, because now the crossover is between the preamp and the amp (or in a receiver tape loop), safely protected from the whims and wiles and impedance nasties of speakers. I recommend the ones I used because they work so well together and cost less than most speakers of the same quality. If you do seek (or have) others, the woofer should be capable of reaching 4kHz, and the tweeter should have an f_S of about 1.1kHz or lower.

There is such a tweeter in the Dayton line from Parts Express, the 275-050 1″ titanium-dome tweeter, with an f_S of 1kHz. I haven't tried it, but I was well pleased with another Dayton tweeter I used on my Super Simpline (*SB* 1/96) which, unfortunately, has an f_S too high for this situation. I mention this because it might be handier to purchase all your components from one place. Since it is the same brand as my recommended woofer, it seems reasonable that it was designed with the woofer in mind. It costs $16.50.

I don't know what the Peerless 810665 costs, but it is probably twice as much as the cost of the Dayton. If I were starting from scratch, I think I would take a chance on the Dayton tweeter in view of my satisfaction with other Dayton products.

ACCENT THE ACTIVE

I have almost always used line-level active crossovers during the initial design process of a new speaker system (and then later had to do it all over again if I wanted to use a high-level passive crossover). It simplifies things greatly, especially in the beginning. It gives much greater flexibility in bringing things together quickly. You can make crossovers from textbook schematics because they load into real resistors, not reactive speakers.

Active crossovers are relatively complex, requiring power supplies and integrated circuits. Purchasing ready-made active filters is a bit expensive. On the other hand, you can cheaply and simply make passive crossovers, but they have one inherent drawback. Unlike active crossovers, which are buffered by integrated circuits, passive crossovers are affected by the input impedance of the load amplifier, downstream from the crossover.

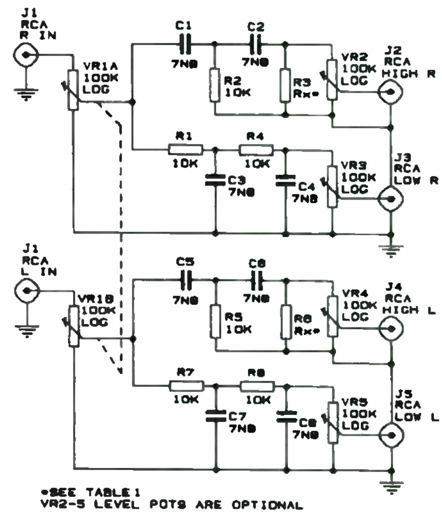


FIGURE 1: Second-order line-level passive crossover.

If you know the amplifier input impedance (most amplifier owner's manuals contain this information), you can design a passive crossover to function correctly. Another drawback to the passive crossover is that, unlike the active crossover, in which gain levels may be set to suit the situation, you can achieve no gain. In fact, there will be an insertion loss when you insert the passive crossover into the audio circuit.

I have found that when the passive crossover has been designed with low impedance in mind, the gain provided by a preamplifier gives adequate amplification. It's my understanding that 10kΩ is a reasonably low impedance for a source load into a transistor amp. Lower impedance will cause too much current to flow into the amplifier, and anything higher will increase the insertion loss of the crossover. (I think perhaps I am wrong in this assumption because the output of most preamps is a few hundred ohms or less. I recently made a similar filter, for another use, using 4.7kΩ resistors. It functioned well. Of course, to change the resistors here would mean refiguring the whole crossover.) Just about any filter circuit I see for use with transistor amplifiers seems to be normalized for 10kΩ.

INPUT SENSITIVITY

If you were to purchase an amplifier specifically for use with line-level passive crossovers, one specification should be input sensitivity. This is an indication of the input voltage required to produce the full rated output wattage from the amplifier. All else being equal, the input-sensitivity figure with the lowest voltage indication should give the greatest advantage in overcoming the passive-crossover insertion loss.

My early version Adcom 535 amp has an input sensitivity of 1V, and that of my Parasound 800 amplifier is 0.775V. I've seen IS figures as high as 1.5V, and I seem to recall an ancient Heath amp with a figure of 0.25V. Old Colony Sound Lab (PO Box 243, Peterborough, NH 03458-0243, 603-924-6371, FAX 603-924-9467) sells amp modules with an input sensitivity of 0.5V. (Its KM-14A series ranges from 100W to 1kW in output power and from $139.95 to $699.95 in price.) This seems to be a very good choice for use with passive crossovers.

Passive crossovers have only one transfer function for a given order. First-order filters are Butterworth, with a Q of 0.707. The second order produces a Linkwitz/Riley filter with a Q of 0.5. This is the limit of the really practical configurations. My second-order crossover has performed immaculately in every situation—clean, detailed, and seamless—with excellent transient response, even when using ten-cent carbon resistors from Radio Shack.

I originally designed the second-order crossover for use with the Simpline Sidewinder Woofer and have since successfully used it in a number of applications. The Squatline is the first system to use it in a treble configuration, and I'm very pleased with the results (*Fig. 1*, *Table 1*).

THIRD ORDER

I also constructed a third-order passive crossover, to which I assigned the rather improbable-sounding name of Third-Order Highly Damped Overlapping Line-Level Passive (HDOLLP). It has a Q of 0.353 (0.707^3). In its natural state, a crossover with a Q of 0.353 has a dip of −9dB, which is −3dB beyond the ideal −6dB of the Linkwitz/Riley. To compensate for this, I

TABLE 1

THE SECOND-ORDER LINE-LEVEL PASSIVE CROSSOVER Q = 0.5

Resistors: 10kΩ (except R_X*)

* Resistor R_X: The value of R_X is dependent upon the value of the input impedance of the amplifier following the crossover. The value is determined by: 1/10k – 1/amplifier input impedance = $1/R_X$.

Capacitors: 0.1μF when used with the prescribed 10kΩ resistors results in a rolloff (−3dB point) of 159.15Hz. For higher rolloff frequencies, use smaller-value capacitors; for lower frequencies, use larger values. Use one-tenth the value to realize a frequency ten times higher, and so on.

Note: Normally, the high-pass section of a second-order crossover should be in reverse polarity to the low-pass section to avoid a null at the crossover point. This is done by reversing the high-pass speaker leads at the speaker terminals. However, with real-world speaker systems, try both polarities and choose the one that sounds best.

SECOND-ORDER LINE-LEVEL SQUATLINE CROSSOVER

Crossover Point: (X_P) 2,040Hz

Resistors: ¼W 10kΩ (except R_X*)

*Resistor R_X: See above details.

Note: Both carbon and metal-film resistors give excellent results, but you may have personal preferences about this point.

Capacitors: 0.0078μF polyester, polypropylene, or silver mica work well. Use standard values of 0.0056μF and 0.0022μF to make up 0.0078μF. Panasonic P series polypropylene (2%) and B series polyester (5%) should be excellent.

gave it the old accordion treatment and overlapped the high-pass and low-pass sections to squeeze out the 3dB dip.

The HDOLLP actually performs excellently, with superb transient response. I can hear nothing to indicate a crossover is in the circuit. The big problem is that, because of the overlapping frequencies, more care is required in choosing drivers. In this case, the tweeter rolls off at 1,895Hz, and the woofer at 3,121Hz.

There are tweeters that will perform well in the required range. Most 1″ dome tweeters with an f_S of 1kHz or lower should work. The woofer would have to go up to about 6kHz for the crossover to achieve an ideal situation, and some smaller ones can do that. For this situation, the HDOLLP crossover should be excellent, but it obviously isn't one to be casually chosen.

TABLE 2

THIRD-ORDER HIGHLY DAMPED OVERLAPPED LINE-LEVEL PASSIVE (HDOLLP) CROSSOVER Q = 0.353

High-Pass/Low-Pass rolloff spread (Lp/Hp): 1.6469657

1/1.6469657 = 0.6071772

$(1.6469657)^{1/2}$ = 1.2833416

$1/(1.6469657)^{1/2}$ = 0.7792158

Crossover Point (X_P) = 1.2833416 × high-pass rolloff (–3dB point)

Or: Crossover Point (X_P) = 0.7792158 × low-pass rolloff (–3dB point) Resistors: 10kΩ (Except R_X*)

*Resistor R_X: The value of R_X is dependent upon the value of the input impedance of the amplifier following the crossover. The value is determined by: 1/10k –1/amplifier input impedance = $1/R_X$

Capacitors: 0.1µF results in a rolloff (–3dB point) of 159.15Hz when used in conjunction with the prescribed 10kΩ resistors. For higher rolloff frequencies, use smaller-value capacitors, larger values for lower frequencies. Capacitors may be scaled directly. Use one-tenth the value to realize a frequency ten times higher, and so forth.

Note: Normally, the high-pass section of third-order crossovers should be in reverse polarity to the low-pass section to avoid a 180° phase reversal at the crossover point. This is done by reversing the high-pass speaker leads at the speaker terminals. However, with real-world speaker systems, try both polarities and choose the one that sounds best.

DETAILS OF MODEL CROSSOVER

X_P = 2,431Hz

Low-Pass rolloff (–3dB point) = 3,121Hz

High-Pass rolloff (–3dB point) = 1,895Hz

Resistors: ¼W 10kΩ, mixture of Radio Shack carbon and Dale metal-film resistors

Resistor R_X: ¼W 17.8kΩ Dale metal-film (the closest value I could find to 18.34kΩ to accommodate my 22kΩ Adcom 535 amplifier)

Capacitors: Low-Pass section 0.0051µF silver mica*
High-Pass section 0.0085µF silver mica**

*0.0018µF and 0.0033µF in parallel = 0.0051µF

**0.0047µF and 0.0039µF in parallel = 0.0086µF (this is within 1.1% of 0.0085µF)

Refer to the bottom of *Table 1* for recommended capacitors.

While typing the above, I realized that I hadn't tried the HDOLLP crossover on the Squatline, so I dug it out and plugged it in. Apparently no level adjustments were necessary compared to the second-order crossover. (Perhaps after extended listening with a variety of material, I might modify that statement.) Theoretically, this isn't an ideal situation. The Dayton woofer is only rated to 4kHz, which is less than half an octave above its rolloff point. My mind is telling me this, but my ears sure aren't.

I'm listening to a Reference Recordings CD: *Nojima Plays Liszt*, #RR25CD. The fine print at the bottom says, "A Prof Johnson Digital Master Recording." He's one of the best. I heard this last night with the Linkwitz/ Riley crossover. With either one of these crossovers, even though I'm only listening to one Squatline, it's difficult to believe there isn't a concert grand in my apartment. At this point, I'm going to leave the HDOLLP crossover hooked up for a while. In fact, I've just decided to print the schematic of it in this article, so you can play with it too and make up your own mind (*Fig. 2, Table 2)*.

CONSTRUCTION

You may construct the HDOLLP any way you wish, but the simplest is to mount the components on a card. I used some pieces of cardboard that are 100% ragboard. Pebble-board photo mounts, or something similar, would probably work just as well.

I sketch the schematic layout on the card, drawing the resistors and capacitors in their normal size so I can mark points for piercing by the point of a pencil compass or scribe (*Table 3*). At one end of the card, I make a rectangular cutout to accommodate an eight-jack RCA jackboard from Radio Shack. It mounts from the bottom of the card, the hole just skirting the eight jacks. You can use either small machine screws and nuts or a bead of Kwik Seal to mount the jackboard to the card. (Only six jacks will be used.)

You should tie all the ground lugs together with bare wire and solder them, cleaning them first with a wire brush, file, or fine sandpaper. Bend the wires of the components at right angles, insert them through the proper holes in the card, and hard-wire them together on

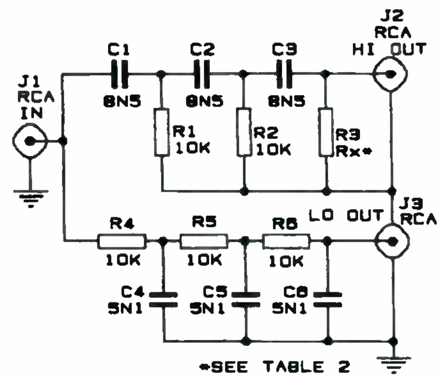


FIGURE 2: Third-order HDOLLP crossover (only one channel shown). If level controls are required, refer to *Figure 1*. R = 10kΩ; C_H = 8,500pF; C_L = 5,100pF. For R_X, see *Table 2*.

the back of the card. If you use two or more components for a value of larger size, use separate holes for each piece.

Bringing wires from all of the ground connections to a single place (star grounding) helps prevent ground loops, which could be a source of hum. A handy tie point would be a place on the bare wire jackboard ground interconnections. Make sure the ground connections and signal connections don't touch one another.

If you leave a border of ¾″ or so around the outside of the card, you could mount it on top of a wooden frame constructed from 1″ × 2″ lumber. This would look neater and would protect the underneath wiring, espe-

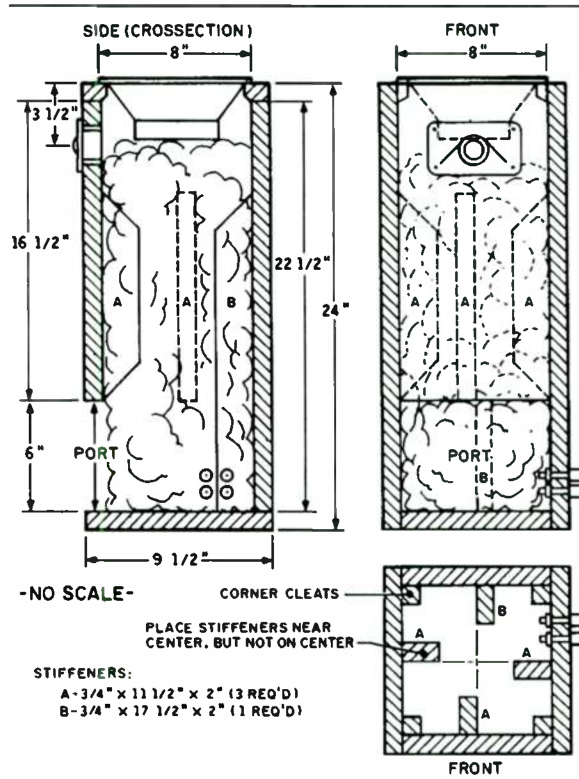


FIGURE 3: Assembling the box.

cially if you cover the bottom with a separate blank card.

ADDING CONTROLS

If this crossover is going between a preamp and an amplifier, it is probably finished. However, if you intend to plug it into the record-out jack of a receiver or the output of a CD player, you'll probably need to add a stereo volume control. You should hook this up between the input jacks on the jackboard and the actual inputs of the crossover. Don't hook up the loudness-control option.

The gain from receiver record-output jacks and the outputs of CD players is generally less than the gain from the output of a preamp, so situations of this type will probably lead to slightly reduced speaker output levels compared to the use of a preamp. Radio Shack carries a suitable audio-taper stereo volume control.

If the power amplifier you select doesn't have level-setting controls, you may add them between the outputs of the crossover and the inputs of the amplifier channels. I have used 100kΩ audio-taper pots from Radio Shack for this purpose with great success. You can mount both the volume control and the level-setting controls on the cardboard crossover panel (*Fig. 1*).

STUFFING AND GLUING

You should stuff the Squatline with 16 oz of Acousta-Stuf or polyester fiberfill pillow stuffing. If you use the pillow stuffing, pull out any tight knots that sometimes occur in that material. I don't recall ever seeing such knots in Acousta-Stuf. The 16 oz provide a stuffing density of about 1.375 lbs/ft^3, which works well here.

I built the original Squatline of ¾″ particleboard. Cut out all parts and see that they fit together properly. I recommend that you preglue all the joints before assembly. This simply means brushing a coat of glue on both sides of each joint and letting it dry. Then glue as usual when assembling.

I prefer to use white glue, such as Elmer's or Wilhold. It is cheaper than the yellow carpenter's glue, such as Tite-Bond, which is also an excellent glue. The white glue is also a good medium for doping speaker cones, when that is desirable, so it's nice to have some around.

TABLE 3

SQUATLINE PARTS LIST (for a pair)

The Squatline is constructed from ¾″ particleboard.

4 ea	9½″ × 24″	sides
2 ea	8″ × 22″	back
2 ea	8″ × 16½″	front
4 ea	8″ × 9½″	top/bottom
6 ea	2″ × 11½″	stiffeners front/sides
2 ea	2″ × 17½″	stiffener back
4 ea	¾″ × 16½″	front–corner cleats
4 ea	¾″ × 22½″	back–corner cleats
2 ea	#295-220	Dayton 8″ treated paper woofer
2 ea	#K010DT	(I believe the current # is 810665) Peerless 1″ dome tweeter

32 oz Polyester fiberfill or Acousta-Stuf
4 pr Speaker input terminals of your choice

For the second-order crossover:
6 ea 10kΩ ¼W carbon or metal-film resistors
2 ea Rx (see *Table 1, Fig. 1*)
8 ea 5,600pF polyester or polypropylene capacitors
8 ea 2,200pF polyester or polypropylene capacitors

For the (optional) third-order crossover:
10 ea 10kΩ ¼W carbon or metal-film resistors
2 ea Rx (see *Table 2, Fig. 2*)
12 ea 3,300pF polyester or polypropylene capacitors
12 ea 1,800pF polyester or polypropylene capacitors
12 ea 4,700pF polyester or polypropylene capacitors
12 ea 3,900pF polyester or polypropylene capacitors
1 ea 8-jack RCA jack board, Radio Shack #274-370 (only 6 jacks are used)

Optional (if required):
1 ea 100kΩ stereo volume control, Radio Shack #271-1732
2 ea 100kΩ audio-taper potentiometer, Radio Shack #271-1722

Miscellaneous:
16 ga zip cord, Mortite, white glue, 16 ea #6 × ¾″ sheet-metal screws (to mount speakers), DAP Kwik Seal (or RTV), hook-up wire (for crossovers)
Dayton 295-240 woofers from Parts Express, (800) 338-0531
Peerless 810665 tweeters from A&S Speakers, 3170 23rd St., San Francisco, CA 94110.
Crossover resistors and capacitors from Digi-Key, (800) 344-4539

ORCA Design & Mfg Corp.
1531 Lookout Drive
Agoura, CA 91301 - USA
tel. (818) 707 1629
Fax: (818) 991 3072

ACCESS

by FOCAL

ORCA is bringing to you from France a whole new and exclusive line of fine drive units specifically designed by Kimon Bellas, ORCA, and by Gilles Brun, FOCAL SA. Why ACCESS ?

Well think of ACCESS as "entry level", "first step". In clear, these drive units have been designed in such a way that any beginner using no other measuring instrument than a set of good ears should have 100% success designing his first system. Indeed most of these units will do great without any X-over part, or at the most with a single inductor. Now don't be fooled, nothing is more difficult to engineer than a drive unit that is easy to use. Experts do know that. And expert designers will be the first ones to dive into the ACCESS catalog !

Also, think of ACCESS as "affordable". That maybe was the toughest challenge for us: to bring you this degree of performance and ease of use at the cost of ordinary paper cone units. We did not cut corners, we cut cost through good engineering. All units feature the finest hand coated paper cones (still an art at FOCAL), alloy cast frame and, needless to say, the legendary quality of FOCAL craftsmanship. The same hands who are making the world renown FOCAL drive units are making your ACCESS drive units.

Makes sense to you ? Call ORCA for your catalog. It includes full description of each unit, large scale curves and graphs, all parameters, and two computer simulated bass response for each ACCESS unit.

ACCESS 4A	Quick, high definition 4" midrange. Wide bandwidth (up to 12 KHz !). A natural and easy match for a highly transparent tweeter. . You pick the frequency and you pick the slope !
ACCESS 4B	Potent & detailed 4" midbass. Clean up to 7 KHz. Very robust low end. Ideal for mini audio-video systems and very small size high quality speakers.
ACCESS 5A	Efficient 5" midrange. Smooth. Superb definition. It needs a good 91-92 dB tweeter for an effective match. Great for surround systems and for high quality high output 3-way designs.
ACCESS 5B	Solid 5" midbass, in the FOCAL tradition. Gentle roll-off around 4 KHz. Like most other ACCESS units, it can be used both in sealed and in vented cabinet designs.
ACCESS 6A	Efficient (92 dB +) and transparent 6" midrange. A single inductor might be all you need to get the quintessence of this beautiful drive unit.
ACCESS 6B	Surprising weight in the low end, which is powerful and well defined. This little woofer does not seem to be much embarrassed by any signal.
ACCESS 7A	Extremely smooth 7" midrange/midbass. Excellent prospect for a simple efficient 2-way bass reflex , It can also be used in surround systems main speakers, with or without a subwoofer.
ACCESS 7DB	Outstanding 7" dual voice coil midbass. Powerful, crisp and efficient, this drive unit will play anything your amplifier will throw with panache and relentless enthusiasm.
ACCESS 8A	Very efficient (93 dB +) 8" midrange/midbass. One of the truly rare 8" that can be used in 2-way designs. You will need a very good and efficient tweeter to match this unit (at least 92 dB/W/m)
ACCESS 8DB	Outstanding 8" dual voice coil midbass. Efficient, smooth and crisp sounding it is also capable of handling large dynamics and true low frequencies with the authority of a much larger woofer.
ACCESS 10A	Impact & dynamics (94 dB/W/m). If a 10" midbass can make it to the tweeter range, this is the one. Its nearly perfect roll-off will allow direct wiring without filtering. Rare unit for 2-way 10" designs !
ACCESS 10B	Deep and musical 10" woofer. Ideal for medium size 3-way systems , with one of the 4", 5" or 6" ACCESS midranges. A classic.

Reader Service #62

After the glue dries on an assembled part, reglue it for strength to make sure it is sealed. To prevent excess running on vertical joints when regluing, mix a little talcum powder or cornstarch in the glue, but don't make your mixture dry like plastic wood. It should be a thick liquid, not a dry paste.

First, glue the enclosure top to one of the sides. Then, add the front, back, and bottom. If you are nailing, it would be better to glue and nail the stiffeners to the various panels that have them prior to assembling the panels onto the enclosure (*Fig. 3*).

WIRING

At this point, allow the glue to dry and put on the second coat. After this dries, cut out the speaker holes and install the speaker input terminals of your choice, but don't forget to install two sets (four terminals). This is a biamped system. Also be sure to place the terminals on opposite sides to provide a right- and left-hand speaker system for stereo. The terminals are on the sides so you can place the Squatline as close to the rear wall as possible.

Add ¾″ × ¾″ corner cleats (they may be cut from particleboard) to the long inner sides of the enclosure. Bevel the inner corner of each cleat to fit over the glue fillet and rest squarely in place. Preglue the cleats and their matching surfaces, using plenty of glue. Don't bring the cleats into the port area; they should not extend beyond the bottom edge of the front panel.

When the glue has dried, place the Squatline on its side with the so-far-nonexistent side facing up. Place blocks under the lower side to accommodate the protruding terminals (if they do in fact protrude). Make sure the stiffener on the still-loose panel has had its second glue treatment and has dried. Wire the terminals. Use 16-gauge zip cord or your preference for the wiring.

MORE STUFFING

After wiring, place the stuffing in the enclosure as evenly as reasonably possible. Stuff beneath the speaker wires so they won't vibrate against the walls. The wires should protrude from the correct speaker holes when you have finished stuffing, and should be marked (with color coding or small gummed labels) as to where they go.

Before adding the final side, press the stuffing down a bit where it comes close to the surfaces to be glued. Place a rather large bead (¼″) around the upward-facing edges and a similar bead around the upward faces of the corner cleats. After again making sure the stuffing is out of the way, line up the side panel and fasten it in place using nails or weights. Then wipe off the excess glue with a damp paper towel.

Let everything dry overnight. Brush a ring of glue around the outside of the woofer hole (about an inch wide) and under the area of the tweeter plate. This will provide a better sealing surface when you mount the speakers. You can also bevel the two front vertical corners and the two side and front corners of the top plate to improve the appearance and help reduce diffraction effects. If you plan to put on a finish, this would be the time to do it.

Hook up the speakers, making sure you wire them correctly. Seal them with Mortite or other sealant, and you're done.

AMP ADJUSTMENTS

Insert the crossover between your preamp and amplifiers, or between the record-out jacks or CD player and amplifiers. My Squatline sounds best when the woofer amplifier is adjusted for maximum output and the tweeter amplifier is set to slightly less than maximum output. (The pointer on the ½″-diameter level-set knob is rotated back about 3/16″ from maximum output.) This adjustment assumes that both of your amplifiers have the same input sensitivity. I used both channels from the same amplifier to help make this reference setting accurate (at least for a ball-park setting). Set the volume control rather low when first starting up, just in case you didn't wire correctly.

If things sound reasonable, you can proceed to make the following tests: first, listen to the system as it stands. Then turn it off and reverse the leads of both tweeters. Again, listen to the system. One of the two wiring systems should sound rather fuller, and the woofer and tweeter will sound as a more coherent unit, rather than just as a woofer and tweeter. It helps to walk back and forth in front of the speakers while listening. Retain the wiring scheme that sounds the best. At this point, you can revise the amp level settings to your taste.

Unless you are certain the amplifiers you are using have noninverting outputs, you should do the following (some amplifiers do have inverting outputs, although this fact is seldom, if ever, noted in the accompanying owner's manual). First, critically listen to several of your better CDs with the current speaker wiring in place. Then turn off the system and proceed to change the polarity of all the speaker connections on both channels. In other words, reverse both the tweeter and woofer connections on both channels. So now you have your speaker connections in reverse of what they were when you just listened to the system.

CRITICAL LISTENING

At this point, again critically listen to the same CDs. If the recordings you use contain music that has been multimiked or otherwise subjected to questionable situations, this may not be a definitive test, but if the engineer used minimal-miking on, say, a live situation, you may find one wiring arrangement sounds better than the other.

Or, maybe one CD sounded better in the first situation and the others sounded better in the second. In this case, you have discovered that at least one of your CDs has been recorded in the opposite polarity from the others. Unfortunately, this is all too common. I have a dozen or so of these odd-balls.

I used to have an in-line switch on my amplifier output leads to change polarity. With biamping, that becomes a bit complicated, and if you use big fancy wires, it approaches the impossible. You could add a switchable inverting stage after the preamp. I've done this and added a headphone output.

The simplest remedy is to separate your CDs into two piles, as you discover the odd-balls, and some day, when you can't wait any longer, reverse your wiring and listen to the darn things. It's sad that two of the gadgets most needed today—the reverse polarity switch and the dynamic signal compressor (at least as far as the consumer market goes)—have gone down the road to obsolescence. Where is the sanity of it?

I hope you enjoy your Squatlines.

EPILOG

Since I originally wrote this article, a few months ago, further thoughts and consequent research prompted me to raise the stuffing density of the Squatline from about .84 lb/ft^3 to about 1.375 lb/ft^3, a difference in the amount of stuffing from 10 oz to 16 oz. This results in a more solid bass foundation and possibly a greater overall smoothness. This change would also benefit my Simpline Sidewinder Woofer (*SB* 4/95, p. 8).

