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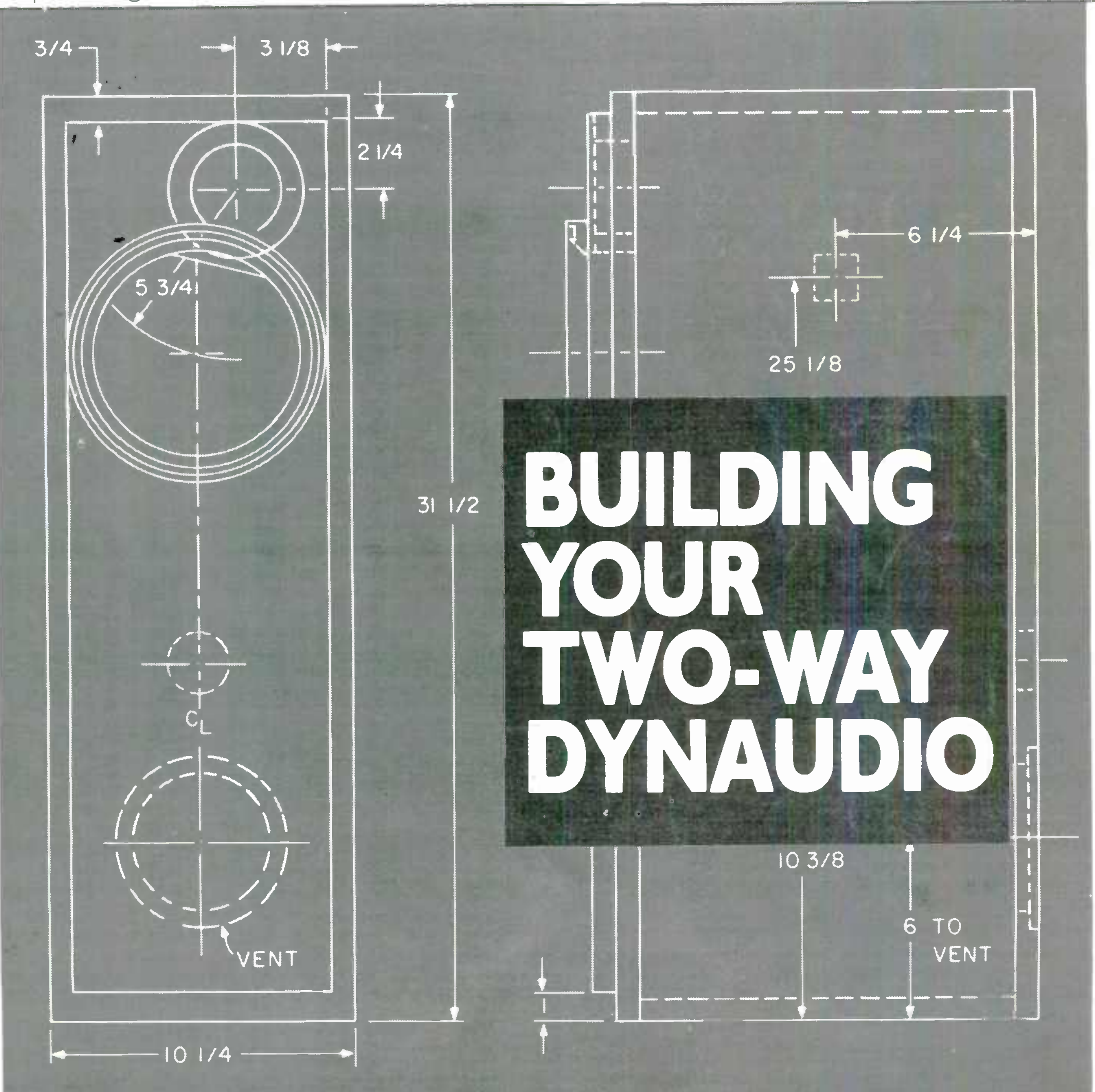
SPEAKER BUILDER

Compensating Crossover ∘ T/S Calculator Programs ∘ Power Lite ∘ USA-61 Kit



BUILDING YOUR TWO-WAY DYNAUDIO

Good News

The *Speaker Bible* is available for $2.50 from **NEW YORK ACOUSTICS,** Dept. SBB, 578 Nepperhan Ave., Yonkers, NY 10701. This useful compendium of advice on speaker building is also their catalog. In it you will find kits for several transmission line systems, mini-monitors and mini-subwoofers, as well as raw drivers, cabinets, crossovers and modifications for Dahlquist DQ-10's and Quad ESL's. Some special parts for speaker building are included, such as driver gaskets, *long fiber* polyester fiberfill, and silicone sealer.

A good answer to the perennial problem of having built too many speakers comes from **THE ALIEN GROUP.** The Voice Box II is a low cost programmable speech synthesizer for the Atari 400 or 800 computer. Although it normally plays through your TV's speaker, its many capabilities seem to demand a small, full-range highly efficient speaker to realize its full potential (you can enjoy improved TV sound as an extra benefit). The Voice Box II will speak with inflection, or even in foreign languages; sing along with three part musical accompaniment; turn the Atari keyboard into a 3½ octave piano; and produce sound effects such as glissando, tremolo, and vibrato. For the name of a dealer near you, contact The Alien Group, Dept. SBCA, 27 West 23rd St., New York, NY 10010.

Woodworking tools have a fascination all their own which is probably endemic among speaker builders. The most beautiful catalog of such instruments, with some excellent basic information using the various types of tools comes from the **GARRETT WADE COMPANY.** The 244 page compendium carries a $3 price tag but is, in our opinion, well worth it. Write to 161 Avenue of the Americas, Dept. SB, New York, NY 10013.

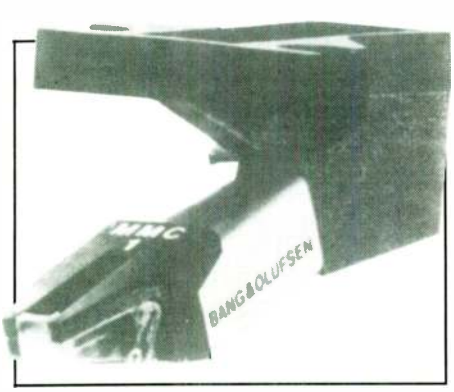
A publication which is familiar to some *SB* readers and which deserves to be read by more people interested in the musical applications of electronics is Bernie Hutchins' **ELECTRONOTES.** It started as a newsletter about digital synthesizers for electronic music, and has developed into a lively forum of ideas about digital audio circuits, much of which applies to other kinds of audio equipment as well. Aimed at electrical engineers, occasionally the text and math can be as difficult as anything in the AES *Journal*, but the ideas and concepts are always intriguing—and worth knowing about. The book and record reviews can be worth the subscription price when they lead you to the right sources. Subscriptions are available from *Electronotes*, Dept. ETD, Pheasant Ln., Ithaca, NY 14850, or call (607) 273-8030.

The **ELECTRONICS SUPERMARKET** has an interesting catalog filled with electronic parts for audio, computer, telephone and video applications. They also sell speaker kits and raw frame drivers, including a ribbon and three piezo tweeters. Cabinets (with minor defects) made for several prominent New England speaker manufacturers (Advent, AR, Genesis) are also available. Write to Dept. SB, PO Box 619, Lynnfield, MA 01940 for a catalog.

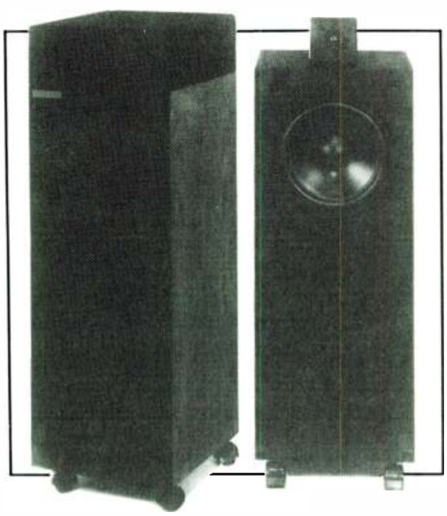
Stereo TV sets with *ambient* sound have been introduced by **PANASONIC.** The 19″ color table model (CT-9092) has 3W amps driving a ½″ round and a 3 × 5″ oval for each channel, with bass, treble and balance controls. The ambience channels are "electronically delayed a fraction of a sound," probably with a simple matrix. Some stereo sound is available on tape and cable, and TV engineers predict broadcasting in stereo within two years. Suggested prices range from $750 to $1300. Since their new line of compacts and portables is bristling with graphic equalizers, Dolby units and such, we wonder when these features will appear on TV sets. Visit your favorite Panasonic dealer for a demonstration and local prices.

A driver without a cone is the best description for a fascinating device from **RELIANCE ELECTRIC MANUFACTURING CO.** Typically, the Acoustic 2000AC attaches to a wall to function as a speaker, but other uses are possible, and readers may want to exercise their imaginations to find new applications for it. It was the driver for Burton Hardin's plate reverb project described in *The Audio Amateur*, 4/82. Apparently waterproof (Reliance suggests placing it in swimming pools for underwater sound and using it outdoors for patios), the device has quite a few latent applications waiting for discovery. Response is 60Hz to 20kHz. Ask for details at Dept. ACSB, Route 2, 1024 West Lake Brantley Rd., Maitland, FL 32751.

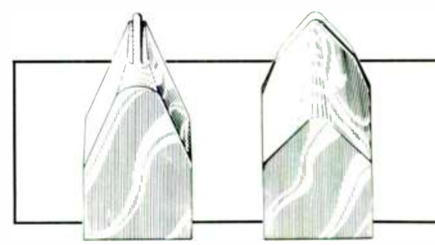
Controlling internal resonance is the new refinement on **BANG and OLUFSEN'S** seventh generation of the MMC cartridge series. The design team headed by S. K. Pramanik identified two sources of resonance in a cartridge. One source, in the 50-60kHz region, is the interaction between the stylus assembly and the yielding surface of the record. The other is the combined resonance of the cantilever, armature, and damping block. This varies with program material, but typically is around 20-30kHz. The obvious approach would be to damp each of the two resonances. B&O engineers wanted to avoid adding mass to the cartridge, so they placed the geometric mean of the two resonances at the same point—39kHz. The result is mutual cancellation (or more accurately, they interact to create two far more diffuse resonances of significantly lower amplitude). Further reductions in mass result from the new smaller, lighter, more powerful samarium cobalt magnets, with 7000 oersteds of coercivity compared to 1500 in the old magnets. B&O also positioned the magnet more advantageously to reduce magnetic current loss. Audition them at your favorite salon, or write to B&O, Dept. JL, 1150 Feehanville Dr., Mount Prospect, IL 60056.



Tools and test equipment for the electronic craftsman are featured in a catalog from **CONTACT EAST,** Dept. SB, PO Box 160, Burlington, MA 01803. The selection of hand tools for various types of electronic work is quite wide, and of good quality. Along with the test gear, they have power tools, ultrasonic cleaners, heat guns, padded tool cases, and other interesting items.



ACOUSTICAL PHYSICS LABS has a new speaker kit, the Acoustic Image™ Model II. The two-way system features computer aided design to gain control over time domain characteristics, enabling the speaker to project a more accurate stereo image. Residing in an acoustic suspension enclosure, the ten inch polypropylene woofer has a long excursion and achieves a maximum power handling capacity of 150W. The soft dome tweeter, mounted in free air and time domain corrected, has fast, smooth, ring-free response from 3.5kHz to 22kHz. The crossover provides a gradual slope for a smooth, phase accurate transition between drivers. Overall system response is ±2dB from 28Hz to 22kHz, with a nominal impedance of 8 ohms. Dimensions are 34½ x 13¾ x 13." Supplied with pre-tested components, the basic kit, consisting of drivers, crossovers and hardware is $225/pair. With cabinetry, the price is $400/pair, and completely assembled, $600/pair. For further information, write to them at Dept. SB, 151 Sixth St., Atlanta, GA 30313.



A new stylus tip geometry is featured on the TK10ML cartridge from **SIGNET.** The tip is a sophisticated evolution of the Shibata, or line contact type, with an extra amount of material cut away from the sides. This leaves a highly-polished, wafer-thin tracing contour extending around the tip. Benefits include reduced tip mass and a greatly improved interface with the groove walls. According to Signet, it provides the most precise transfer of recorded information of any tip configuration they have tested. The square shank stylus is set into a laser-cut square hole in a low mass rigid boron cantilever. The coils are toroidal, with a six layer lamination extending beyond the coil to form the pole pieces. OFHC copper wire is used and is connected directly to the output terminals. Low inductance and low resistance in this highly efficient generator contribute to its excellent sound quality. For more information and the name of a Signet dealer near you, write to Dept. SB, 4701 Hudson Dr., Stow, OH 44224.

Speaker kits, raw drivers, cabinets, and crossovers are available from **SPEAKER COMPONENTS**. Emphasis is on high quality—all drivers are tested for Q, Vas, distortion, and frequency and phase response. Crossover caps are mylar films, selected for better than 2% tolerance. Several types of drivers are available, from the expected polypropylene woofers to ferrofluid filled dome tweeters and a new ribbon tweeter. Speaker kits start at $31 each for basic components without cabinets, ranging up to $180 apiece for fully assembled systems. Send for their catalog: Dept. SBK, Box 297, Marlborough, CT 06447.

About This Issue

The joys of constructing a Dynaudio speaker design are chronicled by **Mike Boulais** in this issue's lead article (p. 7). **Max Knittel** follows with all the guidance you are likely to need to build a passive crossover, which compensates for driver impedance. Programmable calculators are Contributing Editor **Bob Bullock's** focus. He has programmed two calculators (HP and TI) to take the drudgery out of determining Thiele/Small parameters (p. 15) and is making encoded cards available (through Old Colony) for those who don't fancy keying in the program listings.

L. R. Palounek offers helpful tips (p. 24) to those who have not yet purchased a programmable calculator. (By the way, Editor Bullock and **Bob White** are already at work on a Thiele/Small program for the Apple computer).

Bob Carlberg's odyssey continues (p. 28) with monsters and phased units.

Thomas Mosteller does a kit report on Universal Sound's USA61 speaker kit (p. 30), and **Jan Didden** reports (p. 34) on some highlights from the Audio Engineering Society's Eindhoven (March 1983) meeting, where loudspeakers were second in prominence only to the Philips compact disk.

A. L. Newcomb has designed a neat, versatile power indicator for your speaker. A detailed account of his design begins on page 26.

SPEAKER BUILDER

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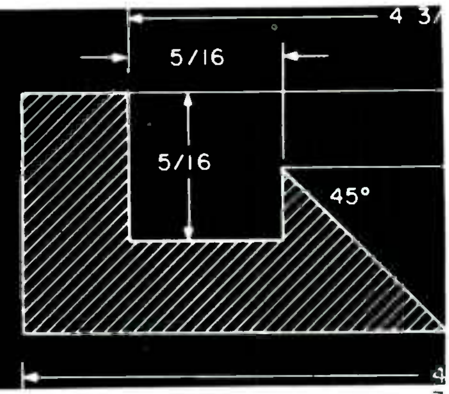

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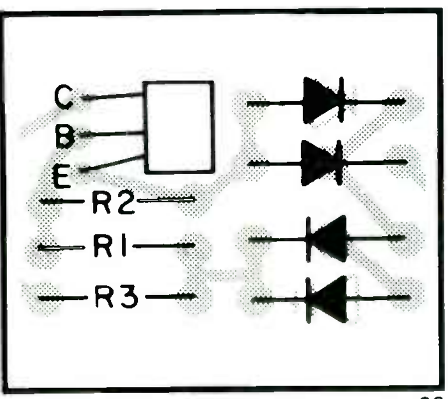

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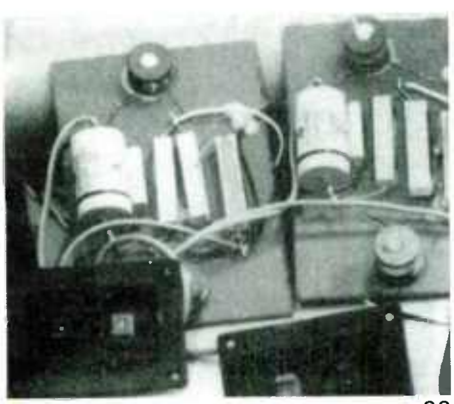
DEPARTMENTS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Editorial

The Digital Decision

The digital age for audio has not only dawned, the day is moving rapidly toward what must at least be coffee break time. Whether the day will be full of sunlight and birdsong or threatening clouds that promise rain, hail and possible tornadoes is a matter of personal viewpoint.