I have also developed a very simple high-pass filter for those who would prefer not to get into the expense and cost of biamplification and yet would like to construct the Squatlines. I was frankly quite surprised at just how closely this simple filter allowed the Squatline to match the biamped version.

The filter has only two elements: a 6µF capacitor in series with an 8Ω variable L-pad (such as Parts Express #260-250). Parts Express also carries the recommended Solen polypropylene capacitors (#027-542). Two of these must be used in parallel as they are only 3µF each.

When constructing the filter, place the L-pad between the capacitor and the tweeter positive (red) terminal. The filter goes between the amplifier output and the tweeter input. The capacitor goes to terminal 3 of the L-pad. The positive terminal of the tweeter goes to terminal 2 of the L-pad. The negative terminal of the tweeter and the negative input terminal of the Squatline both connect to L-pad terminal 1. The remaining end of the capacitor connects to the positive input terminal of the Squatline.

This filter may be mounted close to the input terminals of the Squatline, which are mounted on the side of the enclosure to allow the Squatline to snug up close to the wall, which is where he sings best. Ultimately, the biamped version does give a bit better sound (I think), but many will prefer the savings to the slight sound edge.

Even if not used in this case, I feel that the passive line-level crossovers presented here, and with the Simpline Sidewinder Woofer article, are wonderfully viable solutions wherever biamping is required (especially the second-order versions), whether it be for a tweeter, midrange, or a subwoofer. In the few cases where its rather severe restraints can be met, the HDOLLP is a fine, inexpensive contender.

THE ADRIA: A SATELLITE SUBWOOFER SYSTEM

By Michael E. Hildebrand

After three years of living with full-range speakers based on the Aria 7 design, with cabinets in the tradition of Hales Audio (185 lbs each), I decided it was time for a change. I was no longer happy with the sound—and the ridiculousness of 370 lbs—and I felt I could "push the envelope." Also, being a speaker builder, I just love to build speakers. I decided it was time to return to the satellite-subwoofer type of speaker system that I've had in the past (*Photo 1*). I already had what I believed to be good drivers for the satellites: the Focal 7KO11-DBL and T120ti.

PHOTO 1: Author's completed system with stands.

CHOOSING MATERIALS

I wanted cabinet rigidity in the Adria, but not at the cost of excessive weight. I've used PVC pipe for the acoustic volume in previous speakers with great results, so I decided to use it for the volume in the satellites (*Photo 2*). This provides exceptional damping, yet it's light.

There are several other advantages to using PVC tubing rather than wood boxes; the late Peter Mitchell thoroughly discussed this subject in *Stereophile* (Mar. '91, p. 97). As a driver moves back and forth in a cabinet volume, it compresses and expands the air inside the cabinet, like a balloon inflating and deflating. When air in a sealed box expands or contracts, the corners of the box remain rigid, but the middles of the panels "bow" in and out.

When air expands in a tube, however, this doesn't happen. A tube's material would have to literally "stretch and shrink" because the expansion/contraction forces are distributed evenly along the entire circumference of the tube. The tensile strength of a pipe is much greater than a wood panel's resistance to bending, so the pipe will change very little under pressure. This is why tubes such as water pipes and gas lines can withstand enormous internal pressures. The round pipe, as used here, also eliminates corners and reduces strange standing-wave patterns inside the cabinets.

DESIGN DETAILS

I designed the Adria's satellite cabinets around 8″-diameter PVC pipe, covered on the interior with several coats of Acoustic Magic borosilicate paint. I acquired the pipe as scrap from housing-construction sites in my area, but you can buy it at plumbing-supply and hardware stores. I built the cabinets with the sides at an 80° angle, providing a narrower baffle surface at the tweeter end of the cabinet that helps reduce diffraction and reflection from the baffle.

I cut the panels as indicated in *Fig. 1* and

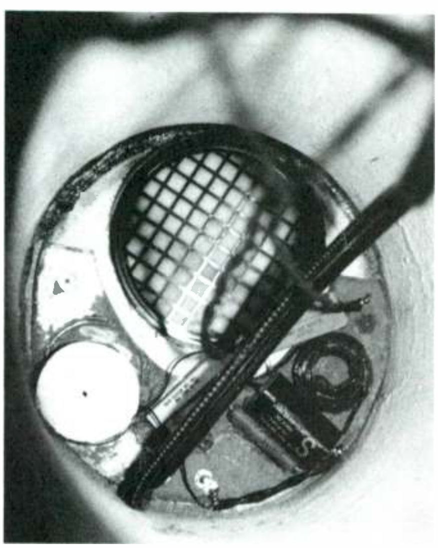


PHOTO 2: Interior of midbass cavity. PVC pipe coated with Acoustic Magic, low-pass crossover, scan vent. Three screws hold crossover and binding posts in place to facilitate removal for upgrade/repair.

PHOTO 3: Front baffle of satellite. Note tweeter (felt) ring, Black Pad material on baffle, Allen-head bolts for midbass driver.

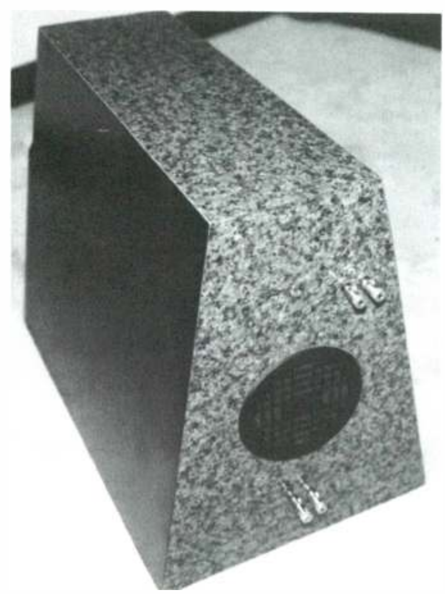


PHOTO 4: Rear of satellite cabinet. Note scan vent, biwiring binding posts, and formica pattern.

PHOTO 5: High-pass crossover. Note the size of the 2mH coil from North Creek Music, as well as IAR Wonder Cap.

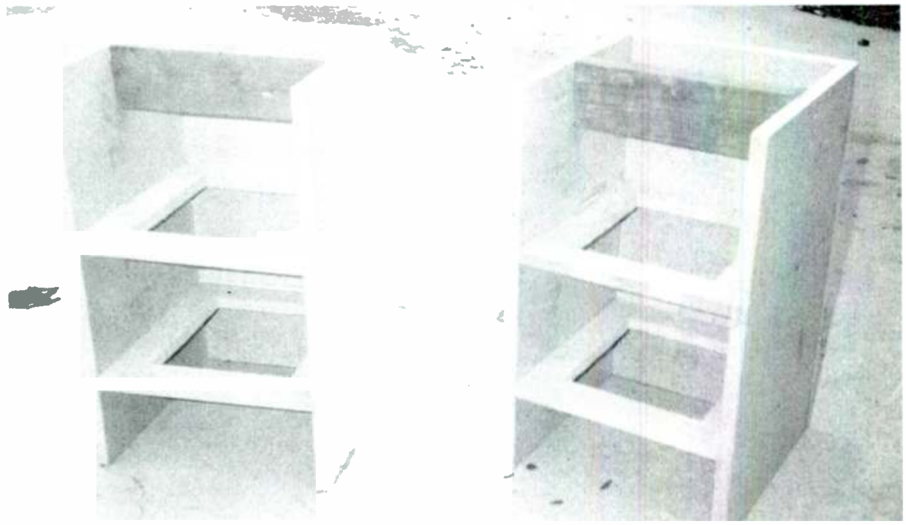


PHOTO 6: Cabinet design.

then, setting the table-saw blade to 80°, sheared off the corners. I believe that time alignment makes an audible difference, so I utilized a "stepped" baffle to bring the 7KO11 into close alignment with the T120ti (*Photo 3*). You do this by doubling up ¾″ particleboard on the lower half of the baffle (*Figs. 2* and *3*). As a side effect, this makes the baffle for the mid bass 1½″ thick for extra rigidity.

I then covered the entire baffle with two thicknesses of Black Pad from Zalytron, trimmed to be flush with the drivers on the baffle. After warming the Black Pad in the sun to make it more pliable, I put it on the baffle and trimmed it along the baffle's edge with a carpet knife.

The Black Pad was scuffed and dull looking, and a friend suggested that I coat it with Armor All, which worked beautifully. If you apply Armor All as a finishing step on Black Pad, you should spray it on a rag and then rub it on the surface to avoid over-spray onto the drivers.

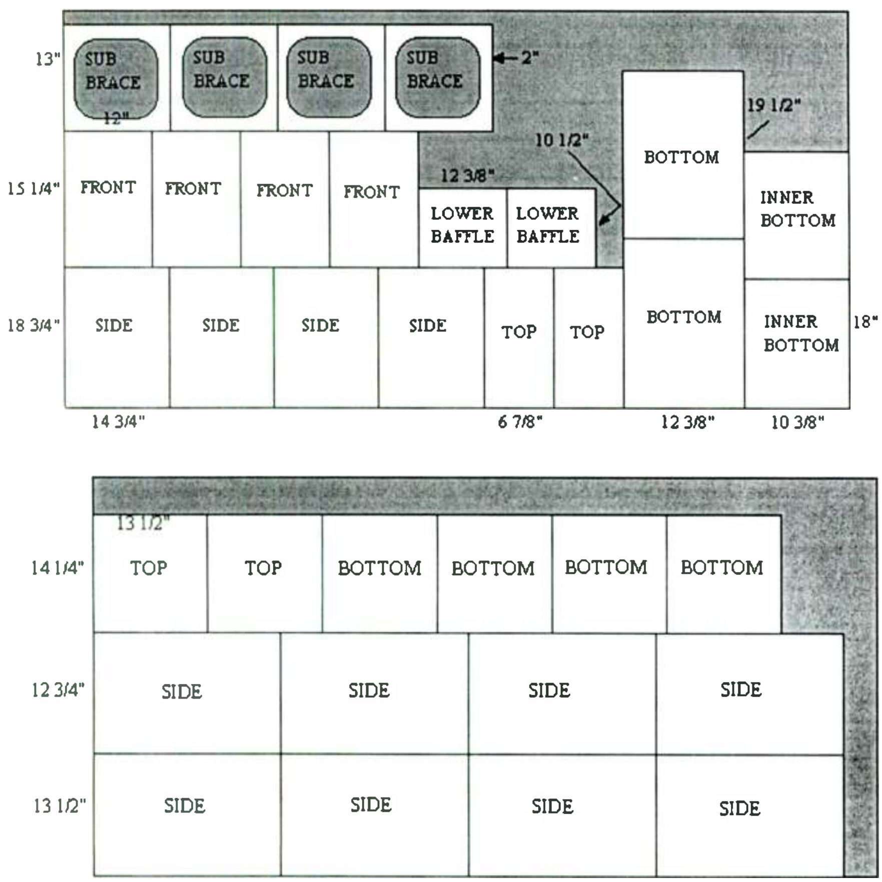


FIGURE 1: Satellite (upper) and subwoofer (lower) cutting guides.

DAMPING

I damped the acoustic volume with Acousta-Stuff and installed a scan vent on the rear of the cabinet for aperiodic loading (*Photo 4*). This type of bass loading yields very good-sounding bass. The PVC pipe, along with the brace above it and the bottom panel, creates four corners in the lower half of the cabinet (*Fig. 3*).

I filled the bottom cavities with silica sand, baked in shallow pans in an oven with low heat to ensure that it is bone dry; this is very important. The sand adds weight, of course, but these speakers are still easy to lift and maneuver. You might wonder why I damped them so much, since these are satellite speakers and the low bass will be filtered out. Yes, they are satellites, but I and many other speaker builders don't like limitations, and it's possible that these speakers will occasionally operate full range, at which point the extra damping will be beneficial.

I filled the top cavities of the lower half of the cabinet with aerosol expanding foam. But a warning: This material is incredibly messy, sticky, and difficult to work with, and it does *not* come off anything once it's on! Wear rubber gloves and be very careful to avoid getting it on anything important.

I rounded the interior of the midbass driver hole with a ¾″-radius round-over router bit and painted it with several coats of Acoustic Magic. I mounted the 7KO11s with T-nuts and Allen-head bolts, and for the binding posts (four per speaker) used gold-plated brass (*Photo 4*). Finally, I finished the cabinets with black formica on the sides and green marble-type formica on the top and rear.

PHOTO 7: DV-12. Note rubber surround, stair-railing feet, aperiodic holes, and binding posts.

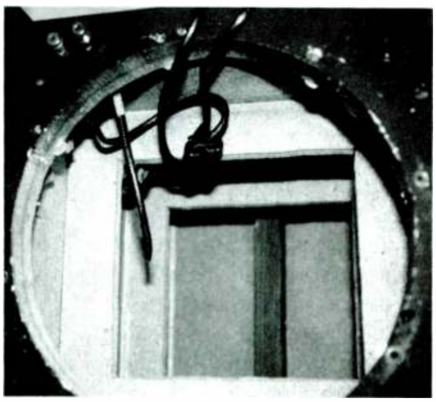


PHOTO 8: Interior of subwoofer cabinet (stuffing removed). Note two braces and 2 × 4 brace, as well as the doubled-up baffle. Low-pass crossover is visible as well.

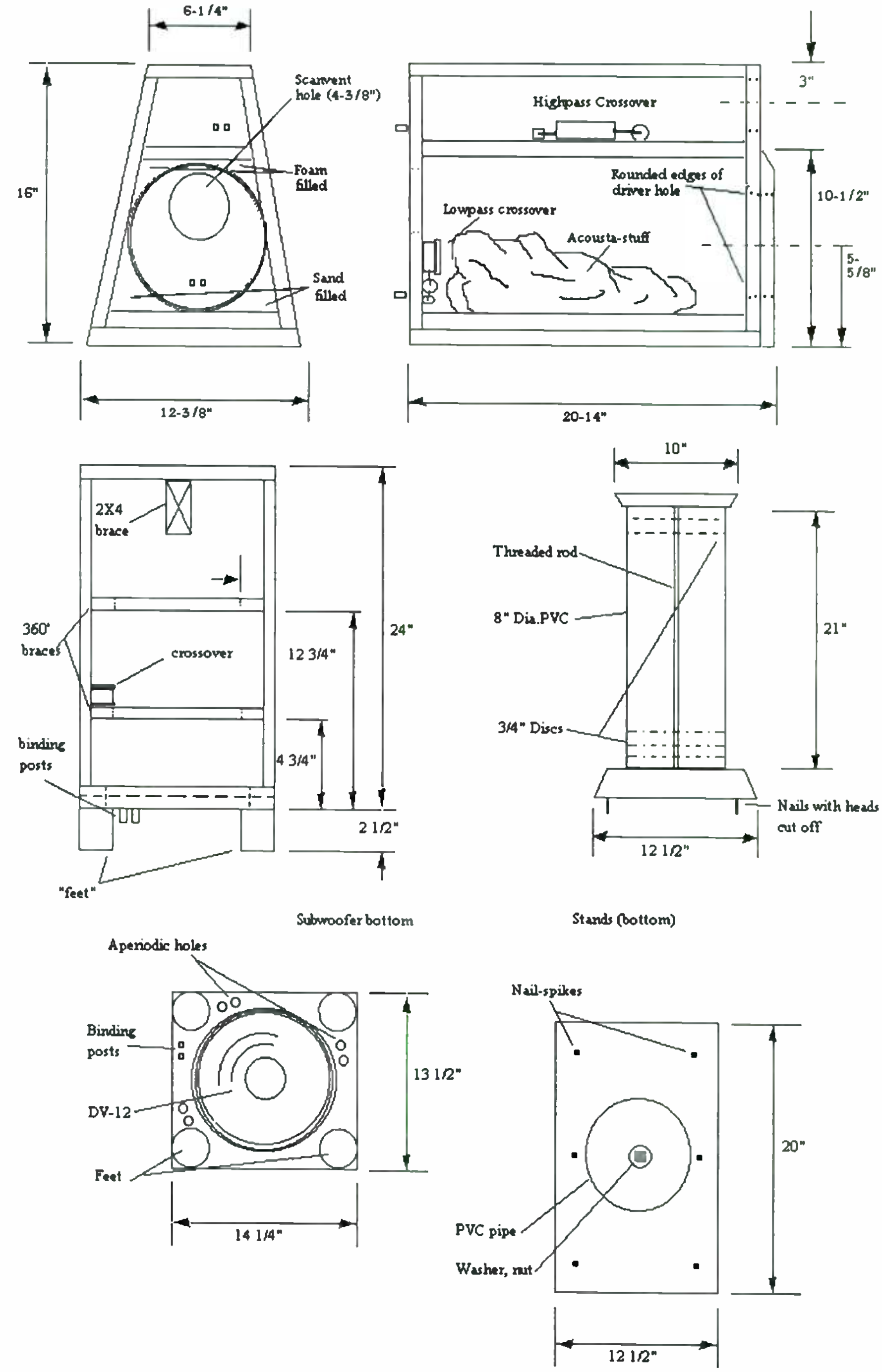


FIGURE 2: Construction details.

CROSSOVER AND WIRING

I have had good results with biwiring and physically separating crossover sections, so I continued that practice in these speakers. Mike Chin's article "Magnetic Crosstalk in Passive Crossovers" (*SB* 5/90, p. 64) was very helpful in this regard. The crossover design is based on an old A.C. kit, which I modified, modernized, and rebuilt with the highest quality components I could find (*Fig. 4*). These include North Creek Music Systems' 14-gauge, 2mH coils (the size of hockey pucks!), Ohmite resistors, and Sprague capacitors, as well as IAR Wonder Cap capacitors from Audio Concepts.

I used silver solder from North Creek throughout the crossover, soldered the drivers direct, and used no slip-on terminals (*Photos 2* and *5*). The internal wiring is Audio Quest's Indigo. Another benefit to biwiring satellites when using a subwoofer with a passive crossover is that you can bypass the tweeter from the high-pass section of the sub crossover and go directly to the tweeter from the amplifier. This prevents a large capacitance from degrading the tweeter's sound.

SATELLITE STANDS

I made the stands for the satellites with a 1½"-thick base of particleboard, a 21"-tall piece of 8"-diameter PVC pipe (3/5 sand-filled), and a ¾"-thick top plate (*Fig. 3*). The sand-filled stands alone are not unmanageably heavy, and they are very stable, providing solid foundations for the speakers.

I drilled four holes 1 1/8" deep towards the corners of the bottom of the base and installed nails with their heads cut off for spiked feet. The base of each stand has formica to match the speakers (black on top and green marble on the sides, front and rear), and I covered the PVC pipe with a sewn "tube" of grille cloth, tucked into each end of the pipe.

I cut ¾" particleboard disks to fit exactly inside the PVC pipe (three at the bottom and two on the top). These are glued and screwed to the base and top of the stand, and screws are driven through the PVC pipe into the discs to anchor the pipe firmly. A 22¼"-long threaded rod having large, flat washers (called "fender washers") and nuts on each end serves to clamp the whole thing together. The stands are extremely rigid and well-damped, and they look great.

HOME AUTO

THE SPEAKER WORKS, INC.

1021 E. Camelback Rd.
Phoenix, AZ 85014
(602) 230-0344 FAX (602) 230-8533

VERSA-TRONICS INC. QUALITY SPEAKERS

Woven Carbon

DOB100R-WCC/8 4"

- Woven Carbon Cone
- Rubber Surround
- Kapton Voice Coil
- Cast Allumalloy Basket

Specifications

Impedance	8 Ohm
Resonance	65 Hz
Upper Frequency	12,000 Hz
SPL 1/W/1M	83 dB
Power Handling	50 W
Qts	0.45
Vas	3.75 L
Voice Coil	25,5 mm
Magnet	10 Oz.

$26.60 EA

EOB130R-WCC/8 5-1/4"

- Woven Carbon Cone
- Rubber Surround
- Kapton Voice Coil
- Cast Allumalloy Basket

Specifications

Impedance	8 Ohm
Resonance	40 Hz
Upper Frequency	7,000 Hz
SPL 1W/1M	88 dB
Power Handling	60 W
Qts	0.21
Vas	21.55L
Voice Coil	25,5 mm
Magnet	13.3 Oz.

$34.12 EA

FQB165R-WCC/8 6-1/2"

- Woven Carbon Cone
- Rubber Surround
- Excellent Damping
- Cast Allumalloy Basket

Specifications

Impedance	8 Ohm
Resonance	36 Hz
Upper Frequency	5,500 Hz
SPL 1W/1M	88 dB
Power Handling	80 W
Qts	0.24
Vas	27.83 L
Voice Coil	35,5 mm
Magnet	18 Oz.

$46.58 EA

GQB210R-WCC/8 8"

- Woven Carbon Cone
- Rubber Surround
- High Power Handling
- Cast Allumalloy Basket

Specifications

Impedance	8 Ohm
Resonance	33 Hz
Upper Frequency	5,000 Hz
SPL 1W/1M	90 dB
Power Handling	100 W
Qts	0.20
Vas	54.15 L
Voice Coil	35,5 mm
Magnet	30 Oz.

$63.69 EA

NEODYMIUM

RARE EARTH MAGNET TWEETERS WITH
REPLACEABLE DOME/VOICE COIL

Specifications

Impedance	8 Ohm
Resonance FREQ: Fs	1500 Hz
Frequency Response:	20,000 Hz
Dome Material:	Drawn Titanium
Suspension:	Supronyl
Voice Coil:	25,4mm
Layers:	2
Winding Length:	2.0 mm
Former:	Titanium
Magnet:	Rare Earth neodymium
SPL:	90dB 1/W/1M
Rated Power:	*100W

*Music Power

66-25Neo/8F
$21.14 EA

49-25Neo/8F
$20.88 EA

All above drivers available in 4 Ohm

Versa-Tronics also offers WOVEN CARBON cones in high-quality 10 and 12 inch woofers as well as counterparts to the listed drivers in WOVEN FIBERGLASS cones at slightly lower costs. The ultimate value from Versa-Tronics is their POLYPROPYLENE cone line of 4 to 10 inch drivers.

ANY QUESTIONS? — CALL US

We accept VISA – MasterCard – Check — No C.O.D.

220 PAGE CATALOG $10.00

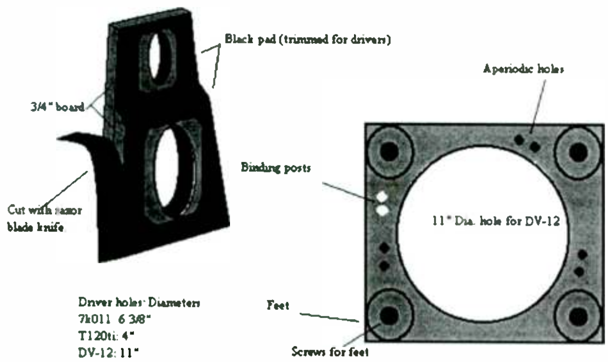


FIGURE 3: Satellite construction.

SUBWOOFER CONSTRUCTION

The stereo subwoofers are much more straightforward and simple to make (*Figs. 2* and *3*; *Photos 6–9*). I made the cabinets from ¾″ particleboard and placed two 360° braces at unequal distances in the cabinets to distribute resonances. Each sub contains three 6′ pieces of bonded Dacron damping material, with one piece stuffed into each section created by the braces. These subs are heavily damped! The baffles are 1½″ thick, with six ½″ aperiodic holes drilled in each one.

I used Audio Concepts' DV-12 drivers, having had great results with them in the past. It's a shame they're no longer sold by A.C., but you can get them from Meniscus (see "Sources"). I anchored the DV-12s with T-nuts and screws, but forgot to install the T-nuts before attaching the baffle. By drilling the holes for the screws and then putting the T-nuts in the bottom of the baffle, I was able to use the screws (with big washers) to "pull" the T-nuts into the wood of the baffle, and this worked fine.

The drivers face the floor, and I raised

to page 36

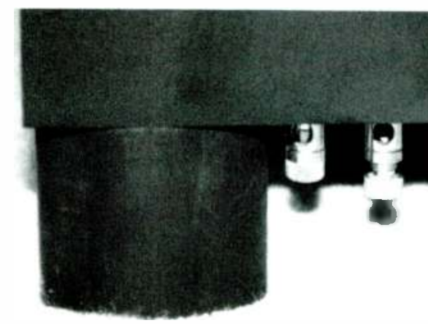


PHOTO 9: Subwoofer feet and binding posts.

TABLE 1
ADRIA PARTS LIST
DV-12 subwoofer cones (2)
Acoustic Magic paint (1 qt)
Scan vents (2)
Felt tweeter rings (2)
12mH, 0.9 DCR ferrite bobbin coils (2)
4mH, 0.35 DCR ferrite bobbin coils (2)
7mH, 0.55 DCR ferrite bobbin coils (2)
0.15mH, 0.16 DCR air-core coils (2)
200µF, 50µF, 100µF N.P. capacitors (1 of each)
100µF, 12µF Solen capacitors (2 of each)
0.68µF, 0.47µF IAR Wonder Caps (2 of each)
50Ω (2), 15Ω (4), 7.5Ω (2), 5Ω (4) resistors
Bonded Dacron (36′)
Acousta-stuff (1 bag)
2mH, 0.31 DCR 14-gauge air-core coils (2)
3µF Sprague capacitors (2)
8.06Ω Ohmite resistors (4)
6.19Ω Ohmite resistors (2)
Ersen Multicore silver solder (1′)
Focal 7KO11.DBL midbass driver (2)
Focal T120ti tweeter (2)
Black Pad (two sheets; 20″ × 20″)
Axon 8 Wire
Binding posts (6 pr.)
Particleboard (two 4 × 8 sheets)
8″ diameter PVC pipe (scrap from construction sites)
Formica (two 4 × 8 sheets)
Audioquest "Indigo" wire (internal wiring)
Silver solder from Radio Shack

FYI² AUDIOPHILE SWEEPSTAKES

What's the most important component in an audio system?

WIN!

Answer this question using the FYI² QUIZ

Answer these trivia questions below by filling in the blanks. Unscramble the circled letters. They spell out a phrase that answers the sweeps question above. We're giving you one free "OF" to start with. Write your answer on the coupon on this page or on the Reader Service Card attached to the magazine and send it in. Winners will be chosen from entries with correct answers.