The CD (compact disk), the 4¾″ laser access brainchild of Philips has burst onto the audio scene with a great deal of fanfare. Also *Stereophile* and the Boston Audio Society's *Speaker* nearly simultaneously are reviewing enthusiastically Sony's PCM-F1 digital processor. J. Gordon Holt's preliminary report on the compact disk is must reading for anyone who wants to know what the machine is likely to be capable of. Those who see *The Gramophone* (March '83) and *Hi-Fi News & Record Review* (March '83) will get an excellent overview of the process, the hardware/software and much else that lends reliable perspective to what is to come.

My purpose here is not to duplicate any of this preliminary exploration nor to "take a position" on the relative merits of digital/analog techniques. I am here concerned with an overview of where I think we are in this Spring of 1983 relative to audio's course as it is, or could be, affected by the advent of the digital revolution.

First of all, a bit of perspective. When the four manufacturers participating in the first demonstration of the video disk at the Audio Engineering Society's 1975 convention in New York finished their presentation, they were unanimous in their declaration that audiophiles should *not* get their hopes up because technology of this sophistication and data density made the whole concept impractical for mere audio purposes. Philips was one of those four.

Much of what is in the early evaluations of the CD system gives us reason to be glad Philips did not believe their own propaganda. Unfortunately, RCA apparently did. I say that because RCA has, in my opinion, the far superior technology for a genuine mass produced digital disk innovation.

The RCA player is a far simpler device yet apparently could have all the reproduction quality advantages of the Philips laser system. The disk is far, far easier to mass produce, the process being similar to the present pressing techniques employed for analog disks. The Philips CD and video disks are proving to be extraordinarily difficult to manufacture with reject rates sometimes as high as 90%. The technology for making the CDs is roughly comparable to IC chip manufacture and has been astronomically expensive to implement.

Alas, RCA has performed in its traditionally fumbling style and let a golden opportunity pass it by. Only recently have RCA's people managed to upgrade the video disk to stereo sound. I doubt we

Continued on page 44

The Dynaudio: An Inexpensive Two-Way with Great Sound

BY MICHAEL J. BOULAIS

These speakers have more power handling capacity than any I have heard. Not only can they soak up large amounts of power, but they are also *efficient* at 94-96dB/watt input.

I spared no effort in making this a no compromise system. Even at extreme SPL's it is capable of a high level of definition and a feeling of boxlessness that can send shivers up your spine. All this is because of those marvelous high technology drivers (the 8¾" Dynaudio 21W54 and the D-28 midrange/tweeter), their mounting and location and the design of the cabinet *(Photo 1)*. They are capable of clean output up to 127dB, and can handle 220W music power DIN (1,000W peak for 10msec). A nearly flat impedance curve along with a smooth rolloff at 4kHz facilitates the use of the 6dB/octave filter.

I built this system with the future addition of a subwoofer in mind. The bass is not weak, but it is physically impossible for an 8¾" driver to have the volume displacement necessary to reproduce the gigantic wave lengths of the low bass region at a level equal to the mid-bass, especially when the system is played at a high SPL (Sound Pressure Level).

Imaging is that quality of speakers which seems to project the sound out into the room and gives the illusion that the performers are arranged across an imaginary stage between the speakers. When this quality is lacking, speakers tend to sound like boxes with music coming out of them. Many details of design help produce out-of-the-box sound and this project makes use of several techniques:

- Tall profile to bring the drivers closer to ear level and away from floor reflections
- Woofer mounted in front of tweeter to compensate for time delay in bass propagation
- Close driver placement (to keep acoustical output of the drivers inphase) results in better stereo imaging
- Aperiodic speaker loading to reduce total system Q
- Wrap around grille, rounded corners, off center tweeter placement, and narrow front—all to reduce coloration resulting from diffraction interference and improve imaging by eliminating out-of-phase reflections
- 1" acoustic foam covering on front to reduce baffle reflections
- Soft midrange/woofer attachment
- Sand/asphalt coating, and cross braces to dampen panel resonances

CONSTRUCTION. I began by cutting out all 14 panels from the ⅝" particle board, leaving the front and rear panels a little over size on all sides, and the side panels a little over size only on the top and bottom ends. All of the other six panels were cut to exact size. For convenience, precut the spacer ring and all cut outs before assembly *(Fig. 1)*.

To improve adhesion of the sand/asphalt mix I first painted the inside surface of each panel with the plain asphalt roof coating. Then I applied the mixture to about a ¾" thickness leaving room for the butt joints and cross braces. The sand

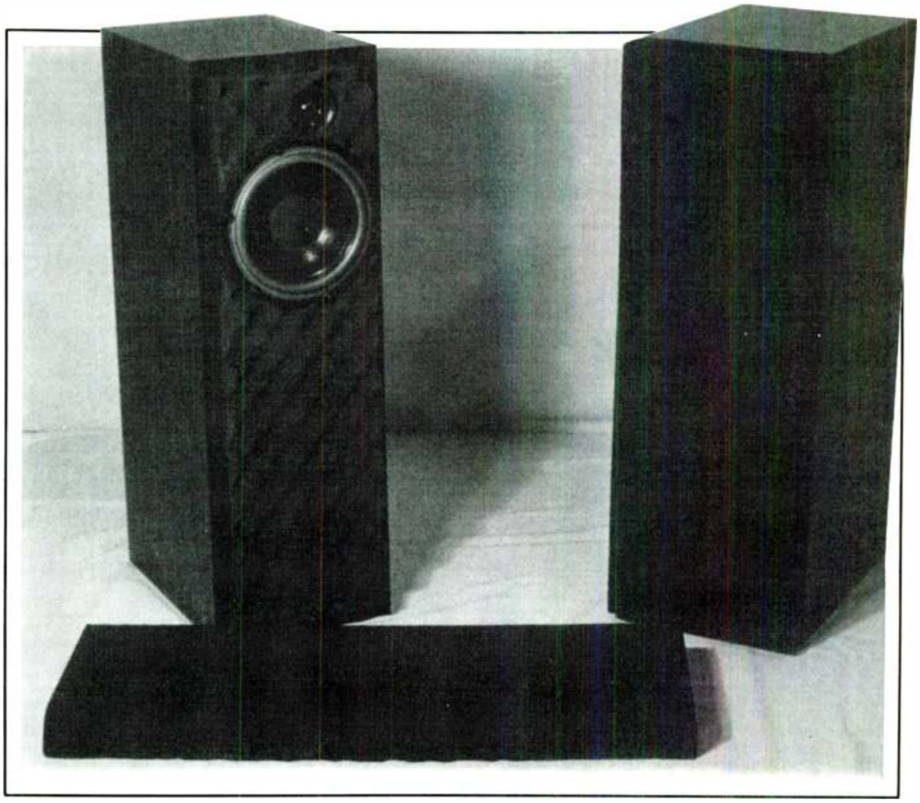

PHOTO 1: Good stereo imaging is aided by driver positioning, while foam on baffleboard controls early reflections. Formica finish improves appearance.

About the Author

Michael Boulais is married and the father of five beautiful children. A graduate of Vermont Technical College with a degree in electronics, he is mostly self-taught in speaker building, but owes much to Mike Dzurko of Audio Concepts. He is a perfectionist at heart and has a keen spirit of inventiveness picked up from his youth where competition was strong and where great excitement and much tinkering on the latest project or family invention was the order of the day.