1. Gilbert & Sullivan's Captain of the Pinafore is never _ (_) (_) _ at sea.

2. First name of the country singer and Taco Bell spokesman credited with writing Patsy Cline's hit song *Crazy*?

   _ _ _ _ _ (_)

3. In an attempt to deal with his alcoholism, composer Sibelius moved to a suburb of this city in Finland

   (_) _ _ _ _ _ _ _ _

4. Paul McCartney's first name.

   _ _ _ _ (_)

5. Alice's Restaurant was how far from the railroad track?

   _ _ _ _ / _ / (_) _ _ _

6. In his later life, what did Beethoven remove from his piano? _ (_) _ (_)

7. Conservative parents of the 60s were outraged by the metaphor for drug indulgence assumed to be represented by this loveable character in a popular folk song. _ (_) _ _

8. Before the "The Grateful Dead," what was the name of Jerry Garcia's band?

   _ _ _/_ _ (_) _ (_)(_) _ _

9. Jazz great Dave Brubeck's big pop/jazz 5/4 hit tune:

   (_) _ _ _/_ _ _ _

10. *Wayne's World* theme "Bohemian Rhapsody" was performed by

   _ (_) _ _ _

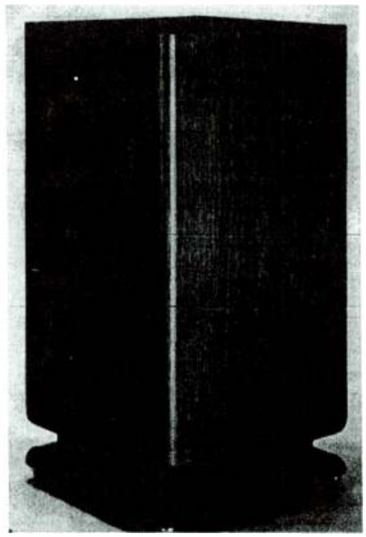
The most critical component in an audio system? Solve it:

_ _ _ _ _ _ _ _ _

O F _ _ _ _ _ _ _

FYI Audiophile Sweepstakes is void where prohibited by law. All entries must be postmarked by July 31, 1996. To obtain a free sweeps entry, send a self-addressed stamped envelope to AAPI, PO Box 576, Peterborough, NH 03458. Employees and relatives of of Audio Amateur Publications are ineligible for this sweepstakes.

Correct answers qualify to win these great prizes!

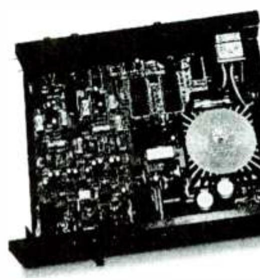


1st PRIZE

The TITAN POWERED SUBWOOFER from ACI

The *Stereophile* Recommended Component Titan is regarded as one of the most "musical" subwoofers on the market. Extended, clean, articulate response to 20Hz. The Titan will improve virtually any high-quality speaker system.

The Parts Kit includes everything you need to build a Titan except the cabinet. We supply the specially designed 12" woofer and a pre-assembled and tested electronics module that features 250 watts RMS, current-sensing feedback, self-limiting and adjustable crossover frequency, volume and phase.



2nd PRIZE

DAC-1 DIGITAL PROCESSOR KIT

Assemblage DAC-1 Digital Processor kit. A great addition to your digital audio source, the Assemblage DAC-1 features dual Burr-Brown PCM1702 DAC's, Crystal CS8412 input receiver, NPC 5813 Digital filter, and Analog Devices AD844 and AD817 op-amps in a direct coupled class A output stage. As reviewed by Gary Galo in *Audio Amateur 2/95*. Compliments of **The Parts Connection.**

3rd PRIZE

The Gatekeeper

"a unique ac line conditioner kit" by **Welborne Labs.**

Name: ______________________

Address: ______________________

City: ______________ State: ______ Zip: ______

HERE IS MY ANSWER: ______________________

[ ] I'd like information from the advertisers in the following magazine:

{ } **Speaker Builder Issue** [ ] #1 [ ] #2 [ ] #3
{ } **Glass Audio Issue** [ ] #1 [ ] #2 [ ] #3

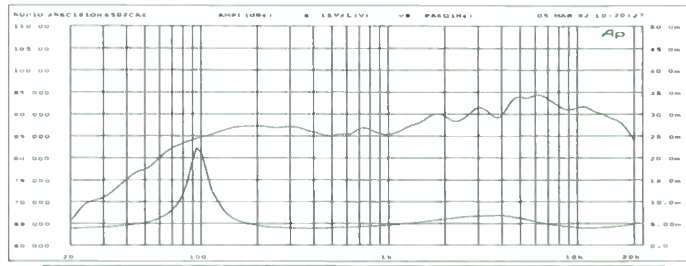
Reader: Please circle the reader service number as seen at the bottom of an advertisement in the magazine about which you want information, or use the card in this issue.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	07	08	99	100

Madisound's Coaxial Drivers

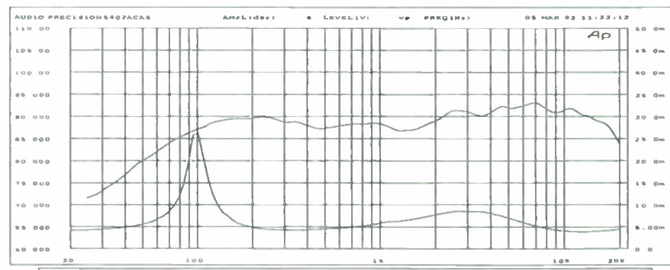
All of Madisound's coaxial speakers utilize AUDAX State of the Art ferrofluid cooled dome tweeters. Mylar 6db filters are included for the tweeter. All drivers have black polypropylene cones.

4502/Audax	
Fs	102 Hz
Vas	3.8 Liters
Rscc	3.7 Ω
Qms	7.77
Qes	.46
Qts	.43
Efficiency	88 dB 2.83V/1m
Power	40 Watts
Depth	2 1/16"
Cut-out	4"
Price	**$35**



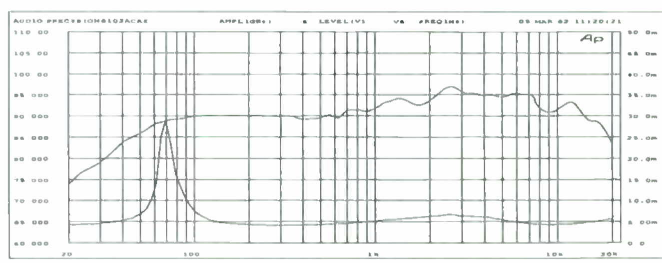
The 4502/Audax will work well in a small sealed enclosure, a 200mfd capacitor is recommended on the woofer.

5402/Audax	
Fs	91 Hz
Vas	5.42 Liters
Rscc	3.68 Ω
Qms	7.84
Qes	.60
Qts	.56
Efficiency	89 dB 2.83V/1m
Power	40 Watts
Depth	2 1/4"
Cut-out	4 7/8"
Price	**$36**



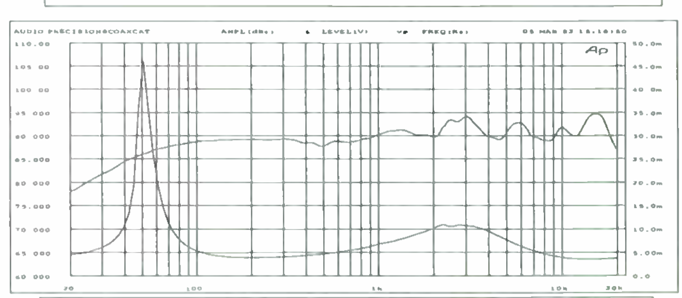
The 5402/Audax will work well in a 9 liter sealed box with an F3 of 115Hz. A 280mfd capacitor could be used to limit the bass when used with a subwoofer or when mounting the driver without an enclosure.

6102/Audax	
Fs	58 Hz
Vas	19.5 Liters
Rscc	3.6 Ω
Qms	6.5
Qes	.55
Qts	.51
Efficiency	90 dB 2.83V/1m
Power	40 Watts
Depth	2 7/8"
Cut-out	5 7/8"
Price	**$37**



The 6102/Audax will work well in a 10 liter sealed box with an F3 of 99Hz. A 280mfd capacitor could be used to limit the bass when used with a subwoofer. You may use this driver in a door without an enclosure.

8COAX	
Fs	38.4 Hz
Vas	38.9 Liters
Rscc	3.6 Ω
Qms	7.56
Qes	.44
Qts	.41
Efficiency	90 db 1w/1m
Power	75 Watts
Depth	3 3/8"
Cut-out	7"
Price	**$49.50**



The 8COAX can be used in a 14 liter sealed box for an F3 of 68Hz or a 28 liter vented box for an F3 of 44Hz (2" dia. vent by 4.4" length). Suitable for In-wall or ceiling mount applications.

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

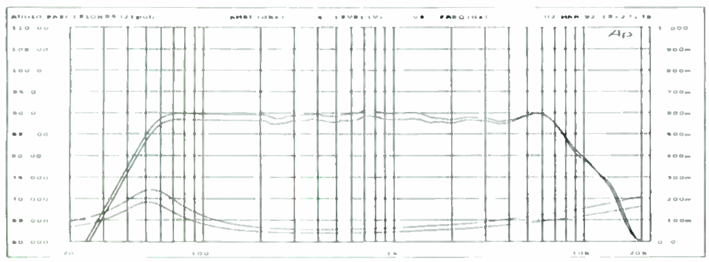
MADISOUND SPEAKER COMPONENTS
8608 UNIVERSITY GREEN
P.O. BOX 44283
MADISON, WI 53744-4283 U.S.A.
TEL: 608-831-3433 FAX: 608-831-3771
e-mail: madisound@itis.com
Web Page: http:/www.itis.com/madisound

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

	5102-4	5102-8
Fs (Hz)	50	52
Rscc (Ω)	3.28	4.73
VcL (mH@1K)	0.09	.12
Qms	1.50	1.41
Qes	.32	.33
Qts	.26	.27
Mmd (g)	6.13	6.5
Cms (μm/N)	1508.44	1353.76
Vas (Ltrs)	8.77	7.87
Efficiency (2.83V / 1m)	90	87
Xmax	1.5mm pk	
Power	50 w	
Magnet	12 oz	
Voice Coil	1" 2-Layer Kapton	
Cone	Black Poly	
Surround	Rubber	
Cutout/Depth	4.25"/2"	
Price	**$22.00**	

Rubber Surround

	Vented		Sealed	
	4 Ω	8 Ω	4 Ω	8 Ω
VB ltrs	2.1	1.9	1.4	1.3
FB Hz	75	78	-	-
F3 Hz	90	95	134	137
Port Diameter	1"	1"	-	-
Port Length	4.3"	4.5"	-	-



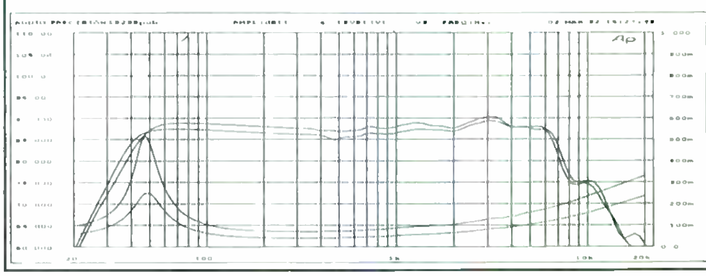
Madisound 5502R 5.25" Polypropylene Woofer 4 or 8 Ω

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

Rubber Surround

vented pole piece

	Vented		Sealed	
	4 Ω	8 Ω	4 Ω	8 Ω
VB ltrs	12	14	7	11
FB Hz	49	48	-	-
F3 Hz	50	49	80	71
Port Diameter	1.5"	1.5"	-	-
Length	3.5"	3.1"	-	-



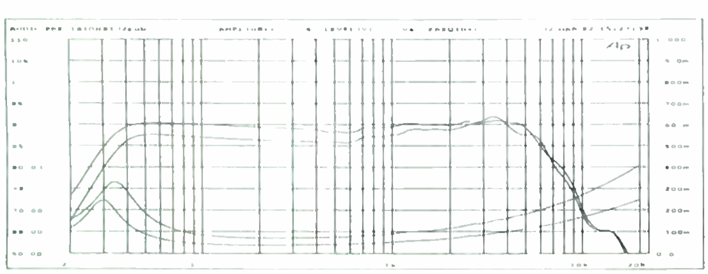
Madisound 6204R—6" Polypropylene Woofer 4 or 8 Ω

	6204R-4	6204R-8
Fs (Hz)	26.8	34.2
Rscc Ω	3.41	6.36
VcL mH@1K	.45	.70
Qms	2.68	1.80
Qes	.369	.457
Qts	.324	.364
Mmd (g)	11.3	13.3
Cms (μm/N)	2877.7	1524.5
Vas (ltrs)	71.9	38.3
Efficiency (2.83V / 1m)	90	87
Xmax	3.5mm pk	
Power	50 w	
Magnet	12 oz.	
Cone	Black Poly	
Surround	Rubber	
Voice Coil	1" 2-Layer Kapton	
Cutout/Depth	5.62"/2.87"	
Price	**$27.00**	

Rubber Surround

vented pole piece

	Vented		Sealed	
	4 Ω	8 Ω	4 Ω	8 Ω
Vb Ltrs	30	23	19	14
F3 Hz	40	42	58	66
Fb Hz	33	38	-	-
Port Dia	2"	2"	-	-
Length	5.7"	5.6"	-	-



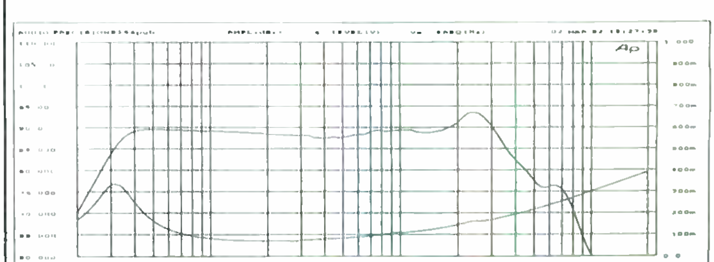
Madisound 8252R—8" Polypropylene Woofer 8Ω

Fs	31.6Hz
Rscc	6.35Ω
VcL @1K	.885mH
Qms	2.06
Qes	.45
Qts	.37
Mmd	23.6g
Cms (μm/N)	989.6
Vas	68 Liters
Efficiency (2.83V / 1m)	89db 1w/1m
Xmax	4.5mm pk
Power	75 w
Magnet	20 oz.
Cone	Black Poly
Surround	Rubber
Voice Coil	1.5" 2-Layer Kapton
Cutout/Depth	7.12"/3.37"
Price	**$39.00**

Rubber Surround

vented pole piece

	Sealed	Vented	Vented
Vb Liters	26	34	42
F3 Hz	60	43	39
Fb Hz	-	33	35
Port Dia	-	2"	2"
Length	-	5"	3.2"



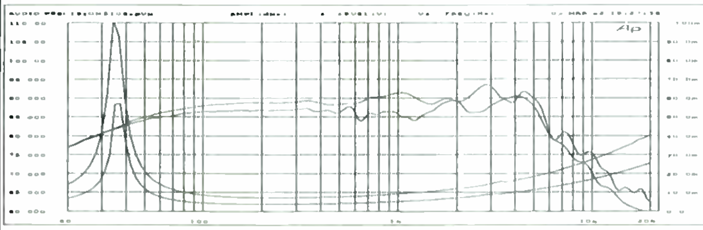
Madisound 6102 6.5" Polypropylene Woofer 4 or 8 Ω

	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 2.83V/1m)	90	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	**$25.00**	

vented pole piece

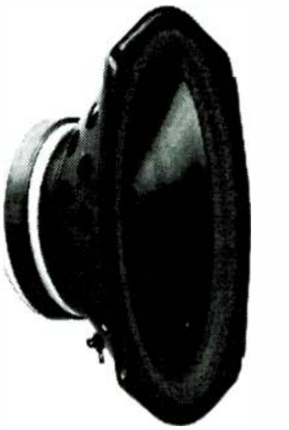
	Vented		Sealed	
	4 Ω	8 Ω	4 Ω	8 Ω
VB ltrs	18	40	11.4	28
FB Hz	36	30	~	~
F3 Hz	41	33	58	47
Port Diameter	1.5"	2"	Qtc= .7	Qtc= .7
Length	4.6"	5.2"	Rg=.4	Rg=.4

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

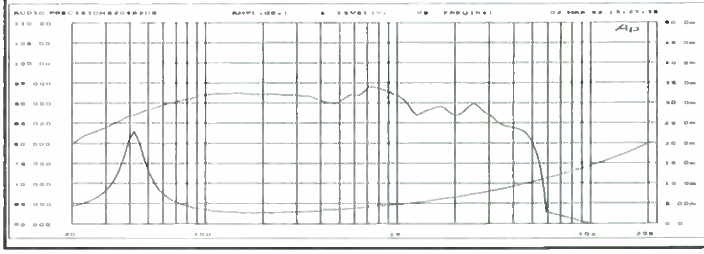


Madisound 6x9153 6"x9" Polypropylene Woofer 3Ω

Fs	38Hz
Rscc	2Ω
VcL @ 1K	.87 mh
Qms	3.77
Qes	.38
Qts	.35
Mmd	25,8g
Cms (µm/N)	626.46
Vas	37 Liters
Efficiency	91dB 2.83V/1m
Xmax (mm) pk	3
Power	75W
Magnet	20 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" Kapton
Cutout/Depth	Buy it, then cut!
Price	**$37.00**



6x9153 B4 Alignments			
Vb liters	12	14	22
F3 hz	78	56	46
Fb hz	Sealed	45	45
Port Dia	Qtc=.7	1.5"	1.5"
Length	-	3.7	2"

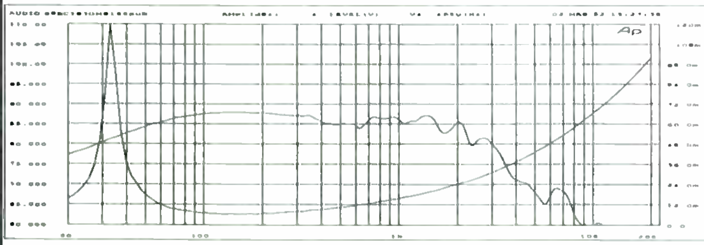


Madisound 8154—8" Polypropylene Woofer 8 Ω

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 2.83V/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	**$36.00**

vented pole piece

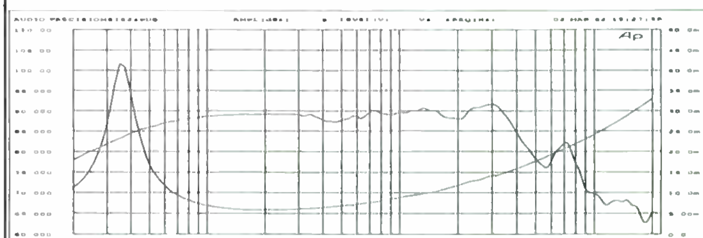
8154 B4 Alignments			
	Rg = 0	Rg = .4	Rg = .7
Vb Liters	15	19	23
F3 Hz	51	45	42
Fb Hz	46	43	40
Port Dia	2"	2"	2"
Length	6.1"	5.3"	5.1"



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 2.83V/1m
Xmax	3.5mm 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	**$35.00**

8152 B4 Alignments			
	Rg = 0	Rg = 0	Rg = .4
Vb Liters	30	50	63
F3 Hz	43	35	33
Fb Hz	34.8	34.8	32.5
Port Dia	2"	2"	2"
Length	5.1"	2.5"	2.2"

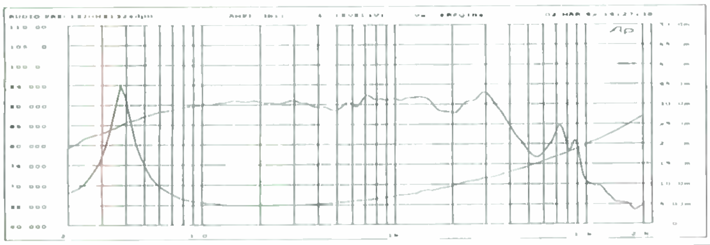


Madisound 81524—8" Polypropylene Woofer 4Ω

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 2.83V/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	**$35.00**

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"

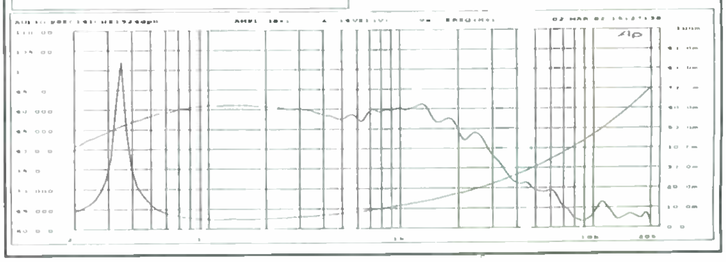


Madisound 81524DVC—8" Dual Voice Coil Polypropylene Woofer 4Ω/4Ω

Fs	31.7Hz
Rscc	7Ω
VcL @ 1K	.34mH
Qms	9.2
Qes	.32
Qts	.31
Mmd	38g
Cms (μm/N)	631.44
Vas	39.2 Liters
Efficiency	See Graph
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	**$37.00**

Measured with coils in series. Graph measured with both coils driven.

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"

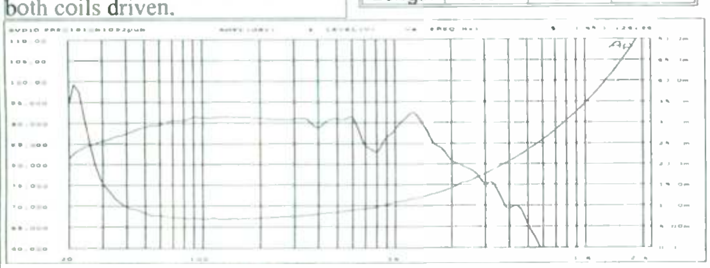


Madisound 1052DVC—10" Dual Voice Coil Polypropylene Woofer 8Ω/8Ω

Fs	20.4Hz
Rscc	12.2Ω
VcL @1K	.46mH
Qms	3.68
Qes	.28
Qts	.26
Mmd	46g
Cms (μm/N)	1220.1
Vas	197 Liters
Xmax	6mm pk
Efficiency	See Graph
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	**$45.00**

Measured with voice coils in series. Graph measured with both coils driven.

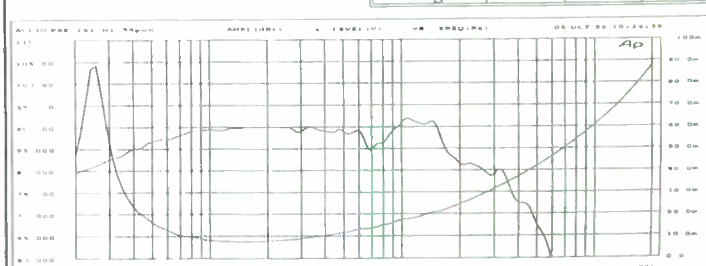
1052DVC QB3 Alignments			
	Rg = 0	Rg = .5	Rg = 1
Vb Liters	47	57	69
F_3 Hz	38	35	33
Fb Hz	31	28.6	26.8
Port Dia	3"	3"	3"
Length	9.9"	9.3"	8.6"



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 2.83V/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	**$43.00**

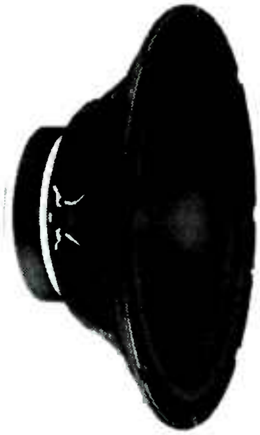
1054 QB3 Alignments			
	Rg = 0	Rg = .5	Rg = .9
Vb Liters	29	35	42
F_3 Hz	52	46	43
Fb Hz	41.7	38	35.7
Port Dia	3"	3"	3"
Length	8.7"	8.3"	7.8"



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

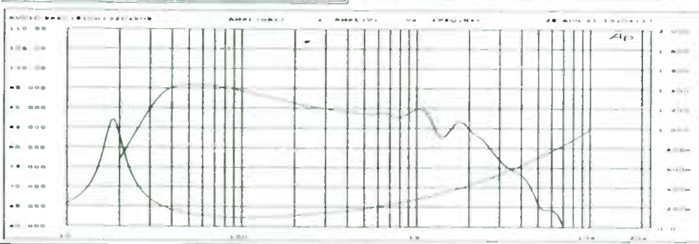
Fs	18.6Hz
Rscc	7.56Ω
VcL @1K	3.48mh
Qms	4.27
Qes	.26
Qts	.25
Mmd	62.2g
Cms (μm/N)	1113.3
Vas	179.5 Liters
Xmax	6 mm Pk
Efficiency	See Graph
Power	100/100 w
Magnet	40 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2" 2/2-Layer Alum.
Cutout/Depth	9.12"/4.45"
Price	**$56 00**

Measured with coils in series. Graph measured with both coils driven.



vented pole piece

10204DVC B4 Alignments			
	Rg = 0	Rg = 0	Rg = .5
Vb liters	28	35	47
F3 hz	53	39	32
Fb hz	-	30.2	27
Port Dia	Sealed	2"	2"
Length	-	6"	5.5"



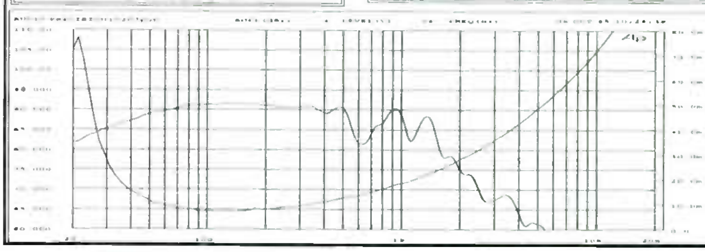
Madisound 10207—10" Dual Voice Coil Woofer 8Ω/8 Ω

Fs	19.2Hz
Rscc	11.4Ω
VcL @1K	.51mh
Qms	3.43
Qes	.23
Qts	.22
Mmd	57g
Cms (μm/N)	1138.6
Vas	184 Liters
Xmax	6 mm Pk
Efficiency	See Graph
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	**$56 00**

Measured with coils in series. Graph measured with both coils driven.

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"

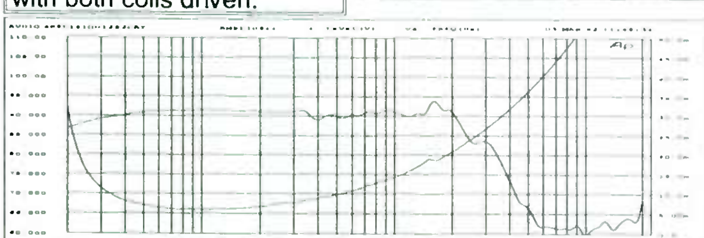


Madisound 1252DVC—12" Dual Voice Coil Woofer 8Ω/8Ω

Fs	15Hz
Rscc	11.2Ω
VcL @1K	.3mh
Qms	4.1
Qes	.39
Qts	.36
Mmd	78g
Cms (μm/N)	1331.4
Vas	533 Liters
Xmax	6mm pk
Efficiency	See Graph
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	**$48.00**

Measured with coils in series. Graph measured with both coils driven.

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"



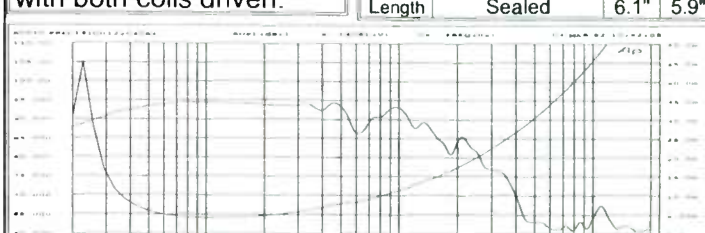
Madisound 12204DVC 12" Dual Voice Coil Woofer 4Ω/4Ω

Fs	22.8Hz
Rscc	7.4Ω
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	See Graph
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	**$60.00**

Measured with coils in series. Graph measured with both coils driven.

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"



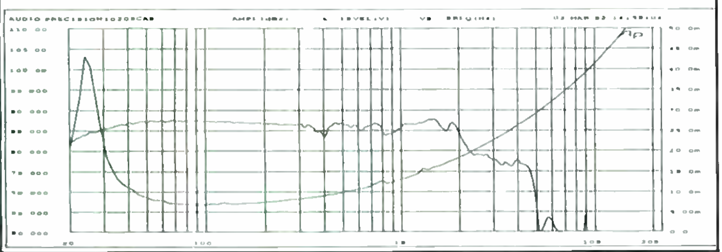
Madisound 10208—10" Sealed Box Woofer 8Ω

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	**$53.00**

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.

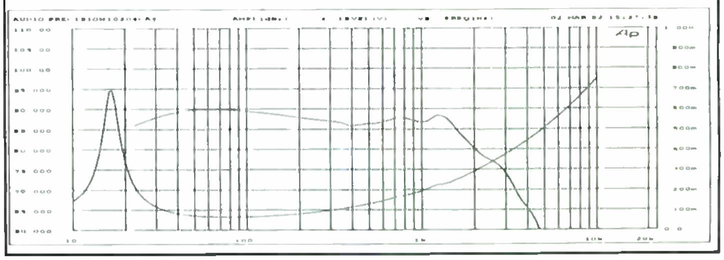


Madisound 1258 12" Polypropylene Woofer 8Ω

Fs	16.6Hz
Rscc	5.6Ω
VcL @ 1K	2.39 mH
Qms	5.32
Qes	.41
Qts	.38
Mmd	57.2g
Cms (μm/N)	1418.99
Vas	568 Liters
Efficiency	90db 1w/1m
Xmax (mm) pk	4
Power	75W
Magnet	30 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	1.5" Kapton
Cutout/Depth	11.12" / 5"
Price	**$44.00**

1258 Alignments			
Vb liters	70	85	100
F3 hz	37.5	35	34
Align.	Sealed	Sealed	Sealed
Qtc	1.15	1	.98

The use of filling will reduce the Qtc



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

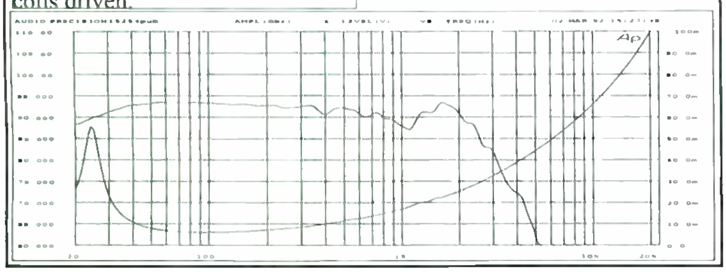
Fs	22.5Hz
Rscc	11Ω
VcL @1K	.36mH
Qms	5.35
Qes	.52
Qts	.47
Mmd	121.5g
Cms (μm/N)	367.38
Vas	368 Liters
Xmax	5.5 mm pk
Efficiency	See Graph
Power	200 100/100 w
Magnet	60 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2 (2") Kapton
Cutout/Depth	13.87"/6.0"
Price	**$80.50**

Measured with voice coils in series. Graph measured with both coils driven.

vented pole piece

15258DVC Sealed Box Alignments				
	Rg=0	Rg=.5	Rg=0	Rg=.5
Vb Liters	100	100	142	142
F3 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

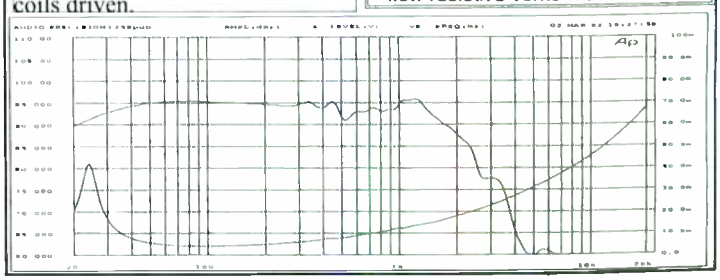
Fs	23Hz
Rscc	7.4Ω
VcL @1K	.25mH
Qms	5.71
Qes	.47
Qts	.44
Mmd	122g
Cms (μm/N)	346.1
Vas	347 Liters
Xmax	5.5 mm pk
Efficiency	See Graph
Power	200 100/100 w
Magnet	60 oz.
Cone	Black Poly
Surround	Foam
Voice Coil	2 (2") Kapton
Cutout/Depth	13.87"/6.0"
Price	**$80.50**

Measured with voice coils in series. Graph measured with both coils driven.

vented pole piece

15254DVC Sealed Box Alignments				
	Rg=0	Rg=.5	Rg=0	Rg=.5
Vb Liters	100	100	142	142
F3 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



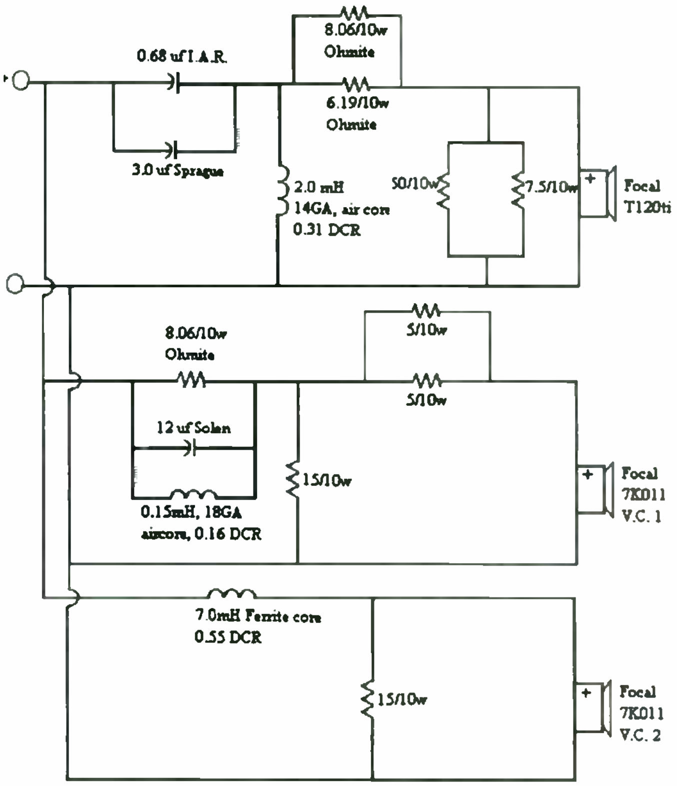


FIGURE 4: Crossover design.

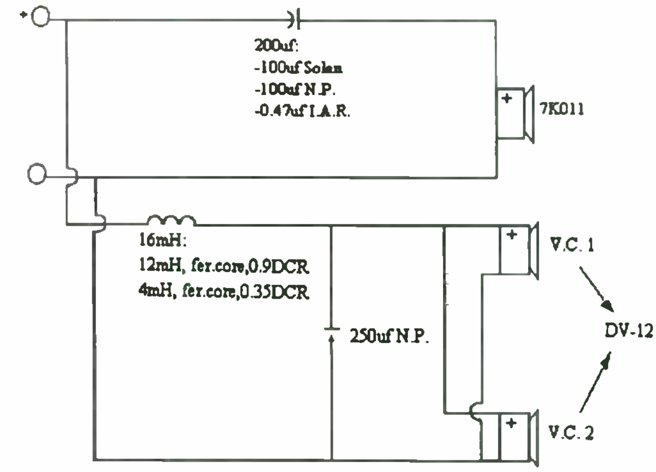


FIGURE 5: Conventional second-order filter at 80Hz.

from page 28

the cabinets by 2½″ with four cabinet feet on each to allow nothing but bass frequencies to escape into the listening room. I cut these feet from a round stair railing I had (*Photo 7*), and there is a conventional second-order filter at 80Hz (*Fig. 5*). I finished the subs with formica to match the satellites and stands: green-marble laminate on the top and black laminate on all four sides.

OTHER COMPONENTS

Associated components include a Rotel 50W integrated amp and a "stock" Mag-

navox CDB-650 CD player. The wire I used from the amp to the speakers is Axon 8 from Zalytron. This wire's eight conductors allow biwiring within a single cable (four go to the tweeter, four to the midbass). The subwoofers use four strands for the positive and four for the negative side. I used Tara Labs' Quantum CX interconnect and recommend it highly.

I have had this system for over a year and still get goose bumps when listening. There is no trace of "listening fatigue." The sound of this system is, in my humble opinion, absolutely first rate, and the words that come to mind to describe the overall impression are "smooth and extended." The Aria 7-based speakers that preceded this system were much more forward and "in your face." The Adria's bass is further extended, thanks to the dual 12" subs. These speakers excel in the reproduction of detail, nuance, and focus in recorded music. Many others have listened to this system and agree that these speakers sound absolutely fantastic. Whether it's the Cranberries, Al DiMeola, Metallica, or Beethoven, these new speakers "sing" beautifully.

SOURCES

Madisound
8608 University Green
Madison, WI 53744
(608) 831-3433

Meniscus
2442 28th St., SW, Suite D
Wyoming, MI 49509
(616) 534-9121
(DV-12, Focal midbass driver and tweeter)

North Creek Music
PO Box 1120
Old Forge, NY 13420
(315) 369-2500
(air-core coils, capacitors, resistors, silver solder)

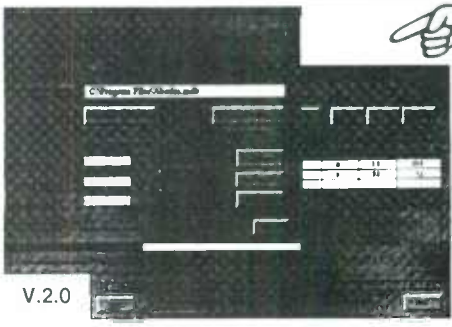
Zalytron
469 Jericho Turnpike
Mineola, NY 11501
(516) 747-3515
(Black Pad, Axon 8, binding posts)

ADDENDUM

My next projects will be to "modify" my Magnavox CD player and build a passive preamp. If anyone has any information (specific magazine articles, manuals, etc.) on doing this, please contact me at the address below.

Michael Eli Hildebrand
653 East Lake Dr.
Edwardsville, IL 62025
618-656-2753

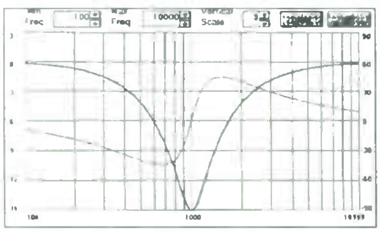
NEW SOFTWARE
NEW TEST CDs



MODES FOR YOUR ABODES
SOFTWARE FOR WINDOWS

Modes for Your Abodes by Joseph Saluzzi is a simple yet powerful program that provides you with a given room's modal frequencies. In addition, it calculates standard deviations and mode spacing, and detects the number of coincidences. User-friendly, intuitive, and easy to use, featuring on-line and context-sensitive help; glossary; fast 32-bit code (Windows 95 version); MS Access 95 database engine that creates databases automatically and transparently; thirteen view screens; and high-quality Crystal Reports output of mode and overview tables. IBM 3.5" DS/HD only. SPECIFY Windows 3.x or Windows 95 version.

#SOF-ABO1 Windows 3.x **$49.95***
#SOF-ABO2 Windows 95 . . . . . . **$49.95***



Filter Workshop band-reject filters graph.

FILTER WORKSHOP FOR WINDOWS V.1.01

This program by Frank Ostrander combines a useful set of passive network design tools with an instructional resource for network design. Calculations include design of attenuation networks (L-pads); high- and low-pass filters; shelving networks (both high- and low-pass); band-reject filters; inductor winding; and impedance correction networks. Determines component values based on resistive termination as opposed to complex driver SPL and impedance load functions. Straight-forward and easy to use. "Undoubt-edly one of the best (resistance-based) network calculators I have seen"—Vance Dickason, editor, *Voice Coil*. IBM 3.5" DS/HD only.

#SOF-FWK **$79.95***

JAPAN AUDIO SOCIETY TEST CDs

#CDJA1. Audio Test. 91 test signals for home and lab use.
#CDJA2. Impact. 26 tracks range from "old Japanese bell bonsho in the deep mountains" to Ferrari 512BB. Also audio system check (L, R, in/out of phase).
#CDJA3. Impact 2. 18 tracks cover musical instruments, vocals, and chorus.
#CDJA4. 3-Dimensional Sound. 31 tracks include rice cracker crunching and Jap-anese folk dance.
#CDJA5. High Resolution Master Sound. 20-bit digital recording of seven musical pieces, plus 16-bit version of six musical and fifteen audio check features.
#CDJA6. Music Reference for Listening Room. 11 musical tracks, 48 audio check.
#CDJA7. Super Bass Sound. 9 musical tracks, 2 sound effects (fireworks and Japanese traditional drums), 25 test signals.

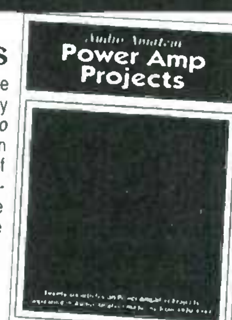
EACH CD $39.95*

PRINTED CIRCUIT BOARDS

#PCBD-3A/B. Didden Super Regulators (*Audio Amateur* 3/95). Each PCB consists of one positive and one negative regulator. . . . .$24.95* each
#PCBY-3. Youtsey Anti-Jitter Board (THIS ISSUE—*Speaker Builder* 3/96). . . . .$15.95* each

BRAND NEW BOOK!

AUDIO AMATEUR POWER AMP PROJECTS



This new handbook features 26 of the best articles on power amps as they appeared in the pages of *Audio Amateur* from 1970-1989. Authors from six different countries offer an array of designs to provide almost any high-quality audio power needed by the resourceful amateur who prefers the pleasure of building his or her own. Predominately solid state. 1996, 8-1/2 x 11, 205pp.

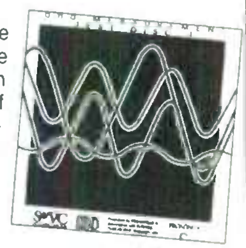
#BKAA40 . . . . . **$19.95***

PROSONUS STUDIO REFERENCE DISC

Developed especially to allow high-quality test and evaluation procedures to be made easily and quickly, this CD contains 62 individual bands of test signals. Some bands also contain individually addressable Index Points, so that families of test signals can be accessed individually by keying in the appropriate track and index numbers on your CD player or its RC unit. This feature also allows you to play tracks in any order or to repeat tracks. Includes L/R test, piano chord, 88-note piano scale, loudspeaker polarity test, sine waves at each octave center, pink and white noise, impulse clicks, much more.

#CDSA1 . . . . **$69.95***

PROSONUS INTELLIGIBILITY AND MEASUREMENT TESTS



These discs are tools to aid the sound engineer in the evaluation of sound reinforcement systems which must project English speech with a highly accurate reception rate by listeners. Through the use of modified rhyme tests and both male and female talkers, they give the user a repeatable, transportable, standard comparison of speech intelligibility for use anywhere needed. Other test stimuli are also included on the disc, and the package also contains printed copies of the tests for recopying and distribution to the listener groups. 2-CD set.

#CDSA2 . . . . **$169.95***

MORE SOFTWARE

BHK UTILITIES DISK

By electrical engineer and audio designer Bascom H. King. Handy disk tackles dB <> ratio, input and output R; loaded potentiometers; unloaded voltage dividers; RC network relationships; second order active filters; parallel resistors; RL network relationships; Watt (P,E,I,R) relationships; frequency response generation; 12dB/octave crossovers; Ohm's Law; and frequency/period relationships. Windows compatible. IBM 3.5" DS/HD only.

#SOF-BHK **$19.95***

OLD COLONY SOUND LAB

PO Box 243, Dept. B963, Peterborough, NH 03458
Tel. 603-924-6371, 603-924-6526 Fax 603-924-9467

* SHIPPING:
Add 7% USA 14% Other Surface 25% Other Air
HANDLING: Add $2 per order

• MC • Visa • Discover • Check/money order US $ US bank •

CAPACITORS: WHY THEY MATTER

Translation by John D. Fourdraine

There are many types and constructions of capacitors. Few audio buffs realize how great an influence capacitors can have on the sound quality in the whole audio chain, from coupling cap to filter electrolytic. Therefore, it seems important to devote a detailed article to the most important capacitor characteristics. Many capacitors were thoroughly tested in the Elektuur lab, as well.

A QUALITY ANALYSIS

Bipolar electrolytic, MKT (polyester, polyethylene), MKP (polypropylene), Styroflex, smooth-foil, rough-foil.... Have you ever wondered what all that is about in capacitors? Most of us probably already know that there are quality differences between various capacitor types. But what is the nature of those differences, are they measurable, and what really is the best capacitor for what application? Through elaborate analysis, we have tried to find answers to all these questions. This magazine looked at the most common capacitor types of the best-known brands—more than 25 in all. But this article is not only about an absolute quality judgment. It also shows you which factors matter in a capacitor, and which type gives the best results in a speaker crossover filter.

CAPACITOR DESIGN

We won't go too deeply into the principles of operation of the capacitor, except for a few basic points. A capacitor consists mainly of two electricity-conducting plates, with an insulator called the dielectric between them. The magnitude of the capacitance is $C = E_R \times A/d \times 8.85 \times 10^{-12}$ farads, where E_R is the insulator's dielectric constant, A is the active surface area of each plate in square meters, and d is the distance between the plates in meters.

This equation shows you that you can increase the capacitance by reducing the space between the plates, by enlarging the plates, or by choosing a dielectric with a larger constant. *Table 1* lists the dielectric constants of several materials. The thickness and choice of dielectric determine the capacitor's breakdown voltage. The dimensions of a capacitor are thus determined not only by the capacitance, but also by the rated voltage, the dielectric used, and the construction. An ideal capacitor should behave exactly according to the textbook formulas; its reactance should then be $X = 1/(2\pi fC)$.

Unfortunately, the reality is a bit more complex. *Figure 1* is a schematic of a capacitor that appears in practically all capacitor literature. The dotted parts are not well known, yet they play an important part in the sound quality. The actual capacitor here is C. In parallel is resistor R_P, the leakage resistance of the dielectric. Usually R_P has a value of many tens of megohms or more, so that here you may conveniently neglect it.

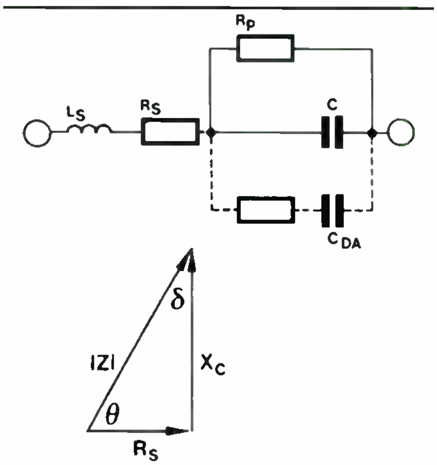


FIGURE 1: Equivalent schematic of a capacitor, with the vector diagram.

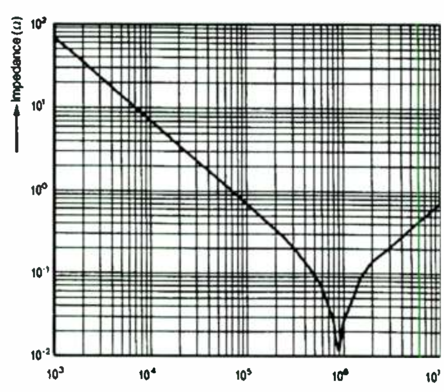


FIGURE 2: Impedance (y-axis) versus frequency (x-axis) of a good 2.2μF film capacitor.

In series is resistor R_S, which represents the connection wire, plate, and joint resistances. The minimum capacitor impedance can never be less than this R_S. This resistor is especially important in low-impedance circuits with greater current flow (i.e., in speaker crossover filters). The last item in the schematic is series inductor L_S, the value of which is determined by the construction of the capacitor (often rolled-up plates), the connecting wires, and the manner in which they are joined to the plates (at one point or over a large part of the plate).

The dotted components (C_{DA} and R_{DA}) in *Figure 1* represent the dielectric absorption (DA), a little-known property of capacitors. This process involves absorption of electrons in the dielectric, from which originates a sort of memory action, a slowed release of stored energy. This phenomenon has been known for years, yet few manufacturers list a DA value for their products. Dielectric absorption has an important influence on the sound quality of a capacitor.

Figure 2 shows a capacitor's impedance curve. With increasing frequency, the impedance decreases continuously, until it reaches self-resonance (f_r). This frequency is determined by C and L_S: $f_r = 1/[2\pi\sqrt{(L_S \times C)}]$. Beyond that, the impedance increases again due to the presence of L_S. The minimum impedance at f_r is roughly equal to R_S. Here we should mention that most components in the schematic are somewhat frequency dependent.

Capacitor specifications usually include the following:

- The dissipation factor D or tan δ. This gives the capacitor's internal losses due to R_S. The Q factor is also used ($D = 1/Q = 2\pi f \times C \times R_S = \tan\delta$).
- The insulation leakage resistance R_P—usually very high.
- The power factor, $PF = \sin\delta = R_S/Z$. This depends on the series resistance.
- The temperature behavior—discussed below in the section on materials.
- The capacitance value, usually measured at 1kHz (or a higher frequency for RF capacitors).

(Reprinted from "Kondensatoren," *HiFi-Luidsprekers*, No. 5, pp. 25–31. Copyright Uitgeversmij, Elektor 1994, Beek—The Netherlands.)

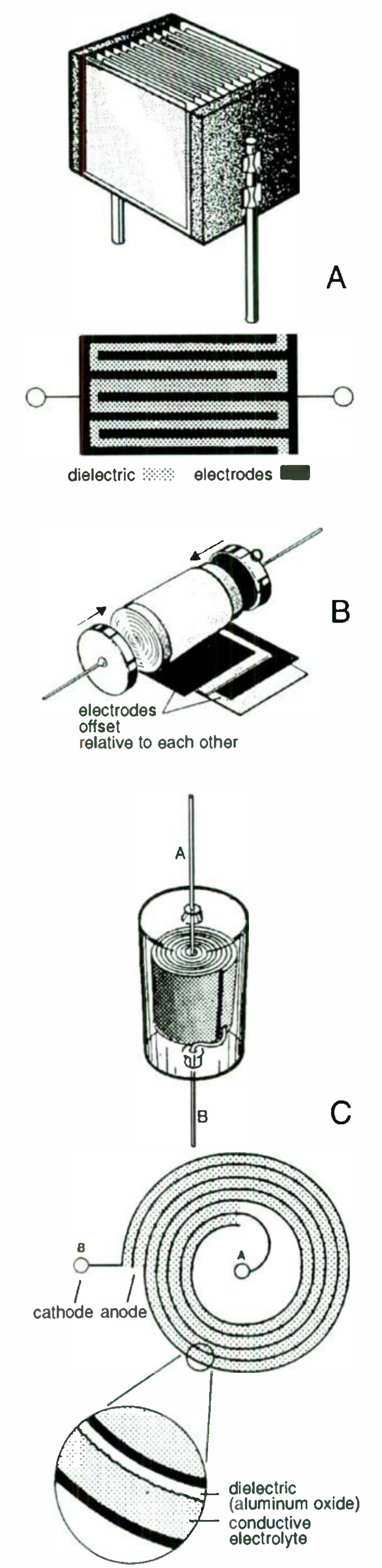


FIGURE 3: The mechanical assembly of a capacitor: a) stacked film capacitor, b) rolled film capacitor, c) aluminum electrolytic.

- For larger electrolytics, the equivalent series resistance ($ESR = R_S$) is often given.

CAPACITOR CONSTRUCTION

In practice, of course, there is little use for a capacitor consisting of two large plates with a dielectric in between. The manufacturers have different solutions for stuffing the greatest possible capacitance in the most compact housing. We limit ourselves here to capacitor types applicable to audio (*Fig. 3*), which, for example, omits ceramic capacitors.

A modern capacitor is usually built up from stacked or coiled layers. In film capacitors, the plates (or electrodes) normally consist of thin metal foil or a conductive layer that is directly vaporized onto the dielectric.

Offsetting the electrodes a bit during the stacking or coiling results in electrode edges protruding at each side, where the connecting wires are attached. In modern film capacitors, the wire is connected to the entire protruding part of the electrode, not just at one point, so that coiled types don't have more self inductance than stacked ones.

Electrolytic capacitors have the largest capacitance per unit volume. They consist of two foil electrodes with (in part) liquid electrolyte in between. One electrode has a thin layer of aluminum oxide, which forms the dielectric. This layer is produced in various ways. In an electrolytic with a so-called rough foil, the aluminum oxide forms on a chemically roughened surface with a very large area, thus resulting in a large capacitance.

In an electrolytic with smooth foil, the surface area is much smaller, resulting in a smaller capacitance for the same size capacitor case. There is also the tantalum capacitor, an anode with a tantalum oxide layer covered with a solid electrolyte of manganese dioxide, which also forms the cathode. Historically, tantalum capacitors were often used in the signal paths of audio gear, but they are totally unfit for that due to their semiconductor effects. Apply only in supply lines!