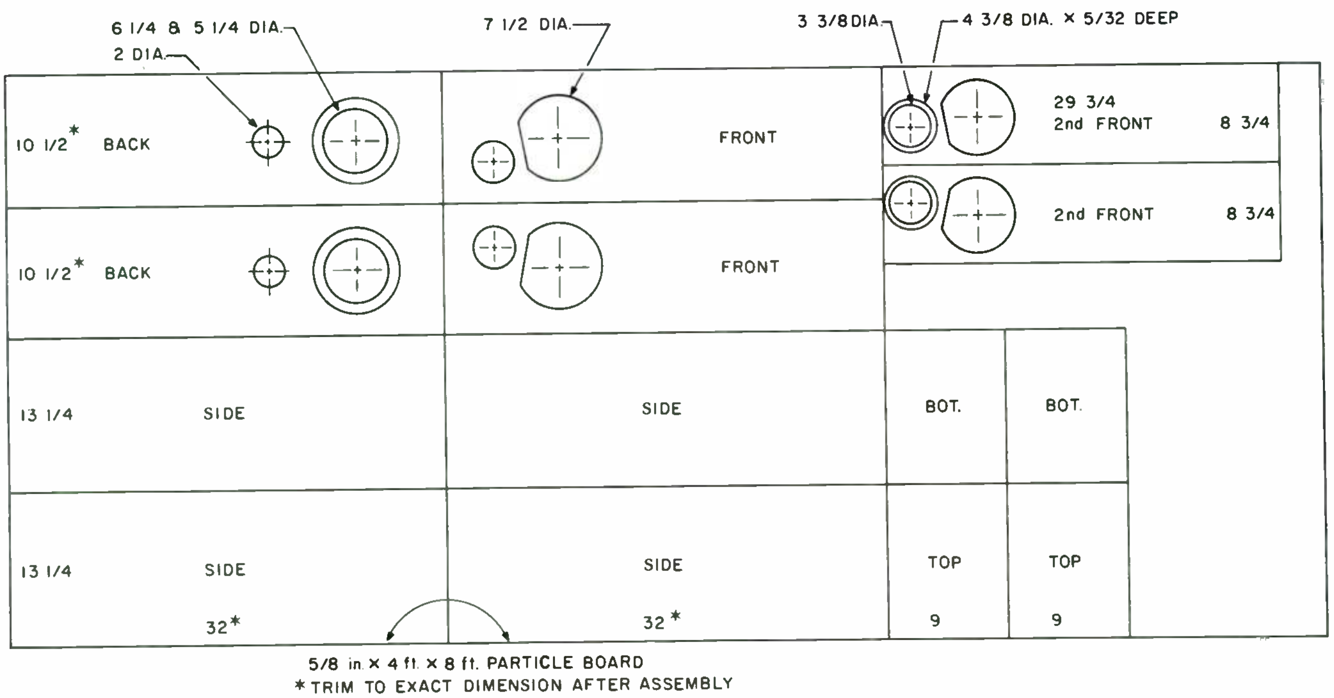

FIGURE 1: Cut the particle board using this pattern to make all the sections for two cabinets.

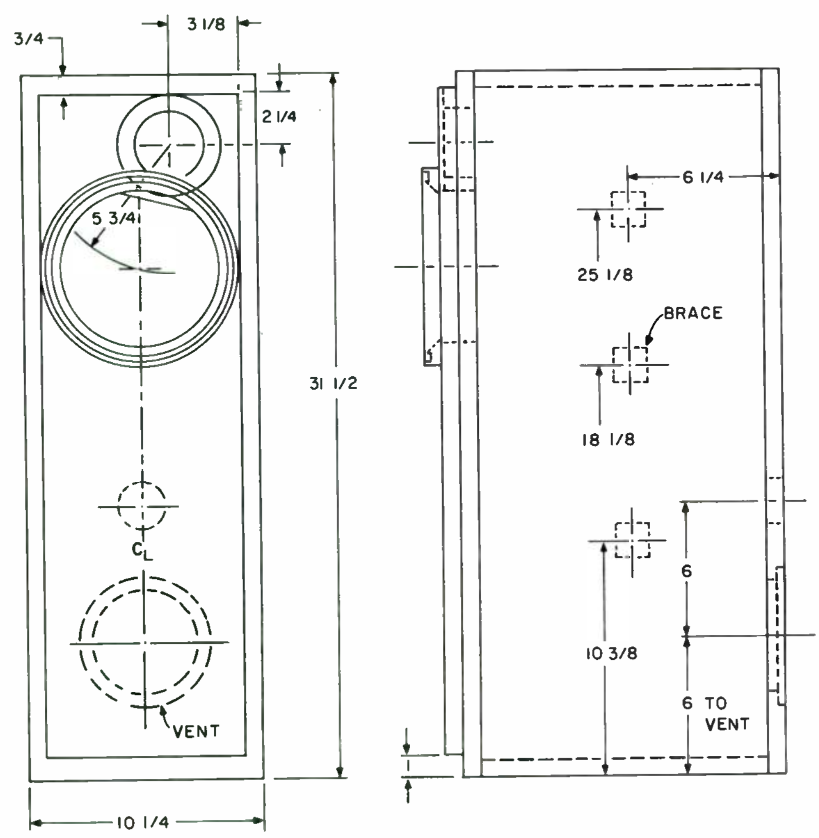

FIGURE 2: Assemble the cabinets as shown, starting by attaching side panels to the braces. Seal all the joints as you go.

was far easier to mix with asphalt when it was dry. I also found it easier to mix by pouring the sand into the asphalt rather than asphalt into sand.

I covered the side panels with four separate patches, each differing in size, so as to distribute and randomize the panel resonances that still might remain, and also to permit a firm footing for the three cross braces *(Fig. 2* and *Photo 2).* To prevent rattles should the mix ever dry out and harden I took the precaution of covering each panel with fiberglass screen tightly stretched over the mix and securely stapled in place.

I covered one side panel, both top and bottom panels, and half of the rear panel with the 1″ acoustic foam. All other surfaces I covered with 1″ to 2″ of polyester Dacron batting. The three cross braces were cut from 2×4's ripped in half lengthwise and cut 8¾″ long.

Assembly begins by attaching the three braces to the side panels with 8×2″ long flat head screws predrilled and countersunk below the surface. Preferred assembly sequence is: side panels first, back panel, top and bottom (inserted, squared up, and nailed), front panel last. (Second front panel left off for now.) Remember to leave the sides, rear, and front panels extending a little beyond the top and bottom pieces.

Fasten all panels using butt joints nailed every 1½″ with 4D hardened steel spiral thread floor nails and generous amounts of latex sealer. Soft nails bend too easily, larger nails break the particle board.

As I assembled my first box I purposely left the top and bottom panels unnailed so they might be removed later. I also left off the foam from these two panels. The purpose was to determine just how effectively the foam actually absorbed standing waves. I then simply sang a tone into the box, starting from the lowest pitch I could make and sliding to my upper limit like a sweep tone generator. While doing this, I listened for any noticeable box resonances. I found a rather pronounced resonance near the lower limit of my voice. Then I stapled the foam onto the two panels and repeated the experiment. The difference was amazing. The resonance had completely disappeared.