TABLE 1

RELATIVE DIELECTRIC CONSTANTS

SUBSTANCE	E_R
aluminum oxide	7–8
ceramic	10 and up
glass	4–10
air	1.0001
mica	6–8
paper	2–5
phenolic	5
polycarbonate	3
polyester	3–3.2
polypropylene	2.1–2.3
polystyrene	2.5
porcelain	4–8
tantalum oxide	11
Teflon®	2.0–2.1

CAPACITOR MATERIALS

You can divide the usually available capacitor types into a few large groups according to their dielectric materials: film, ceramic, mica, electrolytic, and paper. Paper capacitors are a bit of a throwback and hardly available today; historically, they were often applied in speaker crossover filters. Ceramic

TABLE 2

CAPACITOR MEASUREMENTS

BRAND AND TYPE (CAPACITANCE 2.2µF UNLESS NOTED OTHERWISE)	CAPACITANCE (µF)	R_S (Ω)			D			THD (%) (3V)	DA (%)
		100Hz	1kHz	10kHz	100Hz	1kHz	10kHz		
MKP: (polypropylene):									
CELM, CRS, 160V	2.24	0.11	0.025	0.02	0.0004	0.0002	0.0026	<0.001	0.01
SCR Chateauroux, 150/250V	2.19	0.12	0.02	0.01	0.0002	0.0003	0.0017	<0.001	0.01
Eton Cap, 100/160V	2.21	0.15	0.015	0.01	0.0002	0.0002	0.0015	<0.001	<0.01
Intertechnik 2163, 250V	2.19	0.12	0.015	0.01	0.0002	0.0002	0.0014	<0.001	0.01
Rifa PHE 420, 160V DC	2.20	0.10	0.015	0.01	0.0001	0.0002	0.0017	<0.001	<0.01
Ropel, block, PCP, 160W	2.19	0.11	0.02	0.01	0.0001	0.0003	0.0016	<0.001	<0.01
Ropel, round, PSR, 250V	2.30	0.10	0.02	0.015	0.0002	0.0003	0.0023	<0.001	<0.01
Solen MKP-FC, 250V AC	2.22	0.12	0.015	0.01	0.0002	0.0002	0.0015	<0.001	<0.01
VARIOUS DIELECTRICS:									
Wonder Cap 2µF, 7502A, 425V	2.14	0.15	0.055	0.05	0.0002	0.0007	0.0065	<0.001	<0.01
Ero polycarb. MKC 1862 100V DC	2.19	0.42	0.07	0.02	0.0006	0.0010	0.0031	<0.001	0.03
MKT: (POLYESTER, POLYETHYLENE)									
Ero 1822, 250V DC	2.26	1.24	0.33	0.08	0.0017	0.0046	0.011	<0.001	0.05
Intertechnik 2210, 100V	2.20	1.22	0.29	0.075	0.0017	0.0041	0.0099	<0.001	0.11
Matsushita, 400V	2.14	1.42	0.36	0.08	0.0019	0.0049	0.011	<0.001	0.05
Monacor, 250V	2.17	1.27	0.32	0.075	0.0017	0.0044	0.010	<0.001	0.09
Philips 344, 100V	2.12	1.33	0.35	0.09	0.0018	0.0046	0.012	<0.001	0.09
Siemens B32523, (blue), 100V	2.03	1.29	0.315	0.075	0.0017	0.004	0.0096	<0.001	0.06
Siemens B32563, (bare), 100V	2.28	1.22	0.31	0.075	0.0018	0.0046	0.011	<0.001	0.11
Visaton, 250V	2.07	1.12	0.285	0.07	0.0015	0.0037	0.009	<0.001	0.08
ELECTROLYTICS:									
Philips, ordinary 'lytic, 63V	2.37	30.5	3.88	2.40	0.047	0.058	0.35	0.025	1.6
Roe, ordinary 'lytic, 63V	2.62	12.8	3.24	1.50	0.022	0.054	0.24	0.015	2.1
Visaton, bipolar, smooth fl, 35V AC	2.21	44.9	3.86	0.40	0.069	0.053	0.052	0.012	3.3
Visaton, bipolar, rough fl, 100V	2.32	15.5	5.43	0.92	0.024	0.08	0.117	0.003	0.63
Wego, bipolar, smooth fl, 35V AC	2.15	35.7	3.14	0.28	0.052	0.042	0.036	0.011	2.5
MISCELLANEOUS TYPES:									
Efko, MKT, 22µF, 100V DC	22.1	0.13	0.04	0.02	0.0018	0.0057	0.022	-	0.16
Elcap, bipolar, 30µF, 50V	31.5	1.32	0.37	0.27	0.027	0.074	0.5	-	5.7
Intert., bip., sm.fl., 47µF, 40V AC	47.2	0.43	0.06	0.03	0.013	0.017	0.081	-	7.8
Roe, bipolar, sm. fl., 3.3µF, 40V AC	3.28	9.7	0.84	0.18	0.021	0.017	0.037	-	2.9
Siemens Styroflex KS, 47nF, 63V	46.8n	31	0.22	0.03	0.0001	0.0001	0.0001	-	<<0.01
Visaton, bip., sm.fl., 100µF, 35V AC	103.4	0.33	0.07	0.05	0.022	0.046	0.307	-	12.1
Wima MKP4, 4.7µF, 160V DC	4.50	0.07	0.015	0.01	0.0002	0.0004	0.0028	-	0.02

capacitors are irrelevant for low-frequency applications due to the values available (although there are values to several µF, they are not particularly low-distortion). Mica capacitors exist only in very small values (to about 10nF). We will not discuss these types further.

Of the film capacitors, the polyester (also called mylar) type is the most popular, least expensive, and smallest (polyethylene terephthalate capacitors also belong in this group). They have reasonably good properties, and you can apply them wherever you need good quality. They are currently available in values to about 100µF.

You won't find much polycarbonate in the audio realm, yet it is an excellent dielectric with somewhat better properties than polyester. For example, its capacitance change with temperature is much smaller than that of polyester (*Fig. 4*).

Polypropylene capacitors have even better properties than polyester or polycarbonate, but due to their lower dielectric constant, they are a bit larger.

Polystyrene capacitors (widely known as Styroflex) are undoubtedly the best in this group. Excellent temperature behavior, low losses, and a very low dielectric absorption make them suitable for the most critical applications. They have only two disadvantages: they are available only in small values (to about 0.5µF) and have relatively large dimensions.

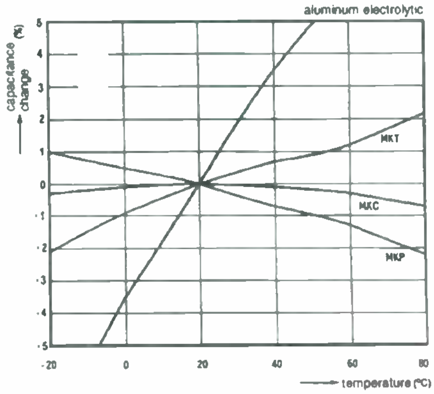


FIGURE 4: The capacitance change of different materials as a function of temperature.

ELECTROLYTICS

Of the electrolytic capacitors, only the ordinary wet-aluminum variety is well known. Due to their properties, however, they're useful only for low frequencies and uncritical applications. The tolerances are asymmetrical, and run from about +80 to −20%, and mediocre stability and limited life make them unsuitable for serious applications. For proper functionality, they also require a DC bias.

Aside from the ordinary unipolar electrolytics with a plus and minus side, there are also the bipolar electrolytics, insensitive to the polarity of the connected DC. They're of two kinds: rough foil and smooth. Both have lower, usually symmetrical, tolerances of ±10% and better properties than the normal electrolytics. The tan δ and dielectric absorption of all electrolytics is rather large.

Tantalum capacitors also belong to the electrolytics group, but, as already stated, these are unsuitable for audio applications, and certainly for loudspeaker filters. Also, they are available only in unipolar types.

ARE THE DIFFERENCES MEASURABLE?

To see how the currently available capacitor types behave themselves, the questions are what you must measure, and how do some properties manifest themselves in the reproduction quality. Naturally, a first requirement of such a test is very good measuring gear. In our own lab, we used an Audio Precision System One analyzer, with built-in FFT analyzer for the transform measurements, and a

HP 3325A synthesizer-function generator for the impedance curves.

The accurate measurement of capacitance, dissipation factor, and series resistance originally appeared to create a problem, because the measured values had to be as accurate as those of the manufacturers. Luckily, Hewlett-Packard (Netherlands) was kind enough to make available for a few days one of its most elaborate (and most expensive) LCR meters, type 4248A. Despite this gear, it took several weeks before all the relevant measurements were complete.

Table 2 shows all the measured capacitors, with the most important measured values. We have as much as possible kept to the same capacitance value, namely 2.2µF. The type and working voltage of each capacitor are given, where known. The capacitors are arranged in groups of the same dielectric, and alphabetically within each group. At the end are a number of interesting capacitors with different values.

For each capacitor the true value at 1kHz is given. R_S (*Fig. 1*) and D (also tan δ) were measured at 100Hz, 1kHz, and 10kHz. Theoretically, you can calculate R_S from D, but from *Table 2* you can see at a glance the influence a capacitor's series resistance has in a filter.

The harmonic distortion is measured at 250Hz, where the capacitor is part of a high-pass RC filter (fc = 1kHz). The distortion is probably caused by the frequency-dependent behavior of the capacitor (particularly in electrolytics) and by forces between the foils caused by the charge differences.

The DA, given in percentages, is obtained with a static test in which you charge the capacitor for a long time, then discharge it completely in a few seconds and measure the self-recovery voltage. We measured several samples of each type and listed the rounded-off measurements of the best. Don't read too much into a comparison of numbers. The small difference between a D of 0.0002 and 0.0003 can be within a manufacturer's tolerance. But if D differs by a factor of 5 or 10, that clearly indicates a quality difference.

VARIABLE PRODUCTION STANDARDS

While measuring, we noticed that several capacitors scored a factor 3 to 5 worse than other samples of the same brand. Some makers seem to have quite a lot of variability in production quality. But only the best capacitors are listed in the table, and the differences between good examples of one brand appear small.

We also measured the self inductance L_S of all capacitors, but did not include this in the table because the inductance of all 2.2µ capacitors was smaller than 50nH and therefore truly negligible in crossover filter applications. Self-inductance is mostly determined by the kind of connecting wire, not by the capacitor itself.

The interpretation of the data in *Table 2* is simple: the best capacitor has the lowest possible series resistance, and the smallest possible D and DA. The data makes it clear that the MKP capacitors (polypropylene) are simply the best, with minimal quality differences between the various brands. Some examples seem by measurement and appearance to be twins. If you want to use MKP capacitors, you'd be smart to first compare prices, since there are certainly substantial differences. As to the mechanical properties, we could judge all examples as good to very good.

In second place are the MKT capacitors—also very good, but R_S and DA are clearly worse (a factor of 5–10). Between these two groups are some strange critters, the Wonder Cap and the Ero polycarbonate. The last is definitely a ringer, clearly with better properties than MKTs. The Wonder Cap doesn't substantiate its extravagant price (about $25 for a 2µF sample) by measurement. In any case, all MKPs do better for a fraction of the cost. The Wonder Cap is an interesting capacitor for tube freaks only, because of its 425V rating.

Below the MKTs come the bipolar capacitors. Just for fun, several ordinary capacitors are included in the test. The measurement results do not confirm the stories we commonly hear about these in the loudspeaker business. You often hear the assertion that bipolar electrolytics with smooth foil have much better properties than those with rough foil. From our measurements, some rough-foil samples appear to do rather better than the smooth-foil ones.

Using some extra distortion measurements under tough conditions (low resistance load, input voltage varied over a wide range) and in more ways than are given in the table, we proved that the properties of both types are strongly variable. Some smooth-foil types produced much more distortion than rough-foil samples, but there were also those that functioned just as well or somewhat better.

It is difficult to give specific advice based on this data. For rather low frequencies (to about 500Hz), you can make up your own mind about an electrolytic with smooth or rough foil; it makes little difference. They are all relatively bad, and the distortion increases with larger AC voltage across the capacitor (10V eff. and up) to more than 0.1%, to say nothing of the DA! Use bipolar capacitors only if you have no alternative.

At the bottom of the table is a mix of types that seemed fun to report on. The Styroflex is especially interesting, but, as mentioned earlier, it is available only in small values. The bipolar electrolytics with large values appear to be acceptable for R_S and D, but the DA is plainly bad. Sadly, such values in crossover filters are often unavoidable, and replacement by MKT, for example, is hardly possible pricewise.

CONCLUSIONS

To summarize, the quality rank of capacitors is (from high to low): MKP, MKC, MKT, and lastly bipolar electrolytics (limited to those types for dividing filters). Electrolytics with a smooth or rough foil appear to give poor measured values compared to the film types—a good reason to use them only in non-critical places.

Another notable point is the strong similarity within groups. All MKPs appear to deliver similar measured values, as do the MKTs. Our advice is to use your brain in choosing capacitors and check your wallet to see how much you can spend on them. Then don't spend $300 on filter components and $150 on drivers. A bad loudspeaker cannot correctly reproduce the most perfectly derived signals from a dividing network.

MEASURING DRIVER FLUX DENSITY

By Don Jenkins

Most readers have experience in the use of permanent-magnet loudspeakers, and *SB* publishes many articles on the installation of speaker driver units into enclosures. The one constant that seems to be "given" is the published data on the driver itself. These design parameters come from the manufacturer's data sheets, their values are often quoted, and usually they appear to be accepted without question.

But exactly what are the significant driver characteristics, and how does their performance affect driver response to the input signal? The following discussion illustrates how these driver characteristics are interrelated and describes measurement techniques that allow you to determine the salient characteristics of drivers.

DESIGN FUNDAMENTALS

The basic operation of all permanent-magnet driver units depends upon the effect of current flow in conductors enclosed by a magnetic field. The general problem of understanding the mathematical relationship between the current, force, and magnetic field strength is twofold. One aspect is that the magnetic field strength (flux density) is inherently difficult to deal with, since it cannot be measured directly. You must derive its value from interrelated variables.

When a manufacturer claims a flux density for his product as 1.15T (tesla), most users have no choice but to accept this value. The other variables of force, current, and voice-coil winding length are at least available for direct measurement, although in the case of the voice-coil length it is effectively prohibited due to the construction of the driver assembly.

A second difficulty in understanding the magnetic circuit is the units of measurements themselves. With tesla and newton, you may be a little vague as to just what the value means.

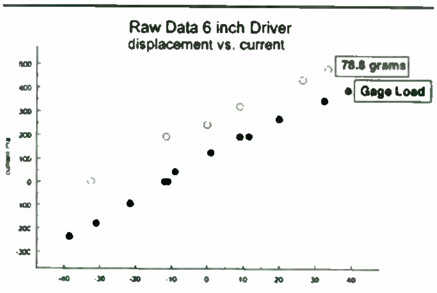


FIGURE 1: Plotting the displacement and current measurements.

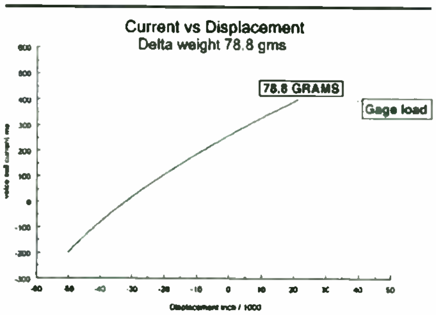


FIGURE 2: Current vs. displacement.

VARIABLE RELATIONSHIPS

The relationship between these variables is given by the expression (F)orce = (B)flux density × (A)current × (l)length. In the International System of Units (SI), force is given in newtons (1 N = 0.2248 lbf), B (now (T)esla) classically in "lines per cm^2," and current in amperes. In the SI system, these elements have the following units.

The units of the newton are kg × meters/sec^2.

The units of the tesla are kg/sec^2/ampere.

The units of voltage are meter^2 × kg/sec^3/ampere.

(In the SI system, all descriptions are "absolute," i.e., the effect of gravity is removed from the unit description. This means that a force of 1

TABLE 1

PARAMETRIC DATA FROM RAW DATA CURVE-FIT COEFFICIENTS

DISPLACEMENT inch/1000	VOICE-COIL mA 78.8g	CURRENT mA *no load	TESLA × LENGTH newton/ampere
−40.0	−86.4	−264.7	4.33
−35.0	−36.6	−213.7	4.36
−30.0	11.5	−164.0	4.40
−25.0	57.8	−115.5	4.46
−20.0	102.4	−68.4	4.52
−15.0	145.2	−22.6	4.60
−10.0	186.3	22.0	4.70
−5.0	225.6	65.2	4.82
0.0	263.2	107.2	4.95
5.0	299.0	147.8	5.11
10.0	333.1	187.2	5.30
15.0	365.4	225.2	5.51
20.0	395.9	262.0	5.77
25.0	424.7	297.5	6.07
30.0	451.8	331.7	6.43
35.0	477.1	364.6	6.87
40.0	500.6	396.2	7.40

VOICE COIL mA	DISPLACEMENT inch/1000 78.8g	DISPLACEMENT inch/1000 *no load	COMPLIANCE Meter/newton
−200	−50.3	−33.5	5.52E−04
−175	−48.3	−31.1	5.66E−04
−150	−46.2	−28.6	5.79E−04
−125	−44.1	−26.1	5.91E−04
−100	−41.9	−23.5	6.02E−04
−75	−39.6	−20.9	6.12E−04
−50	−37.1	−18.2	6.22E−04
−25	−34.7	−15.5	6.30E−04
0	−32.1	−12.7	6.37E−04
25	−29.4	−9.8	6.43E−04
50	−26.6	−6.9	6.49E−04
75	−23.8	−3.9	6.53E−04
100	−20.9	−0.9	6.57E−04
125	−17.8	2.2	6.59E−04
150	−14.7	5.4	6.61E−04
175	−11.5	8.6	6.61E−04
200	−8.3	11.9	6.61E−04
225	−4.9	15.2	6.59E−04
250	−1.4	18.6	6.57E−04
275	2.1	22.0	6.54E−04
300	5.8	25.5	6.50E−04
325	9.5	29.1	6.44E−04
350	13.3	32.7	6.38E−04
375	17.2	36.4	6.31E−04
400	21.2	40.1	6.23E−04

* no load has tare of dial gauge. Mitutoyo Model 2416

newton does not have a "weight" equivalent. Weight is not a part of the SI system, the kilogram being the unit mass (kg). While the SI units are in some ways easier to rationalize for certain derivations, their use in magnetic-circuit evaluations may be a reason you cannot get an intuitive feel for the circuit operation.)

For driver evaluation, the significant parameter is the Bl product, or, in SI units, tesla × length (Tl). The force on the driver cone is the product of the Tl value and the current in amperes.

When you place a mobile current-carrying conductor in a magnetic field, the resultant force will accelerate the conductor. A corollary of this effect is that if you move a conductor through a magnetic field, a voltage gradient forms across the conductor. This gradient is proportional to the conductor velocity. If the conductor forms a closed circuit, then current will flow in it. When the voice coil moves due to current in the coil, a "back emf" is produced that tends to resist this motion.

SOURCES OF NONLINEARITY

Back emf is one source of nonlinearity in speaker drivers, since alternating currents in the moving coil produce a back emf on the driving voltage. This is reflected back to the driving circuit and is seen as an impedance change in the load (voice coil). This back emf is also a significant contributor to "damping," as the series resistance of the source signal dissipates the residual power produced by the moving cone.

The driver-cone resistance to motion is a second variable affecting driver performance. This resistance is resolved as two components. One is a force accelerating the mass of the cone; the second is the mechanical resistance of the cone suspension, which is defined as the "compliance" of the driver cone.

The third variable is the displacement of the air by the cone surface. For free-air displacement, this addition is a small fraction of the total resistance to motion. However, for enclosure-mounted drivers, air compression can be a significant addition to the effective compliance. The compliance value is usually given by the manufacturer as meter/newton (m/N). For small free-air displacements, you can consider this value a constant. However, for large free-air displacements or enclosure-mounted drivers, this value is not constant. Also, for low-frequency drivers, i.e., those with large diameters, there can be considerable nonlinearity of compliance with both

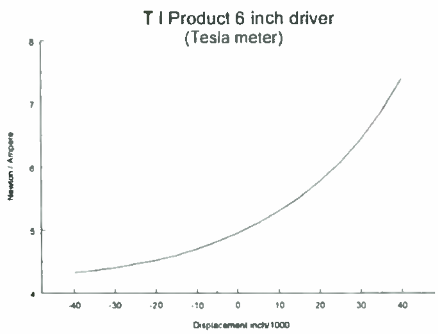


FIGURE 3A: Tl product, 6-inch driver.

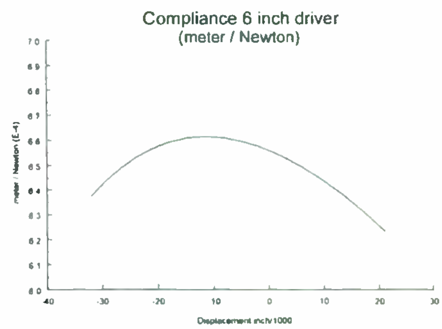


FIGURE 3B: Compliance, 6-inch driver.

Speaker Builder BACK ISSUES

1981 A Testing Unit for Speaker Parameters • Variable-Volume Enclosure • Thiele/Small Theory, Pt 1-3 • Easy to Make Enclosure Using Concrete Blocks • The Tractrix Horn: Good Dispersion From an Old Design • Diffuser Port for Small Boxes • Mini-Speaker Made From PVC Tubes • Closed vs. Vented Box Efficiency • Interview with P.G.A.H. Voigt • Dual 8" Symmetrical Air Friction Enclosure • Thiele/Small Calculator Computation • Thiele/Small Parameters for Passive Radiators •

1982 Transmission Line Theory • Thiele/Small Sixth-Order Alignments • The Quad 63 • Table Saw Basics • AR-1 Mods • Active Crossover and Phase • Three Transmission Line Speakers • A Beginner's First Speaker • How Passive Networks Interact with Drivers • Horn Loaded Heil • Phase Correcting Active Crossover • Wind Your Own Inductors • Series and Parallel Networks • High Performance Corner Speaker • Using Zobels to Compensate for Driver Characteristics •

1983 Building the Two-Way Dynaudio • A Crossover That Offsets Speaker Impedance • Using a Calculator for Box Design • Choosing a Calculator • A Simple Peak Power Indicator • A Small Horn Speaker •Audio Pulse Generator • How to Use Speaker Pads and Level Controls • An Easy-to-Build Voltmeter for Speaker Measuring • Nomograms for Easy Design Calculations • Interview with KEF's Raymond Cooke • Build a Simple Wattmeter • A New Type of Speaker Driver •

1984 Build an Aligned Satellite/Woofer System • BOXRESPONSE: A Program to Calculate Thiele/Small Parameters • Casting with Resins • A Phase Meter • An Interview with Ted Jordan • Building the Jordan-5 System • Self-Powered Peak Power Indicator • Closed Box Design Trade-offs • How to Build Ribbon Tweeters • Build a Dual Measurement Impedance Meter • A High-Power Satellite Speaker Sys-tem • Build and Use a White/Pink Generator • Sound Pressure Level Nomographs •

1985 OUT OF PRINT, some single issues still available at $7 each •

1986 The Edgar Midrange Horn • Sand-Filled Stands • Crossover Networks: Passive and Active • 5-sided Boxes • A 2 x 4 Transmission Line • The Free-Volume Subwoofer • Notch Filters • By-Wiring the LS3/5A • A Push/Pull Constant Pressure System • Current and Power in Crossover Components • The Unbox (Egg) • Upgrade Speakerlab's S-6 Crossover • Measure Speakers with Step Response • A Gold Ribbon System • A Visit with Ken Kantor • A Tractrix Horn Design Program • Reviews: Audio Concepts "G"; Seven TL Midranges; Focal's Model 280; the Audio Source RTA-ONE.

1987 A Compact TL Woofer • Frequency Response and Loudspeaker Modeling, Pt 1-3 • A Manual Coil Winder • The Model-One Speaker • Designing a Listening Room • A Sixth-Order Vented Woofer • Tapered Pipe Experiments • Visiting Boston Acoustics • A Vented Compound System • The Octaline • Spreadsheets for Speaker Design • In Memoriam: Richard Heyser, Pt 1-2 • Using Non-Optimum Vented Boxes • Building Speaker Stands • Evaluating Driver Impedance Compensation • Tuning Bass Reflex • Six Woofers Compared • Bullock on Passive Crossovers: Alternate Bandpass Types • Fast, Easy Filter Calculations • A Mobile Speaker • Polk 10 Mod •

1988 Electronic Turns Counter • Two-Way Design • Minimus-7 Mod • Dome/Midrange/Tweeter Array • Plotting Complex Impedances • A Driver Design Primer • A Cabinet Primer • Tuning Up Old Systems • Low-Cost AR-3 Upgrade • Electronic Time Delay • Enclosures Shapes and Volumes • Minimum-Phase Crossovers • Spot Sound Absorbers • How to Add a Subwoofer • The Swan IV System • Sub-Bass Power Boosting • The Unline: A Short TL • Active Filter Computer Design Program • Low-Cost Two-Way Ribbon • Amp-Speaker Interface Tester and Construction Plans • The QB_3 Vented Box is Best • A Pentagonal Box System • Keith Johnson Profile • Sheathed Conductor ESL • A Symmetrically Loaded System, Pt 1 • Ceramic Enclosure • Inductance Measuring Technique • Polk 10 Mods •

1989 (4 Issue Set: VERY LOW STOCK) The Audio Laboratory Speaker System • A Passively Assisted Woofer • Digital Filter Tutorial • The Listening Arc Alignment • Small IC Power Amp & Crossover • Easy Surround Sound • Building Speaker Spikes • An Isobarik in a Thunderbird • Sheetrock Cabinetry • A Picket Speaker • Servo-Controlling AR-1 • Silent, Safe Muting System • Equalizing the Klipsch Cornwall • A Test Switcher • Visiting the Klipsch Kingdom • Rehab for Kitchen Music • Spreadsheet Design • A Subwoofer/Satellite System • Impedance Measurement as a Tool • Practical Passive Radiators • A Symmetrical Dual Transmission Line, Pt 1 • The Microline • A Voice Coil Wheatstone Bridge • Tweeter Q Problems •

1990 Acceleration Feedback System • Cylindrical Symmetrical Guitar TLs • Compact Integrated Electrostatic TL, Pt 1-3 • Minimus-7 Super Mod • The Show (Bass Horn) • A Small Two-Way System • Helmholtz Spreadsheet • Heresy Upon a (Klipsch) Heresy • Beer Budget Window Rattler • Contact Basics • MDT Mini-Monitor Speaker System • Titanium + TPX + Polypropylene = Fidelity • Tom Holman, Skywalker, and THX, Pt 1-2 • Bud Box Enclosure • Klipschorn Throat Riddle • Modular Three-Way Active Speaker • CD Speaker System • SPEAKER DESIGNER Software • Symmetrical Isobarik • Novice Crossovers • Triamplified Modular System • Magnetic Crosstalk in Passive Crossovers • Mitey Mike Loudspeaker Tester • Symmetrical Loading for Auto Subwoofers • Improved Vented Box with Low Q_{TS} Drivers • BOXMODEL Woofer System Design Software • Four Eight By Twos • Dynaco A-25 Mod • Klipschorn Throat Revisited •

1991 Students Building Systems • Servo Subwoofers • An Apartment TL • L-R Crossover for the Swan IV • More or Less Power • New Guidelines for Vented Boxes • The Pipes • Macintosh's Wave and Sound Programs • Creating Professional Looking Grilles • Octaline Meets D'Appolito • Using Radar to Measure Drivers • Deep Bass for GMC • PSpice LF Response Calculating • Pipe and Ribbon Odyssey • The Delac S-10 • Infrared Remote Volume Control • Backloaded Wall Horn Speaker • Mod for the Minimus 7 • Simplifying Cabinet Assembly • Fibrous Effects on TLs • The DOALs • Loudspeaker Cable • Speaker to Ear Interface • Speaker Sensitivity to Errors in T/S Parameters • TL Speaker Evaluation • Cable and Sound • Kit Reports: Little V; Audio Concepts' Sub-1 •

1992 Rumreich on Box Design & Woofer Selection • MLSSA • Double-Chambered Reflex by Weems • Active Crossover and Delay • Electrical Circuit Bandpass Enclosure • A Dreadnaught System (satellite swivels) • Designing Real-World Two-Way Crossovers • 20-foot Ribbon Dipole Speaker • Biamping the Sapphire II • Capping Passive Crossovers • A High Quality Speaker Cabinet • 1/3-Octave Noise Source • Disappearing Loudspeaker • The A&S Soundoff Winner, Pt 1-2 • Alignment Jamming • Marc Bacon's "Danielle", Pt 1-2 • Double-Chambered Isobarik Bass • Ferguson's Pickup Installation • Electronic Counter for Coil Winding • Oakley on Speaker Placement • Making Your Room Hi-Fi, Pt 1 • More on Dust Caps • Spreadsheet for Nonoptimum Vented Box Design • Acoustic Resistance Tuned Enclosure •

1993 Waslo's IMP, Pt 1-3 • Quasi-Monotonic Vented Alignments • Making Your Room Hi-Fi, Pt 2-3 • A&S Soundoff Winner, Pt 3 • Flexible Dipole Woofer • The Simpline • Stalking F_3 • A Bi-Structural Enclosure • A Sixth-Order T/S Subwoofer Design • Speaker Enclosure Screws • Electric Bass Tri-Horn • Prism V Satellite/JBL Subwoofer, Pt 1-2 • Fitduct: Program for Designing Duct Software • Compact Coincidental Point Source Speaker • IMP: Measuring T/S Parameters • KIT REPORT: Rockford's Beginner Software/Driver Paks • SOFTWARE REPORT: Low Frequency Designer 3.01 • Three Affordable Measurement Microphones • Two Ways to Realize a Dream • Matching Driver Efficiencies • Two-Woofer Box System • Designing a Dual Voice Coil Subwoofer • SOFTWARE REPORT: Blaubox 1.2 • Tale of Three Speaker Projects • A&S Sound-off 1992 • Monolith Horn • Orbiting Satellites • Real-World Three-Way Crossovers • The Simplex • Living with a Speaker Builder • The IMP Goes MLS •

There's More ☞

Please send me the following back issues of Speaker Builder

❑ 1995 $32 ❑ 1994 $32 ❑ 1993 $25 ❑ 1992 $25
❑ 1991 $25 ❑ 1990 $25 ❑ 1989 $18 ❑ 1988 $23
❑ 1987 $20 ❑ 1986 $20 ❑ 1984 $18 ❑ 1983 $18
❑ 1982 $18 ❑ 1981 $18

SHIPPING BACK ISSUES

UPS:	Domestic ground service by value of order:	
	Less than $60.00 - $4.50	$131.00-220.00 - $8.50
	$61.00-130.00 - $6.50	$221.00+ - $10.50
Canada:	Add $6.00 per year.	
Foreign Air:	Europe add additional 40% of total order.	Total Magazines ________
	Other destinations: 50% of total order.	Postage ________
Foreign Surface:	Add additional 20% of total order.	TOTAL ENCLOSED ________

Rates subject to change without notice. All remittance in US $ only drawn on a US bank.

❑ Check or Money Order ❑ Discover ❑ MC ❑ VISA

DISCOVER/MC/VISA NO. ________ EXP. DATE ________

NAME ________ ACCOUNT NO. ________

STREET & NO. ________

CITY ________ STATE ________ ZIP ________

Speaker Builder

Post Office Box 494, Dept. B96, Peterborough, NH 03458-0494
(603) 924-9464 FAX (603) 924-9467

Answering machine for credit card orders only–before 9:00 a.m., after 4:00 p.m. and weekends
Please have all information plus MC/VISA available.

frequency and amplitude.

The TI product will also be nonlinear near the extremes of cone movement. When the voice-coil windings move out of the flux field, the force reduces for constant current. Drivers will show this if they have too small a magnetic field size, or too large coil dimensions for the field. The measurement technique given below shows how well the magnetic and electrical circuit components of a driver are integrated. Drivers with identical magnetic and voice-coil characteristics relative to field strength and winding length can have significant performance differences due to the mechanical design.

MEASUREMENTS

The compliance (Cm) of a driver is simply the quotient of the cone displacement and the force. The unit correction for the displacement is to meters, and the weight must be converted to force in newtons. This is a simple multiplication of the weight in grams by 0.009807. Additional correction to mass units is not required for the force calculation. (The SI unit of force, the newton, is defined as mass × acceleration, and the nominal acceleration of gravity is 9.807 meters/sec^2). See SI Units sidebar.

You determine the TI product as follows. When you place a weight on the cone and note the displacement, introduce a restoring direct cur-

TABLE 2

RESULTS OF RESONANCE TESTS

WEIGHT ON CONE (G)	RESONANCE (HZ)
0.0	58.59
4.9	50.05
16.0	41.02
19.4	39.06

SOLUTION OF SIMULTANEOUS EQUATIONS FOR CONE WEIGHT

CONE WT	INPUT #1		INPUT#2		CM
gms	wt	Hz	wt	Hz	m/N
13.2	0.00	58.6	4.9	50.0	5.58E–04
15.4	0.00	58.6	16.0	41.0	4.80E–04
15.5	0.00	58.6	19.4	39.1	4.75E–04
17.8	4.90	50.0	16.0	41.0	4.45E–04
17.7	4.90	50.0	19.4	39.1	4.47E–04
17.2	16.00	41.0	19.4	39.1	4.54E–04

Average weight 16.1 gms

COMPLIANCE AS CALCULATED FROM DERIVED CONE WEIGHT

COMPLIANCE M/N	CONE WT (G)	RESONANCE (HZ)
4.6E–04	16.1	58.6
4.8E–04	21.0	50.0
4.7E–04	32.1	41.0
4.7E–04	35.5	39.1

Average Cm 4.7E-04 m / N

NOTE: To find the cone weight (Wc) from two resonant runs with different weights attached to the cone, use this expression:

$$Wc = \frac{\left(\text{weight2} \times \text{resonant freq2}^2 - \text{weight1} \times \text{resonant freq1}^2\right)}{\text{resonant freq1}^2 - \text{resonant freq2}^2}$$

All weights in grams, frequency in Hz (cps)

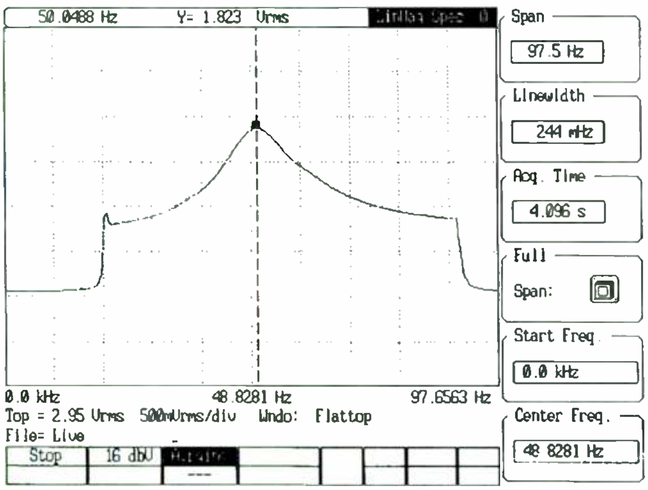


FIGURE 4: Typical resonant sweep.

rent in the voice coil and bring the cone back to "zero." This current produces the force required to support the added weight. By returning the cone to "zero" displacement, you neutralize the cone compliance force and the current measured is only that required to suspend the weight. You can now determine the Tl product as the quotient of the force in newtons and the current in amperes. The units of this value are tesla × meter, or newton/ampere.

The equipment needed to determine the salient driver parameters is relatively simple: a dial gauge you place on the cone's center for displacement measurement, several weights you place on the cone for a calibrated force, and an adjustable DC power supply.

You mount the dial gauge so that you can record both positive and negative displacements. Total movement needed for these measurements is less than 0.10″ for most drivers. Select a weight that will result in about 0.050″ displacement when it is placed on the cone.

CONE DISPLACEMENT

Begin by adjusting the voice-coil current to run the cone over the ±0.050″ displacement with only the force of the dial gauge on it. The data shown in *Fig. 1* is the typical result. You should get about ten points in 0.010″ increments. Repeat these same measurements with the weight placed on the cone. Again, the data will be as shown in *Fig. 1*. Plotting this data should result in two "continuous" functions, so that you can determine the coefficients for a good curve fit. Using the derived curve-fit coefficients, *Fig. 2* is a plot of both sets of data on the same set of coordinates.

The composite plot of *Fig. 2* provides an insight into both the determination of the driver tesla-length product and the cone compliance. The difference between the two curves in *Fig. 2* at a constant displacement (vertical difference) can provide the Tl product as the quotient of the force in newtons (weight in grams × 0.009807) and the restoring current in amperes. The result is newton/ampere or tesla × meter.

You can determine the compliance from the horizontal difference as the quotient of displacement and force. This result is in meter/newton. By using the restoring force provided by a constant voice-coil current, you can calculate the true compliance over the displacement range.

To resolve the discrete values for Tl and Cm over the data set range, calculate the values from the curve-fit coefficients for both constant current and constant displacement, do the required arithmetic (see Calculating Compliance and Tl Product sidebar), and the result is the data of *Table 1*, plotted as *Figs. 3a* and *3b*. How far these parameters diverge from linearity over the operational displacement range indicates how much acoustic distortion results from the driver characteristics.

CONSTANT DATA

For perfect driver design, both the compliance and Tl product would be constant. This data is fairly constant (the scale of the y axis exaggerates the actual dispersion) in that the Tl product is about ±5% over the ±0.030″ displacement, while the compliance is only about ±1% over the same range.

The final parameter needed to evaluate the driver is the effective weight (mass) of the displaced element. Some manufacturers give this in their data sheets. You cannot determine this value directly, but can calculate it with one more measurement: the resonant frequency of the assembly. Connect the driver to a variable-frequency signal generator and sweep the frequency to determine resonance. You can find this point by voice-coil current change, or, in most cases, by watching or listening, or both, as the frequency changes. The resonant point is obviously that point where the cone displacement increases abruptly with constant input.

The resonant frequency of a spring and mass system is given by the classical expression for simple harmonic motion, $T = 2\pi\sqrt{(\text{mass} \times \text{compliance})}$. The Cm value used here should be the value calculated for zero displacement, since that is the point where resonance is determined for small displacements. The effective mass of the suspended cone is then

$$\text{mass (grams)} = 1000/(2\pi \times Rf)^2/Cm$$

where Rf is the resonant frequency in cycles per second (Hz) and Cm is meter/newton. Check this derived value with that given in the manufacturer's data sheets. If there is a big difference, you probably have incorrectly determined the resonant point.

ANOTHER METHOD

A second method to determine both the compliance and the effective cone weight is to find resonance using several different weights attached to the cone. *Table 2* shows such data.

Using the expression Wc (effective weight (g) of cone) $= 100/(2\pi \times Rf)^2/Cm$ and the above values, a series of simultaneous equations yields the average calculated value for Wc to be 16.1g and the average Cm to be 4.7E–4 m/N.

Using the Cm value from the data set of *Table 1* as Cm=6.23E–4 m/N (extrapolated to the "free cone" condition) results in a cone weight of 11.3g—a difference of about 5g. Air load, which is not a part of the direct weight and displacement method, adds only about 0.5g to the effective weight during the resonance tests. The Cm discrete value for the resonant point at 13.2g weight is 5.58E–4 m/N, or about a 10% difference. In any case, the values calculated by either method are surely within the experimental repeatability of these tests.

The method you use depends upon which measurement capability you have. To use the resonance and variable-weight method, a very accurate frequency measurement is necessary. The resonance method is probably the easiest way if you can determine the Rf accurately. *Figure 4* shows how the resonant point was determined by using a frequency sweep and a spectrum analyzer. Resonance is resolved as the maximum amplitude line, which, for the frequency range shown, is ±0.25 Hz.

CONCLUSION

It is interesting to compare your own measurements with the manufacturer's data. You tend to assume that the published data is correct since the source should have better equipment with which to obtain the values. However, with the highly competitive environment in the driver market, some vendors may be inclined either to "shade" their performance, or, more likely, not publish all the results of their testing. This is most noticeable in the presentation of the nonlinearity of the Tl product and compliance. Seldom is this data published. With the described procedure, you can draw your own conclusions relative to these two parameters.

SI UNITS

In the SI system, the weight of an object as recorded by a scale is effectively equated with the mass of the object, according to the definition of the newton as the force that will accelerate 1kg 1m/sec^2. By this definition, the unit mass (kg) imposes a force on the scale of 9.807 newtons, i.e., one "g." In the English system, the unit force (lb) results from the unit mass accelerated by one g.

In the English system, divide the weight by g to calculate the mass (lb × sec^2/ft).

In the SI system, multiply the mass (weight) by g to calculate force (kg × meter/sec^2).

In the metric engineering system, 1kg imposes 1kg force on the scale, so the mass must be resolved the same as in the English system, since 1kg force has the same definition as 1 lb force. When using newtons as the force, weight in kg = mass in kg.

For the problem at hand, the compliance units are meter/newton (meter × sec^2/kg /meter) or, reduced, sec^2/kg.

The product of compliance and mass, which is in the resonance equation and whose units must equal sec^2, is (sec^2/kg) × kg, which reduces to sec^2 and is the correct unit definition for this use.

Thus, the use of the weight (kg) in the resonance equation yields the correct answer when used with compliance expressed as meter/newton.

CALCULATING COMPLIANCE AND Tl PRODUCT

For each data point calculated from the derived function coefficients (curve fit) of the raw data, you determine a value for the Tl product and for the compliance. Using the function coefficients allows you to evenly space and range parametric values.

From the fitted data of *Table* 1, the average Tl value over the range ±0.030″ is 5.02 N/A, with a standard deviation over this range of 0.55, or about ±5%. The compliance average is 6.49E–4 meter/newton, with a dispersion of 0.11, or about ±1% (gauge tare condition).

Wayland's Wood World

ASSEMBLING AN ENCLOSURE

By Bob Wayland

As trivial as it may seem, some of the worst mistakes in building speakers occur when you assemble the enclosure. After all the hard work of careful planning, measuring, and cutting, there is nothing more disheartening than to mess up the assembly and have to start all over. Of course, the key is close attention to detail. Here are some procedures and tricks that make the details easier.

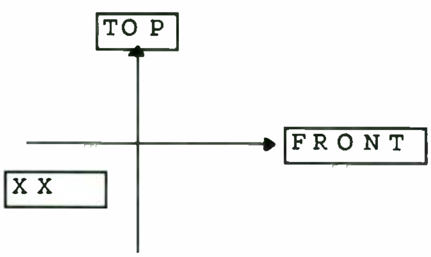


FIGURE 1: Technique for labeling enclosure pieces.

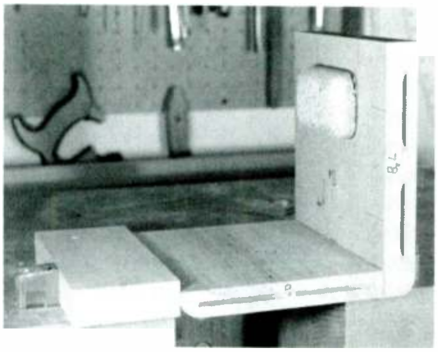


PHOTO 1: Gluing the slot sides to the back panels before assembly.

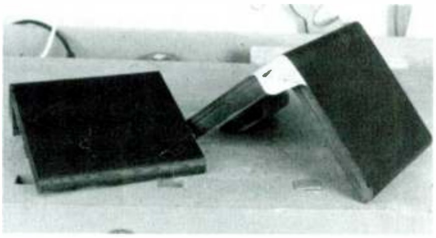


PHOTO 2: Paint the surfaces that would be impossible to reach after assembly. Note the use of masking tape to keep paint off the glue-joint surface.

First, take care of the fundamentals. As obvious as it may seem, make sure the dimensions of all the pieces are correct. One mistake made all too often is to choose inside dimensions to give a V_{as} and then cut the outside pieces to those dimensions. Most builders use 1″ or 1 1/8″ MDF for enclosures. If you're using scraps, it's easy to mix the 1″ and 1 1/8″ stock together. Also, for a number of reasons, a piece usually has a preferred external side; be sure of the orientation you want.

LABELING COMPONENTS

There are many ways to label the components of an enclosure. The technique I use works well for me and I hope it helps you develop one of your own. The basic scheme is illustrated in *Fig. 1*, where the axes are drawn on the inside of the piece. The sides, front, and back have the vertical arrow; it is not needed on the top and bottom pieces. The XX stands for a two-letter combination that identifies the piece, following this notation: T = Top; B = Bottom; L = Left; R = Right; F = Front; Ba = Back; and S = Side.

This approach also allows you to clearly identify any joint, but note that you must choose an orientation. For example, the joint between the front piece and right side should have the notation FR. I usually make this notation right in the area of the joint, which acts as a double check.

SAMPLE ENCLOSURE

The satellite enclosure I will use to illustrate this column is one that Nick Billeci and Brian Smith of A&S Speakers designed. I made the top, bottom, and sides out of 4/4 black walnut and the front and back out of 1″ MDF. It has an unusual feature that makes the system interesting: the use of a slot port instead of the normal tubular one. For a slot port located in the rear panel, you'd normally assemble it in two pieces, with the slot sides glued onto the upper and lower segments of the back panel, as shown in *Photo 1*.

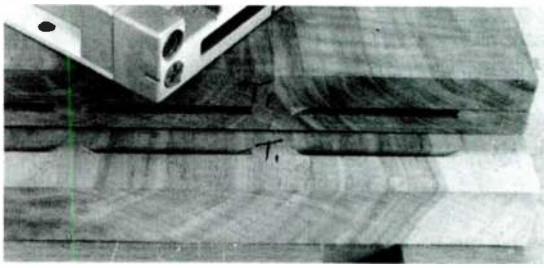


PHOTO 3: Biscuit joints for top and side pieces. Note the marking identification on the joint surfaces.

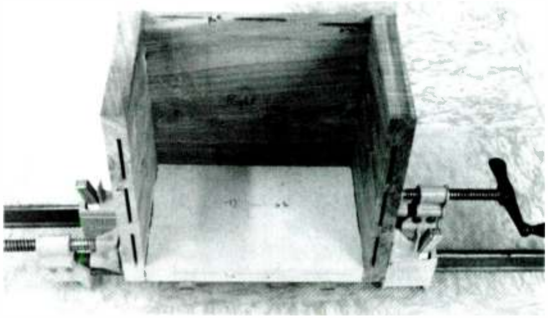


PHOTO 4: Clamping the top and bottom to the front. The side is not glued at this time.

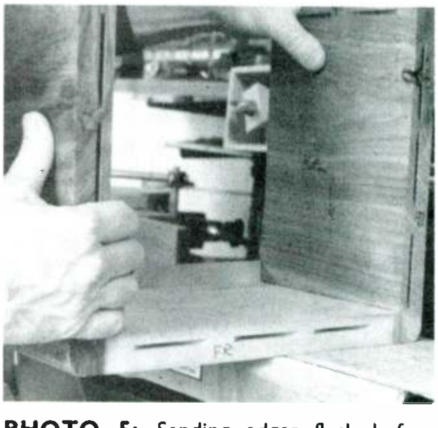


PHOTO 5: Sanding edges flush before going to the next step.

Once you've removed the excess glue and have sanded at least through 400 grit, it's a good idea to paint the inside surfaces of the slot (*Photo 2*). (If you are using a tube port and want it to be a different color from the rest of the enclosure, now is the time to paint it.) The normal practice is to use flat black.

In assembling the enclosure, you normally begin by attaching the front panel to the top and bottom. For this enclosure, I chose to use biscuit joints (*SB* 4/94 and 5/94) (*Photo 3*), but any of the joints discussed in the past would work (e.g., for spline joints, see *SB* 6/94). For this type of construction, the joint pressure should be about 250–300 psi, with a good PVA glue (*SB* 1/94 and 2/94). So if you use bar or I-beam clamps tightened to moderately high pressure, you should have a good joint (*Photo 4*). The side piece is not yet glued, but is held in place to ensure that the top and bottom are perpendicular to the front.

I rounded the front edges of the top and bottom before gluing up because the edge profile on the side pieces would not allow routing after assembly. Before final gluing, it is important to dry-clamp the assembly to reveal any misalignment or improperly fitting pieces. Then, after making corrections, you are ready for the wet clamping. After you apply the glue, be sure to position the clamps to provide the necessary pressure. It is usually easier to plane or sand all edges flush after each step (*Photo 5*).

BISCUITS AND SLOTS

Next, glue on one side. Be sure you have cut all the biscuit slots needed. Also, if you are going to mount the crossover to a side wall, now is the time to drill pilot holes for the mounting screws.

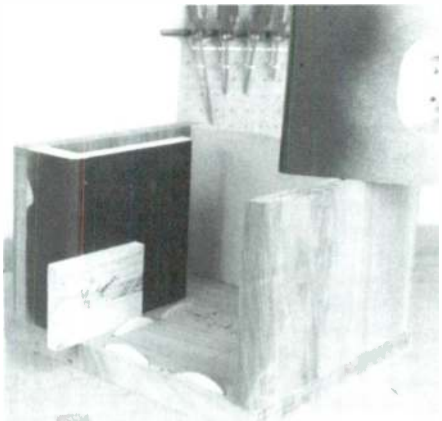


PHOTO 6: Dry test of the back panel and the slot port.

For this type of enclosure, it is a good idea to make up a scrap piece that is the thickness of the slot port. Then, when assembling the back onto the glued-up side, you have a way to accurately establish the slot and also provide a support when clamping across the slot (*Photo 6*). For the wet clamping of the back panel and slot port, you may need a clamp across the back of the port sides, such as the large, deep-throated bar clamp shown in *Photo 7*. If your design requires corner braces or wall braces, now is the time to put them in.

After the braces have set, you are ready to attach the remaining side. As you can see from *Photo 8*, this is the point when a lot of elements come together simultaneously, and I would suggest that you recruit help. Here it is especially important to dry clamp. I seem always to have an overabundance of long clamps, but if you are starting to collect clamps, you might consider half a dozen pipe clamps, with an equal number of 2′, 4′,

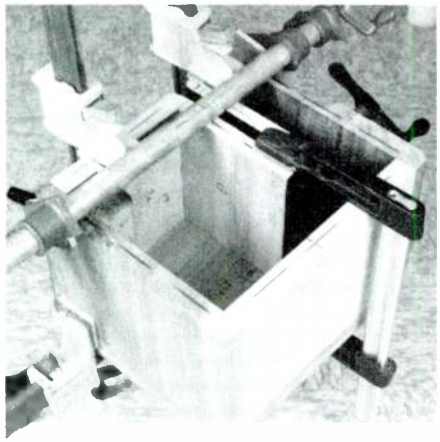


PHOTO 7: Back panel and slot port glued and clamped.

PHOTO 8: Preparing for the final side gluing. The large number of biscuits must be glued simultaneously.

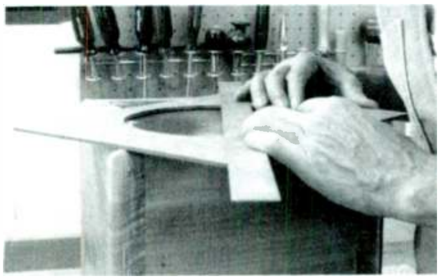


PHOTO 9: Aligning the template to cut the hole for the mid-range driver.

PHOTO 10: The results of the first step in routing the mid-range driver hole.

and 6′ pipe lengths. This can be very expensive, but you can never have too many.

DRIVER OPENINGS

Your closed box is now ready for driver openings, but before you start making them, it is necessary to have the front and back faces flat and smooth. If all the pieces went together perfectly, this would only be a matter of removing excess glue, but usually there are imperfections of technique and material that need correction. A block or smoothing plane is very handy for removing raised surfaces. Don't try to shave off too much at once, however; a very thin cut gives you better control.

In *SB* 4/95 and 5/95, I discussed how to make driver holes for the front panel. *Photo 9* shows the process of aligning the template for the larger hole for the mid-range. The first outer ring is shown in *Photo 10*. Note the center holes in the front panel, which I placed there before I began gluing. When you finish cutting the driver holes, the cabinet assembly is complete.

You may have noticed the non-standard edge treatment. Next time I will discuss how to make different edges, as well as the aesthetics of the design process.

Software Report

ROOM DESIGN POWERSHEET

Reviewed by Mark Zachmann

Room Design Powersheet by Marc Bacon. Available as SOF-RDP1B5 (5¼″) or SOF-RDP1B3 (3½″) for $59.95 plus $3 S/H in the US from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458-0243, (603) 924-6371, FAX (603) 924-9467.

System requirements: an IBM-compatible PC and a spreadsheet program. Comes standard on two floppy disks. The program is compatible with non-Windows versions of Lotus 1-2-3, Quattro, and Quattro-Pro, as well as Windows versions (with a slight key change) of Excel and Lotus 1-2-3. Since I had 1-2-3 for Windows Release 4 available, I used it for all testing. My 486 system also includes a 256-color, 800 × 600 display and an HP LaserJet 3 for printout.

The Room Design Powersheet (RDP) is a group of modules written using Lotus 1-2-3 version 2.01. These are macro-based applications for design of loudspeaker placement in rooms and things to help with room effects. RDP includes utilities for calculating room resonance, reverberation coefficients, and SPL for power applied, as well as for calculating and building Schroeder diffusers and Helmholtz resonators.

INSTALLATION

As no written instructions were included, I was forced to look at the directory on disk 1. Other than a README.1ST file, I found nothing of interest and decided to create a \RDW directory to copy the files. I experienced a disk read error reading a large .wk1 file, and resorted to using Norton's Disk Doctor to fix the floppy. After reading the README file, I then renamed the directory \RDP. Having inferred that the large .wk1 file was actually a page of on-line help, I proceeded without it.

Based on the floppy disk error and the lack of written installation or getting-started instructions, I rate installation as poor.

FUNCTIONALITY

When you get right down to it, functionality is a primary factor. I know this is the hobbyist frontier, and without large consumer markets it is hard to finance a high-quality application. But if the content warrants the cost, perhaps the program is worth it.

Well, the functionality isn't bad. I will discuss each spreadsheet individually.

Room resonances below 250Hz: calculates the room response of a single speaker in a rectangular room, showing the power and frequency of axial, tangential, and oblique standing waves. It works only below 250Hz, so speaker location must not be critical. Enter the room dimensions, and the program calculates the standing-wave frequencies.

This spreadsheet might be useful, but the data output is so poor that it fails completely. Although the tabular display seems extensive, without documentation I couldn't for the life of me figure out how to read it. The single graphic display, which showed all ***s for the frequency, was useless.