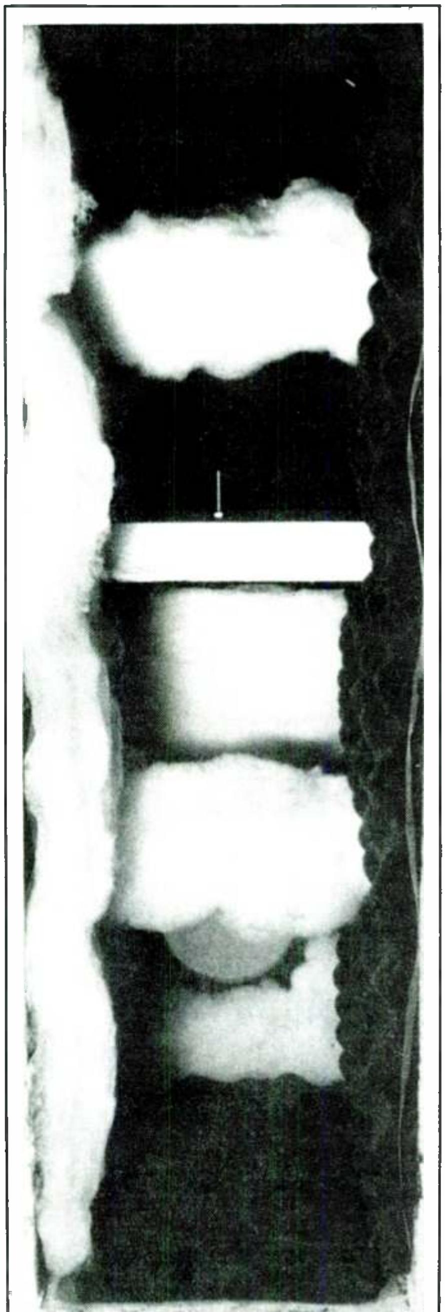

PHOTO 2: Interior bracing and use of absorptive material reduce cabinet resonances. Notice vent opening in rear.

Leave the panel edges protruding a little beyond the abutting panels so that you can now trim each edge perfectly flush with the same router cutter that you will use later for trimming the formica. Now attach and seal the second front panels and paint the rear and front surfaces black.

I cut the formica ¹/₈″ to ¼″ over size on each dimension and trimmed it flush with the box. A 3″ brush was much handier for applying the contact cement to both box and formica than a trowel. By applying it fairly heavily and rapidly, you can minimize lumping.

The fronts are double thickness to provide a "nest" around the edges for the quarter round molding *(Fig. 3)*. The woofer extends in front of the tweeter an optimum ¾″ to ⁷/₈″ making their outputs acoustically in phase.

To do this I routed two spacer rings careful with that screwdriver or it will slip and puncture the cone.

The venting recommended for this system by Dynaudio provides a pressure relief at low frequencies, but acts more like a sealed box at higher frequencies. It is not at all related to the Thiele/Small fourth order vented box system. A 5¼″ diameter hole cut into the rear panel with a larger recess for the wire cloth cover to nest in makes a professional-looking vent. I cut a 2″ thickness of fluffed fiberglass to fit, compressed it to approximately ¾″, and stuffed it into the hole. The fiberglass screen covers the hole from the inside. Finally, cut out a piece of the ¼″ spaced heavy wire cloth and staple it into the relief provided.

If you prefer you can purchase factory made vents from Dynaudio. They recommend using two for each of the 21W54 woofers and list them for $7.00 each.

For the grille frame I used a ¾″ quarter round molding slightly reduced in size

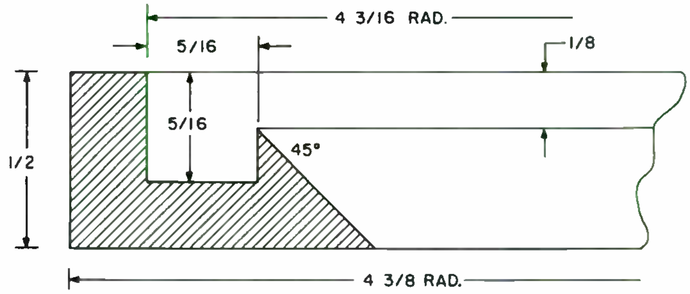

FIGURE 3: Woofer is moved forward by the spacer ring, making its acoustical output in-phase with tweeter.

from ½″ material using a special flat bar attached to my router which extends outward from the router and lays flat against the work. Drive a nail into the center and clip off its head. Select the proper pivot hole on the bar and place it over the nail *(Fig. 4)*. The trick for cutting through holes is to route almost through, leaving a thin web at the bottom. After all cuts are made a full 360° knock out the center piece. Presto, professional-looking holes with only the simplest of tools.

Allow the cabinets to stand open for at least a week before installing the speakers as the solvents given off by the asphalt coating might possibly break down the adhesives used on the drivers.

Wire the tweeter and seal it in place with silicone rubber followed by the spacer ring. A thin bead of silicone placed inside the groove secures the ³/₈″ × ½″ vinyl foam. Wire the crossover as in *Fig. 5* and attach it to the center cross brace.

"Float" the woofer on the vinyl foam and attach it using 8 × 2″ long round head screws with grommets and washers under the heads. Predrilling and careful alignment of the screws is a must. Be

by saw-cutting and sanding the edges. After painting, miter each corner and join by predrilling for a single 6 × 1½″ screw. Staple the ½″ spaced heavy wire hardware cloth to the grille frame, cutting it oversize by ½″ on the sides so you

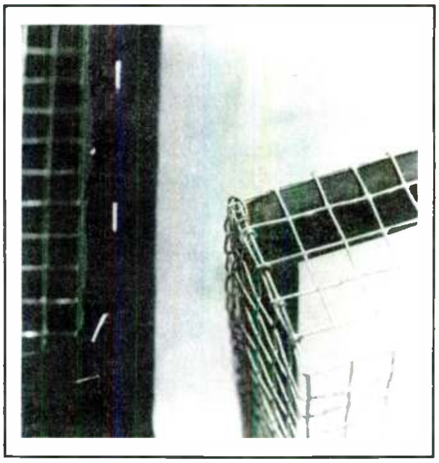

PHOTO 3: Grille is extra deep to accommodate woofer. Form the corner by placing wire cloth over two 2 × 4's and hand work it around the edges using a small hammer.

can staple it behind the quarter round. For neater bends clamp the wire between two 2×4's, working the wire by hand with a small hammer. Rather than cutting and sewing the corners of the grille cloth simply fold them under and staple them in place *(Photo 3.)*

Cover the fronts with the 1" acoustical foam, being very careful to provide plenty of clearance around the tweeter to reduce the narrowing effect it has on dispersion when placed too close to the horn mouth. If you have difficulty finding this foam, I can supply it to you in 30"×76" sheets with 1, 2, or 3" thicknesses.

The finishing touch is to install recessed spring terminals on the rear panels.

EVALUATION. To get outside opinion on this speaker I took it to my brother-in-law's house to get his impression. He has two systems; one is an expensive Japanese 3-way system using horn midrange, and tweeter and 12" woofer in air suspension. The other is an older 2-way Advent.

He conceded that his beloved Japanese system was equal to my Dynaudio system in quality and only a trifle louder. This was at moderate levels averaging from 5 to 30W per channel. Unfortunately he has little experience with good audio, so he did not notice the nice stereo image and clean bass of the Dynaudio. In fact he actually preferred the boxiness and booming upper bass coming from the Japanese system. To me the Japanese system sounded like junk, but to him it sounded like "hi-fi," perhaps because of those same qualities. To me the Advents sounded more balanced, and less boxy than the Japanese system but not as boxless as the Dynaudio, whereas my brother-in-law regarded them as his secondary set. The Advents lacked the crystal highs of the Dynaudio, and because the woofer was close to his beautiful maple floor, reflections prevented the Advent from sounding its best. We both agreed on the difference between the Advent and the Dynaudio systems.

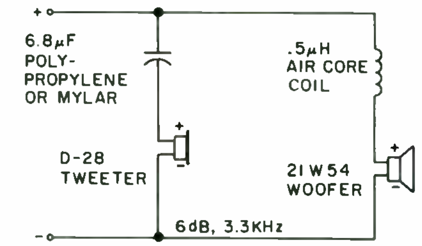

FIGURE 5: Smooth 6dB/octave rolloff is accomplished with this circuit.

If we were to hook up each of the three systems to a 400W per channel amplifier the Japanese and Advent systems would go up in smoke, and their voice coils would pop out of their sockets, but the Dynaudios would sing like angels—rather loudly though. This system cost about $360.00 to build.

What would I do differently a second time? For the stiffeners I might try using 2×4's standing edgewise on each side panel rather than the three cross braces. I would place each stiffener a little off-center (one more off-center than the other). Then I would apply the sand/asphalt mixture afterward. This would save time and would work as well. I also would place acoustical foam on *all* inside panels because of its superior low frequency absorption.