Room resonances above 250Hz: the middle-high frequency version of the first spreadsheet. Using information about room dimensions and materials, it calculates resonances for the higher frequencies. Unfortunately, I'm not sure where the room resonances are in this sheet, and the data entry and output are completely different from the first one.

I found this spreadsheet unbelievably difficult to fill in. The program asks for the area of each room surface with its acoustical absorption characteristics, and users are referred to a book sold by Old Colony as a reference. You must enter each piece of furniture in the room in the same manner.

The graphic display is available via a mysterious key sequence. I used /GV (Classic's graph view command) for one, but never found the other. Since it plots the

TABLE 1

ROOM BOUNDARY EFFECTS

Enter dimensions measured from the center of the woofer to the floor, the front wall, and the rear side wall.

Distance to floor	24″
Distance to front wall	15″
Distance to rear side wall	36″

TABLE 2

STEADY-STATE VALUE OF SOUND PRESSURE WORKSHEET

R5.0 Steady-State Value of Sound Pressure
No HELP available – read text below.

Press Alt-M (Ctrl-M for Windows) to return to main menu

INPUT

Power efficiency of loudspeaker η_0: 0.02
(Power efficiency may be found as given by the speaker mfg., or as calculated from the Loudspeaker Design Cookbook, the Loudspeaker Design Powersheet, or similar source)

INPUT POWER, WATTS: 200
Total absorption units, sabins: 3000
(Use the room reverberation program, and find the total absorption at 1kHz (cell reference K79)

OUTPUT

Acoustic power output, watts: 4
Steady-state SPL in room: 107.25dB

Note that a sustained note of approximately 1 second is required to build the sound up to this maximum value.

To increase SPL:

1) Use more efficient loudspeakers
2) Use more input power
3) Use less absorption in the room, if permissible without causing problems with reverberation.

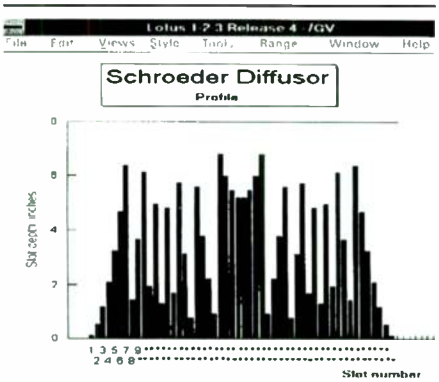


FIGURE 1: Schroeder diffusor profile.

room reverb time (?) at only four frequencies (250, 500, 1kHz, and 2kHz), it isn't all that useful anyway.

This sheet has no support for more than one device, for nonrectangular rooms, or for those which have more than one material covering various areas.

Loudspeaker room boundary effects: shows the usual loudspeaker room placement information. Given the speaker's distance from walls and floor, a response curve displays the room effects. This does nothing for the lower bass irregularities caused by room resonances, and is more appropriate for mid-bass and middle frequencies. As you can see from the data entry area in *Table 1*, the spreadsheet handles only a single driver and loudspeaker. On-line help, which just brings up extra paragraphs of explanation, is included in this module, although returning from Help is nontrivial.

This sheet has the best graphics, with a fairly clear plot of the response irregularities caused by room surface diffraction. Unfortunately, there seems to be no way to remove the visually distracting "standard" speaker response curve. As with the first sheet, there is no support for more than one device or for other than rectangular rooms.

In my opinion, this is the one truly useful application for *SB* readers. From what I've seen, though, you would be well-advised to check out specific room response programs, if that's the primary application.

Diffuser design: produces the design for a Schroeder diffuser à la *SB* 1/93 (Peter Muxlow, "Technology Watch," p. 60). This 1″–10″-thick device is built using slats and depressions. You can set it along a wall and it will diffuse a range of frequencies relatively smoothly, bouncing back in all directions equally rather than with the flat surface's usual directionality. This feature is great for taming hard surfaces that cause slap echo effects, especially when coupled with an absorber.

To use this module, set lowest and highest frequency, and the program displays the diffuser graphically. You can then read the dimension information more precisely from the spreadsheet. At no point is the diffuser response discussed or displayed (even such simple elements as Q or height versus diffusion examples). In the display, slot numbers greater than nine are shown as ** (there isn't enough detail to get heights right anyway), but the tabular display is very good.

On the whole, I think this module is neat. It does the math for you, and the graph is kind of cute (*Fig. 1*). Once I had read the *SB* 1/93 article (the only help was a reference to this issue), the sheet was fairly easy to understand, but before that I was pretty clueless. I thought the article was a bit sketchy, too, and would like to know more about the effect of the diffuser and other variables in its construction—things computer programs do well.

Steady-state value of sound pressure: gives the acoustic power output of a speaker/amp system if you know loudspeaker efficiency and room absorption (at one frequency). Not very sophisticated, the entire process involves one multiplication, one division, and one logarithm (to display in decibels). I would have hoped for perhaps a frequency-dependent result based on a prior room spreadsheet. Also, you need to calculate loudspeaker efficiency, and nowhere is this discussed other than as a reference somewhere in the *Loudspeaker Design Cookbook.*[1]

Table 2 is the worksheet for this section. The values you are expected to enter are highlighted in blue, so it isn't particularly hard to understand, just rather underwhelming. The "to increase SPL" part seems somewhat condescending.

Helmholtz resonator design: again, no on-line help is provided. You don't know what kind of Helmholtz resonator is being designed, and there is no reference. I've read articles that discuss distance between panels, how many and what size holes, absorption materials, and the like. Why not use this in a room design so you can see the effects, or design more than one to cover a range of frequencies?

On-line help: consists of a picture showing the flow of this one menu: a box labeled "menu" with arrows to five other boxes.

EASE OF USE

As an Excel and 1-2-3 for Windows user, I couldn't get the menuing system to function at first. (I haven't used 1-2-3 Classic since 1986 and don't remember how to do everything.) After hours of frustration and trying to track macros, I finally worked out that I needed to change the directory via 1-2-3 Classic. Obviously, this could be fixed and/or better

TABLE 3
MAIN MENU
a) Room resonances (below 250Hz)
b) Room reverberation (above 250Hz)
c) Loudspeaker room boundary effects
d) Diffuser design
e) Steady-State Value of Sound Pressure
f) Helmholtz resonator design
g) Exit
z) Help
Press Alt and your selection simultaneously (Ctrl-selection for Windows software)

documented for current 1-2-3 for Windows users. The error message "file not found" gave neither file name nor reason.

Table 3 is the front menu (note the Ctrl command for Windows users). Pressing a Ctrl-key sequence takes you to the appropriate worksheet.

Since I couldn't get the menuing system to work at first, I loaded the various spreadsheets by hand. Each one has a fairly simple, fill-in-the-blanks interface with both tabular and (usually) graphical output. The latter doesn't approach what 1-2-3 for Windows can do. In one case the frequency axis labels are all ***s, so you can't tell what the frequencies are.

In all modules, returning from graphics mode required hitting "esc" several times. This was annoying; I would hope for a better way to exit from a macro.

The help system was usually nothing other than one or more paragraphs of textual information wrapped around a rather sketchy worksheet. In some cases I wasn't sure what to enter into a spreadsheet, how to access certain areas described in the on-line help, and how to display or interpret results. Data entry locations are always highlighted in blue, which is quite an aid, given the incomplete nature of the help system. No other assistance was given.

Finally, I must ding RDP for completely ignoring advanced features of Windows spreadsheets (or even current DOS ones). The sheets could be much better integrated, the interface simpler (dialog-driven, perhaps), and the program flow better managed. Instead of "find the blanks, fill them in, find the results, and figure them out," it could prompt for the inputs and display easily formatted results.

I rate the program's ease of use as poor.

DOCUMENTATION

Two help files exist (for sheets 1 and 3); the rest of the help is in-line. Given that the worksheets are relatively simple, this is probably enough help. As for tutorial information (e.g., what do *you* think is a Helmholtz resonator?), there is none. With the exception of the diffuser spreadsheet, no adequate references are provided to allow for the lack of documentation.

For most of the spreadsheets there were no clear instructions on how to perform various operations. Furthermore, there were no instructions for interpreting the results (or, in certain cases, finding the results). Thus, even the in-line documentation is inadequate.

The program desperately needs hard-copy start-up discussions. Certainly one sheet of paper describing installation wouldn't hurt the bottom line substantially. It also could use a better summary of what each program is and does. I rate the documentation as below average and barely usable.

OVERALL SUMMARY

I would have preferred a 10-page leaflet with the mathematics analyzed, discussed, and presented to accompany the floppy, as an example. This might be more worth the money and time (even without the floppy). I would also like solid references—with page numbers—and enough information so I could upgrade the functionality to something realistic and not just toy-like.

The boundary augmentation worksheet is the closest thing of clear value in the Room Design Powersheet. (Do you *really* want to design a Schroeder diffuser for your wall?) I've been moving my speakers around for weeks trying to smooth out the bass response, and I zeroed in on a—I hope—much better solution using this worksheet. Still, my room isn't square and I have two speakers which could augment each other in the bass. Overall, this is at best a "shareware-like" degree of functionality.

Most of the other worksheets are pretty simplistic. The lack of integration, minimal documentation, unbelievably poor support for Windows products, and lack of installation program also lead me to urge you to consider a bit before spending your hard-earned money here.

DEVELOPER'S RESPONSE

Thanks to Mr. Zachmann for his informative article. I have included some additional information and tips to help other users, who, I hope, will not be as frustrated as he was. Perhaps he should have asked Old Colony for another disk when his floppy didn't work. The .wk1 help file he ignored may have been useful.

Room resonances below 250Hz: *As Mr.*

Zachmann surmises, this program calculates standing wave frequencies, not loudspeaker placement. The object is to produce a pattern of standing waves that is as regular as possible, without undue emphasis at certain frequencies. The graph he thinks is useless looks fine on 1-2-3 v 2.01. A bit of reformatting to his particular version of spreadsheet will solve the problem.

Room resonances above 250Hz: *This does not calculate room resonances, but reverberation time! Unfortunately, the only way to do this accurately is to input surface absorption factors, square feet, and so forth, no matter what software you use. Since reverberation times follow a generally continuous curve in most rooms, using four frequencies is the normally accepted practice of displaying them. In fact, many architects start from a simple value at 1kHz; then work up and down with proper room treatment and traps to get the time as constant as possible.*

Regarding the graphing problem, once again the user should check the Help screens on his spreadsheet to find how to show 1-2-3 v 2.01 graphs.

The program uses the Sabine formula to calculate reverberation, which works equally well for nonrectangular rooms. You can enter up to ten areas, and more if you wish to insert lines into your spreadsheet. The program does not refer to "devices" such as loudspeakers, but to room reverberation. As such, it will support as many devices as required.

Loudspeaker room boundary effects: *The program is intended to model the effects of room boundaries on a single loudspeaker's power response as per Roy Allison's classic work. In a typical well-set-up listening room, the stereo pair will be symmetrically placed in the room, and placement which is good for one side of the pair will be good for the other. Without resorting to a multithousand dollar modeling program, which is far too intimidating for amateurs to use, there is no way to accurately model the behavior of asymmetrically placed multiple loudspeakers in a listening room that departs from a rectangular shape. In my experience, and that of many other engineers, room placement according to Allison's simple formulas results in an outstanding midbass, as well as deep, natural extension.*

Steady-state value of sound pressure: *This program involves only one calculation, as Mr. Zachmann states. It is very useful, however, in determining the maximum steady-state SPL level attainable in a given room before spending time and money on speakers and amps. This simple program may save amateurs the most money when selecting equipment for a PA application such as a small auditorium or restaurant.*

I sympathize with Mr. Zachmann's frustration with regard to ease of use, as I now use the latest version of Microsoft Office for much of my work. I wrote the program as a series of utilities related by macros in 1-2-3 v2.01. This was in the prehistoric days somewhere between the invention of fire and the writing of Windows. Although the old code is usable by all new software written since 1988, macros may not work well, graphs may appear archaic, and printouts may not be very pretty.

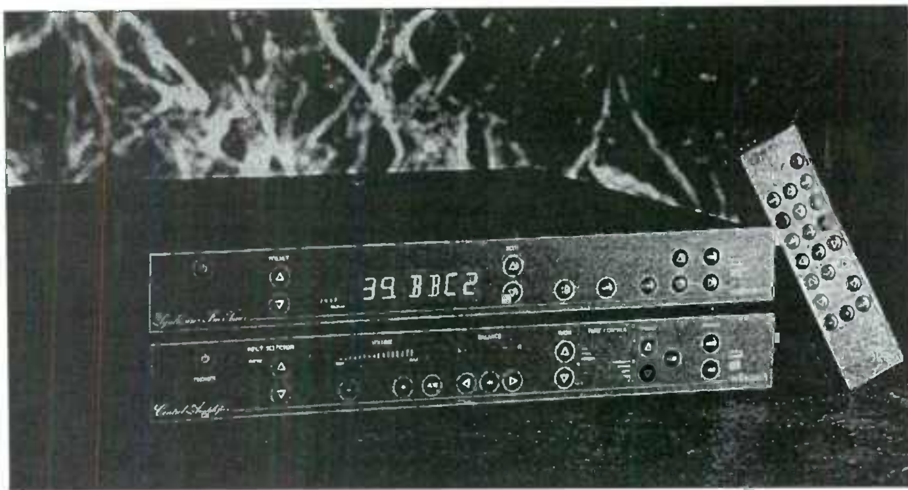
Profit was not my motivation for developing this program. To date, I have earned less than $2 per hour on the software—a far cry from my normal consulting rates and insufficient justification to warrant writing upgrades on every available software platform. I wrote the software to help amateurs quickly perform acoustical room calculations and experiment with some of the variables involved. It is impossible to write spreadsheet software that will format exactly on other software platforms and in upgrades, as would a BASIC or C program. On the other hand, the end user can customize the spreadsheet to suit his needs, a feature missing in slick special-purpose programs, and the program contains a collection of routines unavailable in any under-$1,000 package.

Should you purchase RDP? If you have never used a spreadsheet, the answer is either "No" or "Have a buddy customize the code for your particular platform." If you have used spreadsheets and need a package to help you select the best room dimensions, surface treatment, and speaker placement for the maximum enjoyment from your speaker dollar, this package (or an equivalent from a BBS or audio publication) will provide you with far better results than tiptoes, fancy cable, and other audio paraphernalia. Other than the obvious, yet forgotten, solutions of removing wax buildup in the ears and reducing ambient noise, control of the loudspeaker/room interface is probably the best single way to increase listening enjoyment.

Marc Bacon
MDB Consulting
St. Hubert, Quebec J4T 3L6

REFERENCE

1. V. Dickason, *The Loudspeaker Design Cookbook*, 4th ed. (Audio Amateur Press, 1991).



K4500 SOLID STATE SYNTHESIZED FM TUNER

This high-quality FM receiver kit is the ideal complement to Velleman's K4100 preamp, although it can of course be used with other amps as well. The idea behind it is to make adjustments as easy as possible, without special measuring equipment. The high-frequency end is therefore assembled and preset in the factory. Complete with case. Functions: 40 presets; station name for each preset; 2 antenna inputs (selectable); automatic recognition of stations already stored during tuning; signal strength indication; dimensions 16-3/4"W x 2"H x 13-3/4"D; wt. 11 lbs. Remotely controllable by infrared transmitter #KV-K4101 (below).

#KV-K4500 **$269.00***

NEW KITS FROM VELLEMAN!

K4100 SOLID STATE DIGITALLY-CONTROLLED PREAMP

Containing no potentiometers whatsoever, this preamp kit features digital control of all functions. Volume, tone control, balance, and input selection all can be operated using push-buttons, with LEDs giving an a clear indication of all settings. All functions may be operated with optional remote control unit #KV-K4101 (right). A switched power output has also been provided, allowing the rest of your installed equipment to be switched on and off via remote. On top of this, your own priority settings can be programmed in, which become the default settings when the unit is switched on or can be invoked at any time. Input sensitivity: Phono 5.5mV/50 kOhms, CD 500mV/32 kOhms, Tuner, Tape 1 & 2 360mV/22 kOhms. Output level: Line 1V. Signal-to-noise ratio (A-weighted): Phono 75dB, Tape, CD, Tuner 100dB. THD: 0.01%. Frequency response: 8Hz-150kHz (-3dB). Channel separation: 90dB. Crosstalk: 99dB. Headphones (not included) output: 280mW 32 Ohms. Mains output: 5A. Consumption: 6W max. Dimensions and wt.: same as K4500 above.

#KV-K4100 **$269.00***

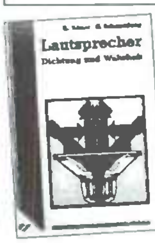
K4101 15-CHANNEL IR XMTR

This infrared transmitter kit may be used to remotely operate Velleman preamp K4100 or tuner K4500. A special safety key is provided, which allows the memory content (or stations in the case of the tuner) to be preserved in order to prevent unwanted overwriting. This remote control unit kit is unique by virtue not only of its versatility, but also of its classy aluminum case and special Velleman tactile keyboard. Transmitter/receiver range: +/-98 ft. Supply voltage: 9V battery. Dimensions: 1.97" x 0.87" x 6.9".

#KV-K4101 **$49.00***

FASCINATING FOREIGN-LANGUAGE LOUDSPEAKER BOOKS!

• Fun to look at • Often understandable • Great conversation pieces • Complete your library or collection



Lautsprecher: Dictung und Wahrheit

(Loudspeakers: Fiction and Fact)
by Römer and Schwamkrug, 1986, 229pp.

IN GERMAN. Common problems of room acoustics, speaker placement, frequency response, bass reproduction, and directivity. Construction and operation of speakers. Dynamic loudspeaker theory: transfer function; impedance; high-pass, band-pass,and low-pass filters; complete crossovers. Closed and vented enclosures. Acoustical and electrical measurements.

#BKEE39 **$49.95***

Elektrostatische luidsprekers

by Fikier, 1993, 227pp.

IN DUTCH. This unique book describes a number of construction projects for electrostatic loudspeakers. Some deal with plate systems, others with relatively unknown wire systems. Besides practical tips on construction, the book also gives a number of hints on the placing of electrostatic loudspeakers in the listening room.

#BKEE46 **$49.95***

Het luidspreker bouwboek

(Build Your Own Loudspeakers)
by Klinger, 1990, 328pp.

IN DUTCH. This book is intended for the serious loudspeaker constructor. Its large number of construction projects is preceded by some chapters giving fairly detailed information on electroacoustics, drivers, filters, and various types of enclosures. The latter vary from simple and compact closed versions horn systems standing well over six feet tall. Listening room acoustics and speaker placement are also covered.

#BKEE48 **$49.95***

Personal HiFi

by Nachbar, 1992, 256pp.

IN DUTCH. Build your own amplifiers and loudspeaker enclosures. This book contains a number of construction projects for high-qualitypreamps, output amps, and loudspeaker systems.

#BKEE44 **$49.95***

The PA handbook

by Beckmann, 1989, 211pp.

IN DUTCH. All about sound systems for the stage. Terms, units, and properties in electroacoustics. Parts of a PA system, including tips on component selection. Practical operation of a PA system. Troubleshooting problems during performance.

#BKAA50 **$49.95***

OLD COLONY SOUND LAB

PO Box 243, Dept. B963, Peterborough, NH 03458
Tel. 603-924-6371, 603-924-6526 Fax 603-924-9467

* SHIPPING:
Add 7% USA 14% Other Surface 25% Other Air
HANDLING: Add $2 per order

• MC • Visa • Discover • Check/money order US $ US bank •

SB Mailbox

A BUMPY PATH

Thank you for your series of interesting and thorough articles on waveguide speaker enclosures, G. R. Koonce's "The Waveguide Path to Deep Bass" (*SB* 6–8/95). They inspired me to build one myself. I started with an old "air coupler" enclosure that I built a number of years ago and modified it to give a folded duct 16′ long with a cross section of 4.3″ × 4.5″, or 19.4 in^2. The volume of the enclosure behind the speaker is 370 in^3.

The box is made out of ¾″ plywood, and the internal partitions make it very stiff. I used radius bends as you did, because I think that the wave-front discussion in Bruce Edgar's article ("The Monolith Horn," *SB* 6/93, p. 13) is more appropriate for high-frequency performance, and I was interested only in low frequencies. I think that for best low-frequency performance, the duct area should be maintained as constant as possible.

Since I did not have a suitable driver available, I bought a Cabasse 21NDC. Although it's expensive, I was attracted by the very large X_{MAX} of 1cm and stiff honeycomb cone. I think this is probably the best 8″ subwoofer driver available.

Initially, I used the enclosure with only one side of the driver loaded by the duct and the other side open. Short's article ("Acoustic Wave Cannon: Sound for Cinema," *Audio*, Nov. 1991: 30–39) seemed to indicate that a single ¾L duct can give useful performance up to a frequency where it is ¾ wave long, and down to a frequency where it is ¼ wave long; however, I found the performance unsatisfactory. Therefore, I built a ¼L extension consisting of a 5.33′ long duct made out of 1 × 6 poplar hardwood boards. The inside dimensions of the extension are 4″ × 5.4″, giving an area of 21.6 in^2, slightly larger than the ¾L section. As you pointed out, this also makes measurements easier.

To determine a frequency-response curve for the subwoofer (*Fig. 1*), I used a sine-wave generator and microphone that is flat to 10Hz. The result seems a bit disappointing for the effort expended. Although not inconsistent with the theoretical result shown in your first article (6/95), I was hoping for flatter response and better low-frequency extension.

Charlie Pike
Lexington, MA

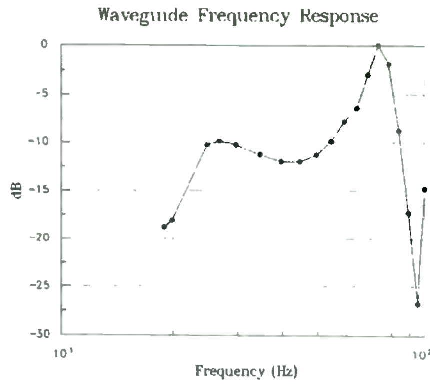


FIGURE 1: Subwoofer frequency response curve.

Contributing Editor G. R. Koonce responds:

I thank Mr. Pike for his kind words on my waveguide article, and I'm glad he has decided to experiment with these structures. You should be aware that the double-ended waveguide structure may be covered by a current patent that might restrict you to experimental usage without permission from the patent holder. It would also prohibit publication of practical construction plans for these devices.

I compared the theoretical response for the waveguide in Part 1 of my article with the response reported by Mr. Pike for his unit. I was working from a very small figure, so the results can't be very accurate. Mr. Pike's plot varies from theoretical in that it has excessive droop between the two peaks and falls off too quickly at low frequency.

The response variations appear somewhat exaggerated in Mr. Pike's plot, due to the expanded dB scale; but the nearly 10dB difference between the two peaks is what theory predicts. In my testing, however, I was able to *find configurations where the response was much flatter than this. I looked through the many waveguide responses I had measured but not used in the article, and while I obtained a wide variety of shapes, none of them look like what Mr. Pike has reported.*

Not knowing exactly where the driver is mounted, I assume it is on the same face as the port for the ¾L pipe. So, based on my experimental waveguide results, I see the following potential problems with Mr. Pike's unit:

1. *The pipe length ratio does not appear to be the correct 3:1. Remember, I learned the hard way that the pipe length starts at the driver, not at the compliant box (rubber throat) output. This should produce a dip somewhere; however, I never got the wide droop shown by Mr. Pike's unit.*
2. *The back of the driver is coupled to the waveguide through a compliance, while it appears the front of the driver is tightly coupled. This was true with my attempts with a single driver, and they did not perform as well as the dual-driver approach.*
3. *Mr. Pike's unit uses the same approach I did with my first single-driver configuration; the driver cone moves at a right angle to the input to the ¾L pipe. This approach never worked very well for me.*

None of the above can explain the shape that Mr. Pike reports. I can only suggest that he experiment with the coupling of the back of the driver into the ¾L pipe throat and move the port to correct the length ratio. If it can be implemented, a movable port would allow playing till the best response is obtained.

The math says that Mr. Pike's waveguide should be usable from about 17Hz–85Hz. A low-pass crossover at 85Hz would help knock down the upper peak and attenuate the trash that appears above this peak. To be flat down to 17Hz, equalization would be needed as discussed in my article. Without the use of complex equalization, I doubt he will ever obtain a really flat anechoic response for a waveguide, but remember that he is playing in a frequency range where room effects may produce even larger response variations.

I wish I were more of an expert on these structures, but I have only played with the one covered in my article, and Mr. Pike's waveguide is about 65% longer than any structure I tested. I just do not know if this could be part of the problem. I do hope Mr. Pike will continue experimenting with his waveguide and report further on his findings.

SURFACE EXPERIMENTS

I realized about two years ago that a pair of "Audiophile grade" speakers cost over $10,000 (at least in Calgary, Alberta), and there was no way I could afford a pair. I then stopped reading *Stereophile*, and started subscribing to *Speaker Builder.*

During the past two years, with the help of *SB* articles and a few software programs such as CALSOD and BOXMODEL, I have completed a few speaker projects. I can testify that building and listening to my own speakers is a far more enjoyable experience than buying a pair of commercial products.

My questions are: when making speaker measurement using the ground plane method, does the surface texture of the ground plane affect the measurement? Would the result be the same if the measurement was taken on a concrete surface or an asphalt surface? What if the surface is carpeted?

S. Wong
wongs@cadvision.com

Contributing Editor Bill Waslo responds:

Your question is "interesting" (meaning: I didn't know the answer). The differences in texture between concrete and asphalt would not seem to be able to make much difference unless the surface irregularities were on the order of a quarter wavelength (about 0.2″ at 20kHz) or greater, which is more than is normally found. I certainly wouldn't expect to see any significant changes at bass or low-midrange frequencies.

The carpeted case is a little more difficult to guess. In a spare moment, I made a quick Audiosuite test on a cellar floor. I didn't have a piece of loose carpet available, but some other variations were readily at hand: particleboard, a sheet of 1″ foam rubber, and a thin (about 1/8″) textured rubber sheet.

Figure 1 *is the result of the ground-plane measurement of a two-way system, made with the microphone lying on the ground surface about 2′ from the speaker (the distance is short because of rather cramped conditions in that area). Next, I inserted the foam underneath the speaker and the microphone, being careful to keep the relative positions between the speaker and mike the same. This made a dramatic difference* (Fig. 2), *making a deep notch at slightly under 4kHz and dropping the sensitivity for frequencies as low as 1kHz.*

The 1″ foam is a quarter wavelength long at about 3.4kHz and is the same distance the *mike was lying above the concrete surface, which explains the notch position, although the depth of the notch is surprising. I imagine carpet would behave somewhat similarly. Ground-plane measurements on carpet are probably not a good idea, at least for higher frequency measurements.*

Fig. 3 *shows the result for the 1/8" rubber sheet. Some of the change relative to* Fig. 1 *may be due to reduced precision in placement of the speaker and mike, as the rubber sheet was not as easy to scoot under the transducers. But there is definitely a significant reduction in high frequency sensitivity, although nothing like the disastrous results with the thick foam. This occurs even though the surface variations in the rubber sheet are well under 1/8 wavelength at all frequencies measured. Maybe the compliance of the rubber surface also plays a part.*

As a last check, I changed the surface to smooth particleboard (Fig. 4). *This again strongly resembles the measurement made on the concrete floor, which is of similar smoothness.*

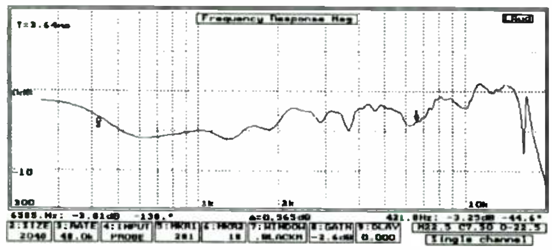


FIGURE 1: Ground surface results.

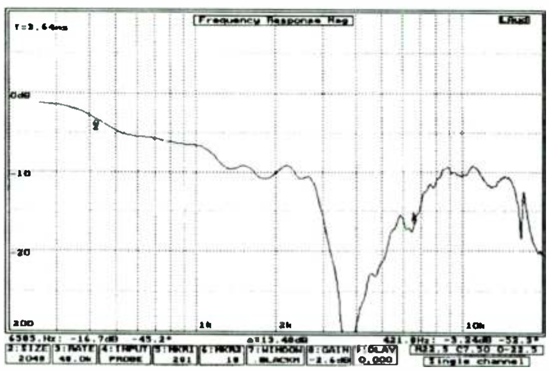


FIGURE 2: Results with foam.

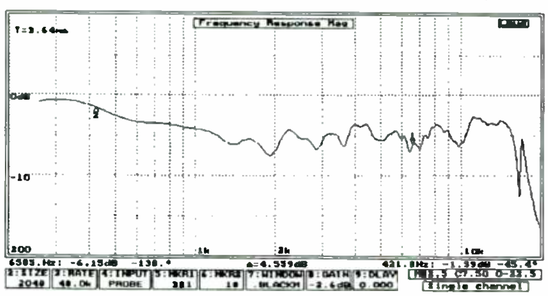


FIGURE 3: Using a rubber sheet.

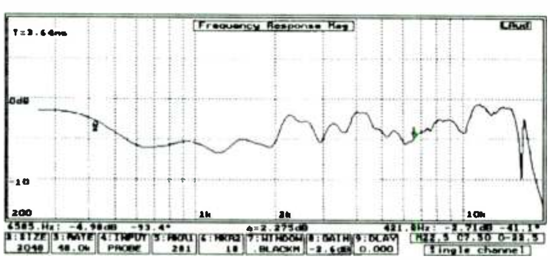


FIGURE 4: Smooth particleboard surface.

MONO VS. STEREO SUBS

I read with interest Tom Nousaine's article "Stereo Bass: True or False?" (*SB* 6/95, p. 16). He maintains that stereo subwoofers are not the preferred subwoofer configuration. This article seems to be based upon Mr. Nousaine's earlier work "Subwoofer Secrets" (January 1995 *Stereo Review*), which makes similar claims.

I stand by my statement that stereo subwoofers can offer a noticeable improvement over a monaural subwoofer ("One Thump or Two: The Advantages of Stereo Subwoofers," *Audio* 2/94). It's very simple to demonstrate this on a system having stereo subwoofers: turn the subwoofer amplifier to "mono" and turn off one of the subwoofers. Then listen.

The problem is in showing this to those who do not already have a stereo subwoofer system and therefore cannot try it! For those who do, it's like "preaching to the choir." Dan Hildebrand, in his "Speaker Design and the Internet" (*SB* 1/96, p. 58), says, "Pipe organ music reproduced on the two subwoofers resulted in an impressive sense of 'space' that was absent when I listened to the same piece on a single-subwoofer system."

The Technical Subcommittee of "Acoustic Renaissance for Audio" proposed the following provision for stereo subwoofer outputs to take full advantage of the forthcoming DVD audio disk format: "7.2 Subwoofer feeds: We strongly recommend that music should not be recorded to layouts with a mono subwoofer, since single-subwoofer replay is very inferior in terms of energy response and spaciousness." ("Setting the Super-CD Standard," *Stereophile*, August 1995. Also available on the world wide web at: http://www.meridian.co.uk/ara/.) I think more work begs to be done in this area.

John Sehring
Baker, MT

Tom Nousaine responds:

My thanks to Mr. Sehring for his interest in the topic. His "simple to demonstrate" stereo subwoofer experiment is fraught with error and bias. Simply turning subwoofers on and off and switching to mono without compensating for level differences and listener bias do not produce valid evidence. Nor do his subjective anecdotal comments.

Indeed, my experimental hypothesis supported his original point: stereo bass was better. As Mr. Sehring points out, many others hold this opinion as well. However, careful, unbiased experiments show the conventional wisdom to be untrue.

My experiment, with levels matched and listeners blinded, showed that stereo bass is audibly imperceptible with crossover frequencies of 80Hz or lower. All the spaciousness and locational cues are delivered at higher frequencies through the main channels. Not only is "stereo" below 80Hz a misnomer, but conventional stereo left and right subwoofer positioning penalizes frequency response smoothness and extension.

I encourage Mr. Sehring to conduct a rationally designed bias-free controlled experiment to prove the worth of his position. He, unfortunately, took the luxury of establishing the position without supporting experimental evidence. If he can produce a fair experiment that proves his point or can find mistakes in my experiment that restrict the applicability of the results, I will gladly entertain the new evidence.

However, this is not subject to a popularity poll...the sonic truth is the sonic truth. It's no one's fault if we don't like it or if it conflicts with our preconceived notions. Anecdotal accounts of uncontrolled listening can only serve to cue up hypotheses for controlled experiments. They are not evidence in and of themselves. The ones that contain truth are borne out when bias controls are applied.

I agree that more work begs to be done. The ball is in your court.

STRAIGHTEN THE BENDS

In one of his excellent articles regarding bass horns, Bruce Edgar states that he measures the hornlength as the path in the geometrical middle of the horn. Writing on the subject of pipes for *HiFi News & RR* in 1968, Rex Baldock stated that airwaves are like people in a crowd, trying to cut corners to reduce somewhat the effective pathlength at bends. At 90° bends, the reduction is 0.4 r and at 180° the loss is r.

I have measured a bass horn similar to a Belle Klipsch using a 12" bass driver with a frequency of 30Hz and Q_{ES} of about 0.3. Despite the theoretical cutoff at about 200Hz, the response is flat to well above 400Hz! Anybody have similar experiences?

Lastly, I have read that by using chamber between the driver and the horn, you can increase both the upper-frequency response by a half octave and the slope from 6–12dB/octave. I have considered building a straight 100Hz horn to experiment with, but I would prefer to hear from anyone who might already have done this.

Thomas H. Eberhard
Sweden

Contributing Editor Bruce Edgar responds:

Baldock's observations about pipe bends are applicable to your results. I have encountered the same situation, in which the measured horn cutoff is much higher than the predicted mass rolloff frequency. The pathlength reduction due to bends raises the effective flare rate, especially in horns where the distance between bends is rather short, as with your Belle Klipsch clone.

Olson (J. Soc. Mot. Pic. Engr., *30, p. 511, 1938) shows that a short higher flare-rate horn section at the throat will boost the higher frequencies. Klipsch later borrowed Olson's idea (termed a manifold exponential sectioned horn) and called it a "rubber throat"* (J. Acous. Soc. Am., *13, pp. 137–144, 1941).*

You may think that this horn-design technique will allow the use of lesser drivers on horns, but I have found that the increase in higher-frequency response also can result in a decrease in the low-end response. Klipsch had the same idea, but discarded the rubber throat in later papers, probably due to its adverse effects on the low-end response.

Brociner (Audio, *pp. 16–25, March, 1971) briefly discusses the idea of using the front air chamber to shape the upper-end response of a horn. However, the technique usually works only for midrange-tweeter horns that use phase plugs to shape the air chamber and correct for path-length differences. The air chamber in front of large woofer cones on bass horns is usually too large to boost the top-end response.*

If you couple a woofer 1:1 on a throat, the air chamber is nonexistent. You would need to fit a large phase plug on the bass horn to reduce the air-chamber volume and affect the top-end rolloff. I have seen phase plugs on a *number of pro midbass straight horns, so the idea has some merit.*

FROM THE HEART

I read your article, "A Push-Pull Planar Speaker Quest" (*SB* 8/95, p. 8), with great interest. Congratulations on a very fine piece of work and an excellent manuscript.

I am a surgeon-engineer-inventor and have a great interest in designing and building some form of ribbon speaker. My professional experience with inventing has been in the field of artificial hearts and blood pumps, for which I have received a number of US and foreign patents. At first glance, it might seem that my experience would be of very little use in the design of an exotic speaker. However, any pursuit of artificial hearts has caused me to spend a great deal of time designing and building magnetic bearings. I confess that this has stirred an old love affair with magnets which I have had since my high-school days.

While I was in the process of designing permanent magnetic bearing circuits, I was forced to learn a little about the use of AMPERES, an electromagnetic finite element analysis program. I have found this program to be extremely useful. Its predictions have been very accurate and of tremendous value in optimizing the performance of magnetic bearings. It occurred to me that AMPERES would be very useful in optimizing a magnetic circuit in a ribbon speaker design.

I am also including a copy of an article by Ole Thofte which appeared in *Hi-Fi News & Record Review* in October 1988. Mr. Thofte provided a means for adjusting the tension in his planar membrane. He seemed to think it was pretty important, although you seem to have been successful without providing for any adjustment. Do you think adjusting the tension would be useful in your design?

Richard Wampler, M.D.
Granite Bay, CA

Daniel Patten responds:

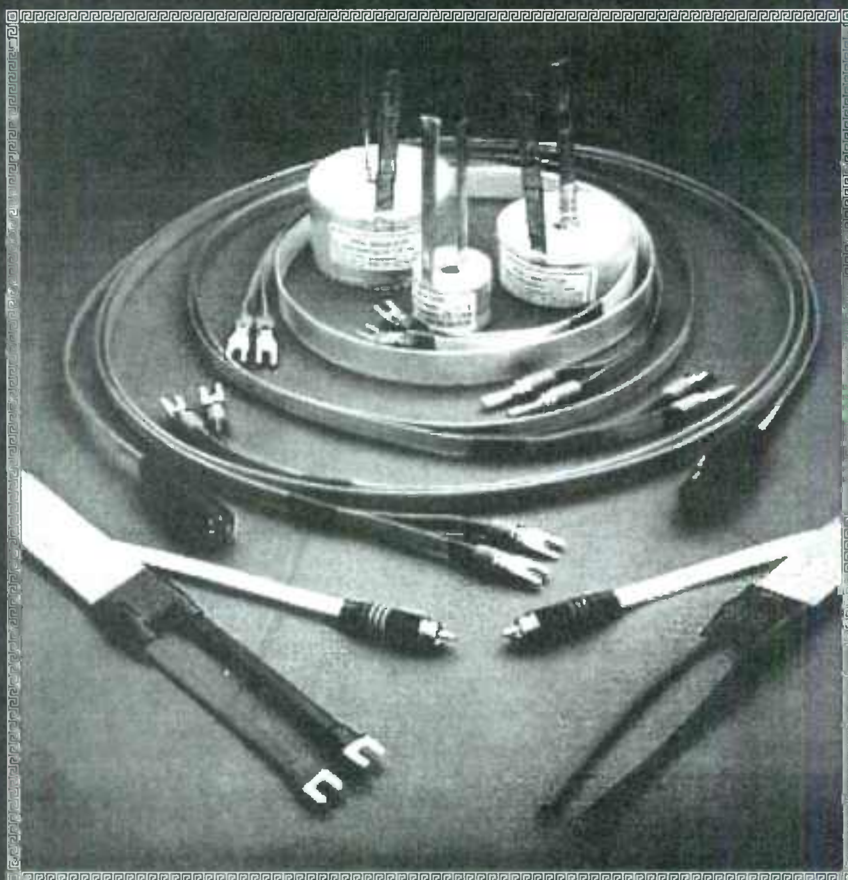
I must admit that I also have always been fascinated by magnets. I am not familiar with the AMPERES program. I have looked for magnetic field analysis software but have never come across one, always resorting back to my college physics books. It would be interesting to analyze my magnetic structure and see if some improvements can be made.

Some of my primary goals were to eliminate the low-efficiency/low-impedance problems of Thofte's designs. My current revision has a DC resistance of 6.7Ω and is approximately 88–89dB efficient. I have listened to the speakers with conventional 50W receivers and the speakers go loud enough for me.

I believe a major improvement on the design presented by Mr. Thofte is to make the magnetic field push/pull. A push/pull field, in theory, should result in less distortion since the diaphragm is always under control. Also, the increased magnetic field heightens the speakers' efficiency.

I have experimented with tension on the diaphagm quite a lot. In that the WPS40 is not a full-range speaker, the tensioning problem is not as critical. Also, because of the narrow width of the WPS40 (about 4″) it is fairly easy to get a uniform tension across the diaphragm. In experimenting with different diaphragm tensions, I have found for the frequency range that I desire, tighter is better. In early trials, I used plastics that over time would start to stretch and sag. This really causes havoc (sounds really bad) as critical diaphragm to magnet distances are compromised. The Mylar plastics seem to work very well, in that they do not stretch much over time.

I welcome any other questions or comments about my design—either through the magazine or via E-mail (dpatten@miralink.com or DASDPatten@aol.com).



Classifieds

TRADE

STATE-OF-THE-ART PASSIVE CROSSOVERS featuring Hovland MusiCaps. Software available, free design guide. ***ALLPASS TECHNOLOGIES, INC.***, 2844 Charmont Dr., Apopka, FL 32703-5972, (407) 786-0623.

WANTED: LOUDSPEAKER SALES MANAGER. Self-starting manager with minimum 5 years experience in engineering and sales in loudspeaker field to work with major accounts in development of drivers, crossovers, and related projects. Company will relocate the right person. Send résumé to: ***CULVER ELECTRONIC SALES, INC.***, 13701 Cimarron Ave., Gardena, CA 90249, FAX (310) 532-9176.

NEW! BREAKTHROUGH SPEAKER PADS expand tonal range, add clarity, optimize full range reproduction, protect surfaces from spike holes, dampen distortion-causing vibration, maximize coupling, $7.95–$69.95. ***KLEIN TECH SYSTEMS***, 4262 Northlake Blvd., Palm Beach Gardens, FL 33410, (407) 863-2198, FAX (407) 845-9844. Dealers welcome!

SPEAKER PARTS — wholesale prices. ***PARTY DOWN, INC.***, (305) 836-9692, FAX (305) 836-0758.

WANTED: ELECTRICAL ENGINEER — San Diego area based subcontract manufacturer for the audio industry seeks electrical engineer for design and sales support. Experience with crossover, amplifier, and pc board layout helpful. BSEE or previous experience preferred. Send résumé to ***TECATE PRODUCTS***, PO Box 1585, El Cajon, CA 92022, or FAX (619) 448-0912.

THE BEST MUSIC YOU MAY NEVER HEAR. Free catalog. ***CREATIVE MUSICIANS COALITION***, Dept. GBM, 1024 W. Wilcox Ave., Peoria, IL 61604, (800) 882-4262.

WE RE-CONE all home, auto, or pro speakers. Re-foam kits, parts. ***TRI-STATE LOUDSPEAKER***, (412) 375-9203.

FOR SALE

Pair Altec 12" 414-8C, $200; pair Altec 811B, near mint, $125; pair McCauley Hartzfield-type 2" horns, $100; Crown D-150A amp, $250; Altec 921, $100; E-V/Tapco 6100 mixer, designed by Mackie, $125. Kent Elliott, phone/FAX (913) 677-1824.

Voice Coil, '92–'95, $15/year; *Audio*, '75–'89, $5/year; Infinity RS-1B active crossover/servo box, $250. Vance, (805) 735-6177.

Pair LaScala bass horn black Formica cabinets, $200; 1.5kW isolation transformer, commercially made with ammeter, $125. Maury, (360) 887-3640, FAX (360) 887-0601.

Vintage power amps, tuners, turntables, tubes, tape decks, oil caps, power supplies, drivers, misc. items — too many to list. Send SASE or call after 10 a.m. Craig Davis, 2573 Conifer Tr., Milford, MI 48381, (810) 685-0273.

Focal 5N412DBL 5" dual voice coil bass-mid matched pairs, $60/driver; Swan IV MTM, beautiful professionally-made cabinets, finished in real oak veneer and solids, as new, $80 each; Swan IV passive crossover network, $40 each; Hafler TransNova 9300 THX power amp 150+150W, rated Class B in *Stereophile*, new in carton, $825 + shipping. Fred, (610) 693-6167, E-mail: SRRT12A@prodigy.com.

Two pairs of used Cogan Hall interconnect cables, model E-M. One pair is 36" long, the other is 33". Best offer. Aaron Shipow, 3408 Ramstad Dr., San Jose, CA 95127, (408) 272-6836.

Heathkit AD1308/1309; Ivie IE-10; JBL B380, BX63, 4435; KEF 107/2; Kenwood KD-500, KT-615; Marantz 9, 2500; McIntosh C-22, MC-275, MC-30; Melos 402; Phase 4000; Pioneer M22, SF-500, SF-850; ReVox B791, B795; QUAD ESL; E-V 30W 30" subwoofer; Quicksilver 8417 preamp; Sound Lab A1; Teac X1000R; Technics 8065. Best offer. John, (408) 737-2980.

Pair Scan-Speak 18W8546 6½" Kevlar midbass drivers, $195; pair Scan-Speak D2905/9300 1" soft dome tweeters, $115. Brand new — matched pairs — ordered too many, asking about 25% less than most mail order prices. Ed, (206) 562-9848 (PDT).

Celestion 3 MkII speakers, $75; Bang & Olufsen Beogram RX2 turntable, best offer; Atlantic Technology pattern speaker system, three piece, biamped, self-powered, $100; Yamaha CD-X5U CD player, needs work, $25; two Harrison Labs AMOD 25W 12V mono amps, $20 each; a/d/s P120 car amp, $50. Offers accepted. Jim Peitersen, phone/FAX (509) 332-7907, eves. (PST).

Thorens model 320 turntable, $220. Gayle, (606) 581-3763 (KY).

WANTED

JBL 12" & 15" speakers, blown; tube microphone mixer. Kent Elliott, phone/FAX (913) 677-1824.

Coaxial/triaxial speakers; Altec 601 or 604; Jensen G-510 and CX-225; Lowther full-range; Goodman; Tannoy; E-V 12TRX/15TRX; any Western Electric. Sonny, (405) 737-3312, FAX (405) 737-3355.

Reasonably priced crossovers, any brand. Need two-way model for main/subwoofer project; prefer steep-slope model with both stereo and mono subwoofer outputs. Also need older solid-state amp for same system. Any help appreciated. Jim Peitersen, phone/FAX (509) 332-7907, eves. (PST).

Altec 291-16A drivers; Altec 291-16A diaphragms (stamped #21531); JBL 2402 "bullet" tweeters & diaphragms; Crown Macro-Tech 2400 amps, dead or alive. Bob, (804) 523-0711.

Copy of schematic for Sony TA5450 preamp; output module for B&W 750C. Harry Frank Conover III, 1146 South Dale Ct., Denver, CO 80219, (303) 934-4210.

JBL 375, 2440, 2482 horn drivers, burnouts OK; HL89 or 2390 horn/lens assembly; 2327 adapters; Marantz 240, 250, 400, 500, or 516 power amps, repairable OK; JBL L-100 grilles; dbx 118 for parts; flat response condenser mike. Maury, (360) 887-3640, FAX (360) 887-0601.

ReVox G36 at 15ips; Studer C37; single Altec 1568; single Klipsch Heresy; old mikes and tube broadcast gear for vintage recording studio; Altec speakers, EQs, components; old audio/sound/recording books and magazines. Mike States, Box 81485, Fairbanks, AK 99708, phone/FAX (907) 456-3419.

Dyna PAM-1 for parts, any condition. Paul H. Leo, 103-10 Queens Blvd. 5H, Forest Hills, NY 11375, (718) 459-5443.

CLASSIFIED INFORMATION

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

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

WANTED: Help readers find equipment or services.

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

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

PRICING

All advertising is $1.50 per word, $10 minimum per insertion. Deduct 5% for a 8x contract. Please indicate number of insertions. Payment MUST accompany ad. *No billing for word classified advertising.*

AD COPY

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

SUBSCRIBERS

Receive *free For Sale* and *Wanted* ads, 50 word maximum, each additional word $.20, $10 minimum. For *Club* ads, follow instructions at the bottom of the Clubs listings. Please submit only one ad per category per issue.

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

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

I want to repair a Scott 222 tube amp (a preamp & power amp combined; will drive Edgar horns), but I don't have any information on it. Please help! Robert, (360) 830-9173, evenings and weekends.

Hartley speakers, Reference or Concertmaster. Craig Heerlein, 14435 Ladue Rd., Chesterfield, MO 63017, phone/FAX (314) 576-5377.

Plans for construction of guitar and PA type speaker cabinets; guitar 4″x12″, 2″x12″ cabinets, etc.; PA 4530, 4560, folded horn, bass reflex-type cabinets. Bob Koniak, 208 Park, Gillespie, IL 62033-1356.

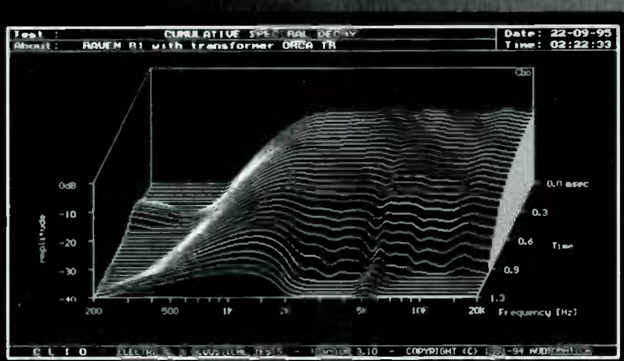
Service manuals for Heathkit AG-10 sine-square wave AF generator and Heathkit HD-1 harmonic distortion meter. I will gladly pay the costs of copying and postage. John Sehring, PO Box 373, Baker, MT 59313, (406) 778-2452, E-mail: john_sehring@ecunet.org.

AD INDEX

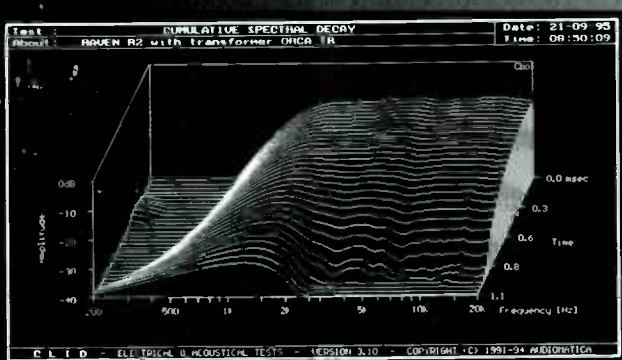
RAVEN

HIGH EFFICIENCY PURE RIBBON TWEETERS

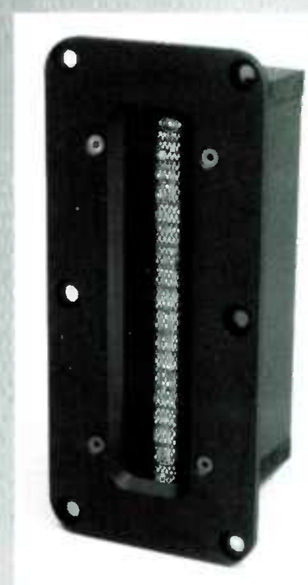
ORCA is sincerely proud of introducing these exceptional high frequency transducers from France. The RAVEN tweeter is a true ribbon tweeter, possibly the purest transducer available today. In a dome tweeter the signal is carried through the voice coil wire, and the sound is radiated by the dome attached to the voice coil. Here, the carrier of the electrical signal and the radiating diaphragm are one and the same part: the ribbon itself. Furthermore, the RAVEN ribbon is 100% pure conductive material, no metalized film. To have an idea of the high frequency performance of the RAVENs, imagine that the moving mass here is about 30 times less than a high quality dome tweeter. The music comes through effortless, almost immaterial. The special and massive NeFeB magnet of the RAVENs is five times more powerful than a conventional magnet. The result: the RAVEN R1 is capable of 118 dB peak with no measurable distortion (R2: 120 dB). At 10WRMS, that is continuous power now, R1 reaches 105 dB with less than 1% distortion, and R2, 107 dB. The RAVENs come with a specially designed matching transformer (very low distortion, low loss and wide bandwidth) for optimum coupling with your power amplifier. Now look carefully at the decay of these units !



RAVEN R1
KGS 1.14
LBS 2.5
92 x 80 mm
3.63 x 3.15 in.
Moving mass:
0.0061 g
0.0002 oz.
dB/W/m 95
2 KHz to 40 KHz



RAVEN R2
KGS 2.22
LBS 4.9
166 x 76 mm
6.54 x 2.99 in.
Moving mass:
0.013 g
0.0005 oz.
dB/W/m 98
2 KHz to 40 KHz



RAVEN TRANSDUCERS are distributed worldwide exclusively by ORCA Design & Manufacuring Corp.
1531 Lookout Drive, Agoura, CA 91301 - USA
TEL (818) 707 1629 FAX (818) 991 3072
E-Mail: arcades @ aol.com
OEMs, stocking distributors and importers inquiries welcome, Goods now in stock in America.

Reader Service #32

Reader Service #19 →

Dedicated To Quality

Parts Express is dedicated to bringing serious speaker builders the finest products currently available. We have recently become a distributor for Linear X and now carry their superb loudspeaker design program, LEAP Version 4.5, plus the outstanding LMS loudspeaker measurement system. We are also very pleased to announce that Parts Express is now an authorized distributor for Morel Acoustics. Morel's unique vented magnet system and large diameter Hexatech voice coils provide smooth frequency response, high power handling, and astonishingly low levels of distortion. We also carry the high performance line of drivers from Audax, featuring the revolutionary High Definition Aerogel and Carbon Fiber cone materials. For high quality crossover networks, we stock Solen polypropylene capacitors, 14 gauge air core inductors from ERSE, Solo copper foil air core inductors, and Monster Cable speaker wire. Our software programs for enclosure design include BassBox 5.1, Quick Box from Sitting Duck Software, and Loudspeaker Architect 2.01 from N.A.M.E. Call now for your copy of our FREE 228 page catalog and to get the details on these and many other quality products.

FREE

CATALOG

Parts Express

CALL TOLL FREE

1-800-338-0531

SOURCE CODE: SPM

340 E. First St., Dayton, Ohio 45402-1257, Phone: 513-222-0173, Fax: 513-222-4644

morel