I might opt for a three-way system using the Dynaudio D-52 2" dome midrange which would allow me to substitute the D-21 super-tweeter for the D-28. The D-21 has an even faster rise time of 10μS for the D-28. It also has better dispersion and responds well above 30kHz. Crossovers would be 6dB at 700 and 5,000 Hz.

For a subwoofer system with matching SPL capability I would use a minimum of two drivers per channel, 12" or larger, crossed over with 18 or 24dB/octave slopes at 70-100Hz.

I would try transmission lines if I had room enough for the huge enclosures required and lots of cone surface on the drivers. Otherwise I would use very, very tight Thiele/Small vented sixth order enclosures because of the excellent cone loading and volumetric efficiency possible with the ported box.

A subwoofer using two #30W54 Dynaudio 12" drivers per channel properly baffled as above combined with the three-way system mentioned earlier would make a system unequaled by anything this side of Alpha Centauri in terms of head room and definition. □

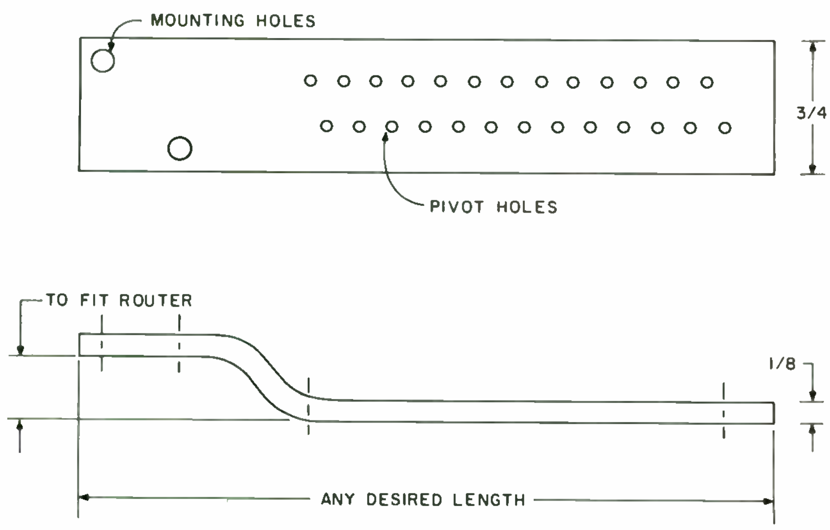

FIGURE 4: Cutting circular openings is easy with this tool.

PARTS LIST

- 2 Dynaudio D-28 Tweeters $32.00 each
- 2 Dynaudio 21W54 Woofers $79.00 each
- 2 Spring loaded cup terminals $.99 each
- 2 6.8μF Polypropylene or Mylar capacitors
- 2 .3mH air core heavy wire inductors $2.00 each
- 1 sheet of 4'×8'×5/8" good quality particle board
- 1 4'×8' sheet of Bookmatched Windsor Walnut #232 formica
- 1 sheet of 1/2"×12"×24" cabinet quality plywood for spacer rings
- 1 38" length of 2×4 for bracing
- 1 1/2" spaced heavy wire hardware cloth 36"×36" for grilles
- 1 1/4" spaced heavy wire hardware cloth 6"×12" for vents
- 1 "transparent" grille cloth 42"×48"
- 1 16' length of 3/4" quarter round molding
- 1 roll of 1"×30"×76" sheet of acoustical foam
- 1 roll of 2"×12" ft² of polyester Dacron batting
- 1 32"×8' fiberglass screening
- 2 gallons of Premier asphalt roof coating #RC-24 or equal
- 1/2 ft³ clean dry sand
- 50" 3/8×1/2" vinyl foam weather stripping
- 1 can of flat black spray paint
- 2 qts. contact cement
- 12 3/16" I.D. grommets
- 1 1/2 lb. 4D hardened steel spiral thread floor nails
- 1 tube each of latex caulk and silicone rubber
- 12 #8×2" long flat head screws
- 12 #8×2" long round head screws
- 14 #8×1 1/4" hex head screws (to attach second front)
- 8 #6×1 1/2" flat head screws
- 1 box of 5/16" staples

IMPEDANCE COMPENSATING CROSSOVER

BY MAX R. KNITTEL

Once the speaker builder has measured all his driver parameters and built his very accurately-designed boxes, he still is faced with the problem of how to design a crossover network that will transfer the loudspeaker's output smoothly from one driver to the next. Not only might he desire that the crossover aid in producing a flat amplitude response for the speaker system, but also he may desire a flat phase response, good power handling, and some smoothing of the responses of the individual drivers themselves. The design of a good passive crossover network can become very complex.

Few books or articles treat the design of real-life passive crossovers. They do not tell how to adapt a complex crossover design from one speaker to another. Most discuss theoretical 6, 12, and 18dB/octave low- and high-pass filters with perhaps some real-life examples to show how complex (and different from the nice, simple theoretical ones) crossovers can become.[1] However, this gives little help to the amateur speaker builder who does not have the complex testing equipment and detailed knowledge needed to design these complicated networks.

Fortunately, we can do some things to help in designing simple yet satisfactory crossovers. The first is to choose drivers with as linear and extended a frequency response as possible. If we use first-order filters (6dB/octave) to achieve an ideal total network response (flat frequency response with zero group delay), then the drivers should have flat amplitude and phase response over a wide frequency range on either side of the crossover frequency, at least one octave or more.[2]

Ideally we would like the driver to present a constant and resistive impedance to the crossover. Usually this is not possible because the inductance of the driver voice coil causes the impedance to rise with increasing frequency. However, placing a series resistance/capacitance network across the driver terminals, compensates for the rise in the driver impedance.[3] *Figure 1* shows the impedance of a typical 8″ woofer in a closed box with and without the inductance compensation network.

To calculate the required network components, first determine the driver DC resistance R_e and inductance L_e. The compensation resistor R_c is then equal to R_e (although several ohms larger often produces a more nearly flat impedance curve). The compensation capacitor C_c is given by:

$$C_c = \frac{L_e}{R_e^2} \qquad (1)$$

For example, for the woofer of *Fig. 1* $R_e = 6.9\Omega$ and $L_e = 9.55 \times 10^{-4}$ H. (See Box A for a method of measuring voice coil inductance.) Using $R_c = 9\Omega$, then $C_c = 9.55 \times 10^{-4}/9^2 = 11.8\mu F$. The impedance curve in *Fig. 1* is now centered at 9 $\pm 2\Omega$, ignoring the low-frequency box resonance. This is particularly important in this two-way system with its crossover frequency of 3500Hz.

Soft dome tweeters, along with this rising impedance curve, present an additional problem because of underdamped resonances caused by insufficient air trapped between the dome and the sealed back. This is not only audible but also limits the tweeter's power handling. Thus, we need to devise a network to cancel out the resonance of the tweeter.[4] *Figure 2* shows the impedance of a dome tweeter with and without the inductance compensation and resonance cancellation networks.

To calculate the required network components for the tweeter requires a bit more knowledge than for the woofer. In

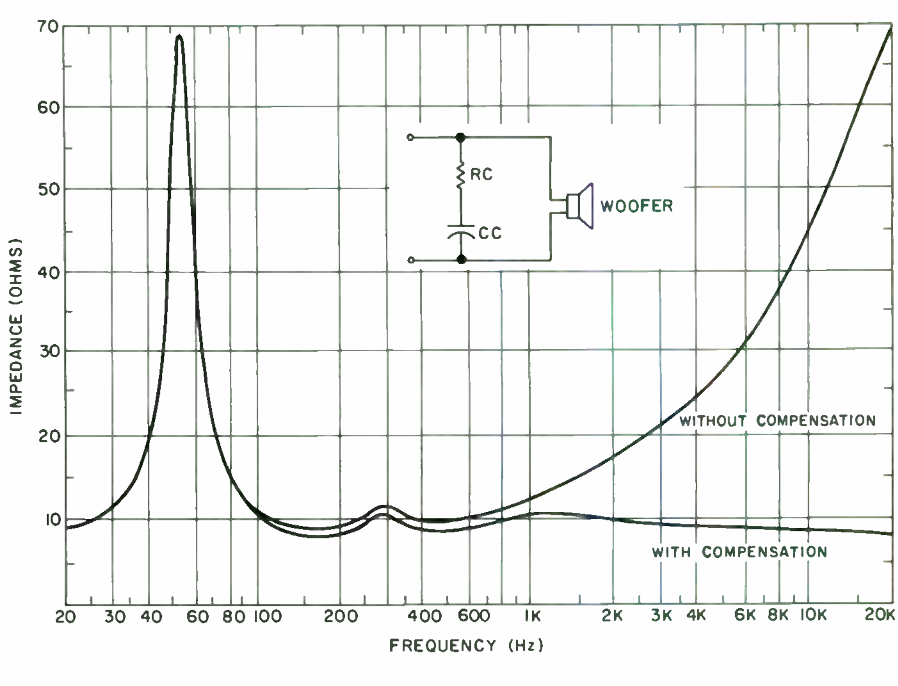

FIGURE 1: Impedance curve of the Audax HD20B25H4C12 woofer in a closed box is flattened by the compensating network. Note the box resonance peak at the left.

this case we need to know a number of tweeter parameters.

f_s = resonance frequency
R_e = DC resistance
L_e = inductance
Q_e = electrical Q
Q_m = mechanical Q

These parameters are measured or calculated in exactly the same way as they are for a woofer when determining box volume.[5] The network components are then calculated from:

$$R_1 = R_e \quad (2)$$

$$C_1 = \frac{L_e}{R_e^2} \quad (3)$$

$$R_2 = \frac{Q_e R_e}{Q_m} \quad (4)$$

$$C_2 = \frac{1}{Q_e R_e}\left(\frac{1}{2\pi f_s}\right) \quad (5)$$

$$L_2 = Q_e R_e\left(\frac{1}{2\pi f_s}\right) \quad (6)$$

The compensation network is wired across the tweeter's terminals, as shown in *Fig. 2*.

As an example, the parameters of the tweeter in *Fig. 2* are:

f_s = 1130Hz
R_e = 5.67Ω
L_e = 6.76 x 10^{-5}H
Q_e = 1.13
Q_m = 3.38

Therefore, R_1 = 5.67Ω, C_1 = 2.10μF, R_2 = 1.90Ω, C_2 = 22.0μF and L_2 = 0.90mH. The resistance R_2 includes the DC resistance of the inductor L_2 (or can sometimes be entirely comprised of it). (See Box B for a method for designing and winding inductors.) In this case, the inductor's DC resistance was 1.4Ω, requiring a separate 0.5Ω resistor in series.

Once the impedance of the woofer and tweeter have been tamed with these networks, you can measure the respective impedances at the crossover frequency and calculate book values for first or third order filters.[2] These work surprisingly well and often need only some fine tuning by ear. *Figure 3* shows the impedance curve of the completed two-way loudspeaker using first order filters calculated directly from:

$$C = \frac{1}{2\pi f_c Z_t} \quad (7)$$

$$L = \frac{Z_w}{2\pi f_c} \quad (8)$$

where f_c is the crossover frequency of 3500Hz. In *Fig. 4* is a circuit diagram of the complete speaker, including 3dB of attenuation for the tweeter.

Crossover design is a very complicated and somewhat mystical subject (to me, anyway). The ideas presented here have been very helpful in designing crossovers for several different types of loudspeakers. The crossovers have worked well—some even superbly—with a minimum of trial-and-error adjustment. What we amateur speaker builders need is practical advice for designing better crossovers based on driver parameters we can measure or calculate. □

Box A and Box B on page 14

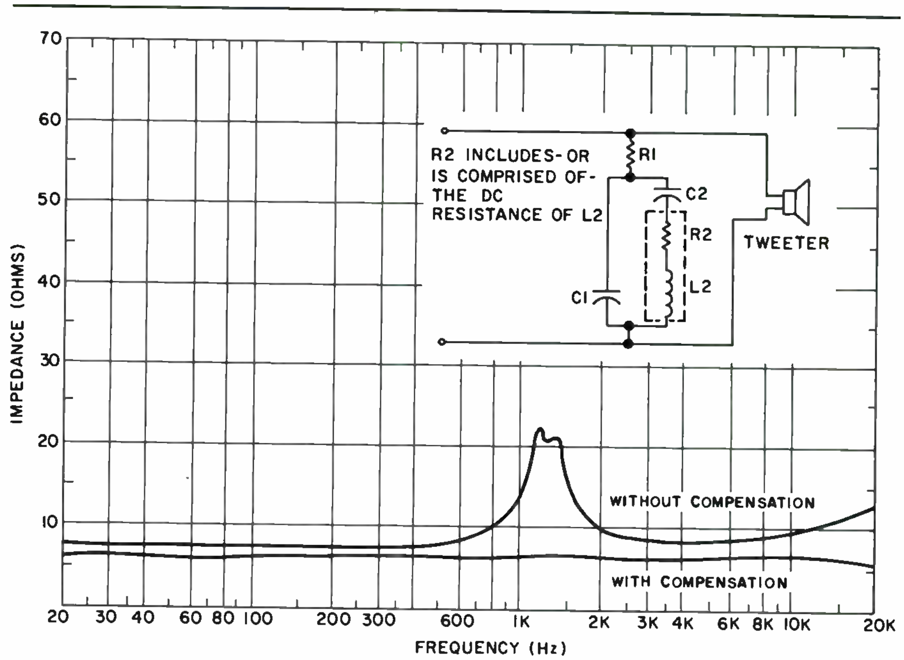

FIGURE 2: Resonance peak of the KEF T27 tweeter is eliminated by the compensating network, which also flattens out the rising trend at end of curve.

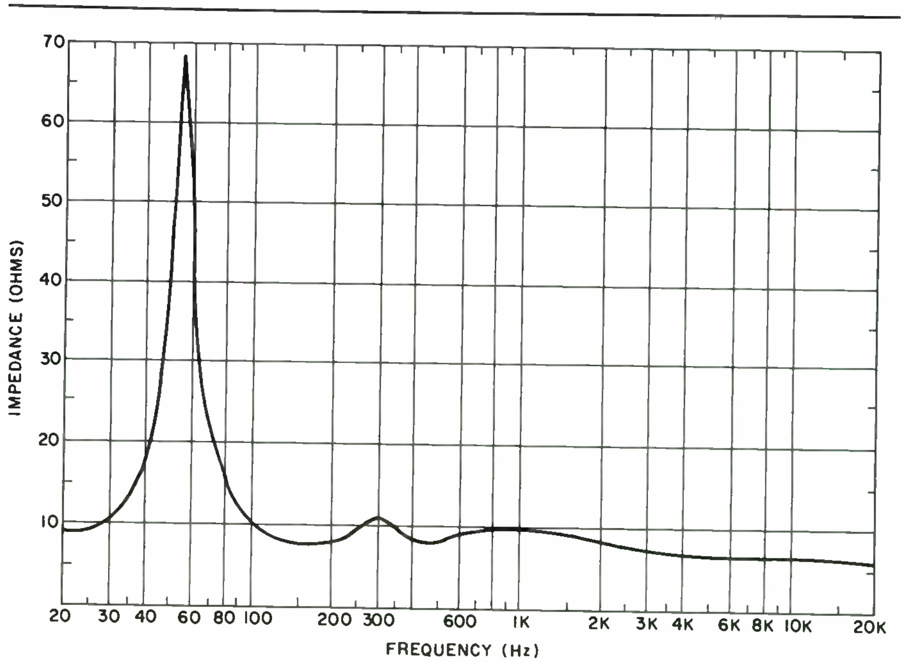

FIGURE 3: After compensation, the completed speaker presents nearly the same electrical impedance to the amplifier at all frequencies.

REFERENCES

1. M. Colloms, *High Performance Loudspeakers*, Halstead Press, second ed., New York (1980), p. 149.
2. A. N. Thiele, "Another Look at Crossover Networks," *Audio*, August 1978, pp. 38-45.
3. R. H. Small, "Constant Voltage Crossover Network Design," *Proceedings* of the IREE

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Australia, Vol. 31, No. 3, March 1970, p. 66.
4. A. N. Thiele, "Optimum Passive Loudspeaker Dividing Networks," *Proceedings* of the IREE Australia, July 1975, pp. 220-224.
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6. D. B. Weems, *How To Design, Build and Test Complete Speaker Systems*, Tab Books, Blue Ridge Summit, PA (1978), pp. 93-94.
7. A. N. Thiele, "Air-Cored Inductors for Audio," *Journal* of the Audio Engineering Society, Vol. 24, No. 5, June 1976, pp. 374-78.

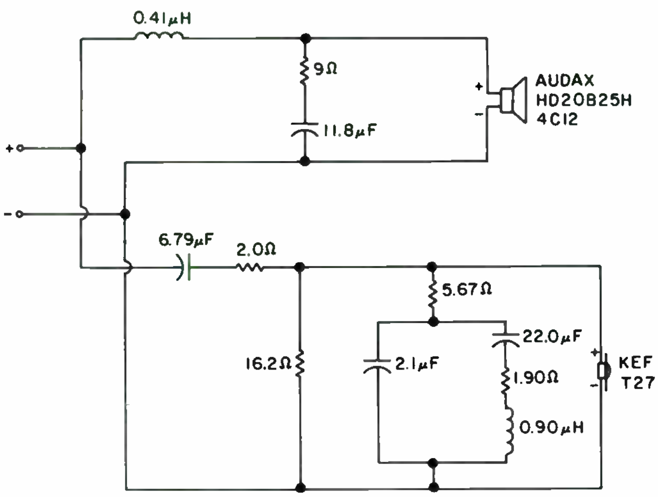


FIGURE 4: In the completed two-way crossover, impedance compensation for each driver occurs after the crossover point.

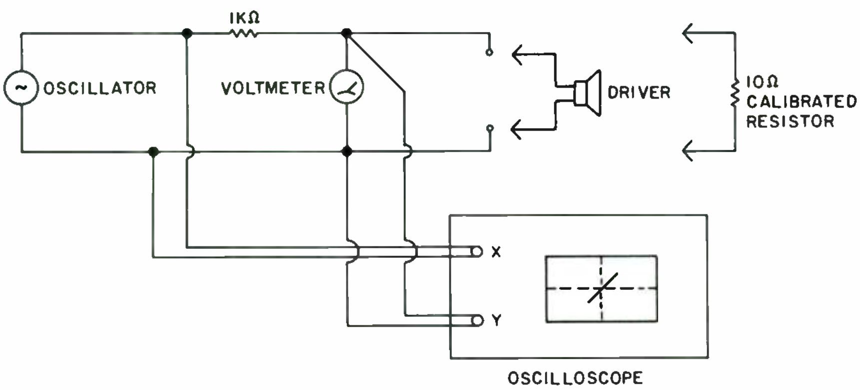


FIGURE 5: Use this test setup to measure inductance without blocking the motion of the driver.

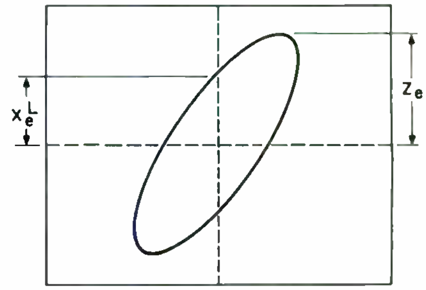


FIGURE 6: Values for impedance and inductive reactance are read from the oscilloscope.

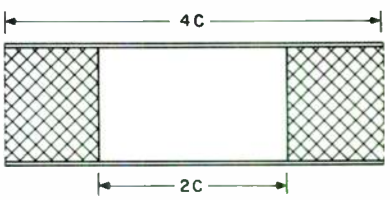


FIGURE 7: Wind the coil with these proportions to obtain correct electrical values. In this edge view, the crosshatched area represents the wire, the white area the center core.

TABLE I
How to Wind Inductors Using Standard Wire

L = Inductance (mH)
R = DC Resistance (Ω)
ℓ = Length of wire (ft)
c = Core radius and length (in)
N = Numbers of turns
d = Wire diameter (in)

L mH	d in.	d AWG	R Ω	ℓ ft.	c in.	N turns
0.1	0.0508	(16)	0.0844	21.0	0.460	58.1
	0.0403	(18)	0.122	19.2	0.383	63.7
	0.0320	(20)	0.177	17.5	0.318	69.9
	0.0253	(22)	0.257	15.9	0.264	76.7
	0.0201	(24)	0.372	14.5	0.219	84.1
	0.0159	(26)	0.541	13.2	0.182	92.4
	0.0126	(28)	0.785	12.0	0.151	101.4
	0.0100	(30)	1.14	11.0	0.125	111.3
	0.0080	(32)	1.62	10.0	0.105	121.5
	0.0063	(34)	2.38	9.1	0.087	133.8
	0.0050	(36)	3.45	8.3	0.072	146.8
	0.0040	(38)	4.92	7.6	0.060	160.5
XL			$X^{0.6}R$	$X^{0.6}\ell$	$X^{0.2}c$	$X^{0.4}N$

Inductors wound in this manner by fairly neat scramble winding will produce, at worst, ±5% error with ±1-2% more common. Most coil forms can be made from standard wooden dowels and tempered hardboard cut with a circle cutter, but a lathe and drill press are a great help, as is an impedance meter to achieve the exact value desired. Glue the hardboard to the dowels or fasten with brass screws. Do not use steel or other ferrous metal fasteners.

IMPEDANCE COMPENSATING CROSSOVER

Continued from page 12

Box A

How to Measure Driver Inductance

One method often given for measuring driver inductance is to block the cone of the driver so that it cannot move and measure the inductance with a commercial impedance meter or bridge. This method has not been very successful for me because it is difficult to stop the motion of the cone completely. Blocking the motion of a soft-dome tweeter seems hazardous.

Weems[6] gives an alternate method for measuring voice coil inductance that uses an oscillator and an oscilloscope with X-Y capabilities. The method is as follows:

1. Set up a test system for measuring driver impedance using the constant current method of Ref. 5. (See *Fig. 5*).
2. Set the oscillator to the driver resonance frequency f_s and sweep up in frequency until the Lissajous figure on the oscilloscope screen becomes a straight line. This is near the driver's minimum impedance at 200 to 400Hz for a woofer or midrange and 2 to 6kHz for a tweeter.
3. Adjust the oscilloscope's vertical and/or horizontal controls for an exactly centered, 45 degree inclined line.
4. Replace the driver with a 10- or 15Ω calibrated resistor and adjust the oscillator output level to yield a vertical deflection of 1cm above and 1cm below the center line of the screen.
5. Restore the driver to the circuit and tune the oscillator to a high frequency f_e (5kHz for a woofer or midrange, 20kHz for a tweeter).
6. Measure the maximum vertical height (from the center) of the oval Lissajous figure on the screen. This is the total impedance of the driver at this frequency and is what is normally measured with a voltmeter in the constant current method of impedance measurement.
7. Measure the vertical height of the oval where it intersects the Y-axis line. This is the inductive reactance X_e^L of the driver at this frequency. *Figure 6* shows a typical picture. The measurements below the center line should be equal to those above.
8. Calculate the voice coil inductance from:

$$L_e = \frac{X_e^L}{2\pi f_e} \qquad (9)$$

Box B

Making the Inductor Coil

When winding inductors it is useful to know how many turns of which size wire to wind on what dimension of coil form. This is particularly important if we wish to make an inductor not only of a particular inductance but also of a particular DC resistance (or at least not larger than a particular resistance). Fortunately, the work has already been done by Thiele[7] in a paper that explains in depth and with great clarity the relationship between the coil inductance and the physical parameters of the wire and coil form. Not only does Thiele's method allow impressively precise prediction of a coil's inductance given the core size and wire length and diameter, but it also predicts equally well the coil's DC resistance. This is needed when calculating a woofer's electrical "Q" and when designing tweeter resonance cancellation networks.

Figure 7 shows the cross-section of an inductor coil form in terms of the dimension "c." Thiele's method requires that the coil have these proportions. The cross-sectional area of the wire winding should be a "c" by "c" inch square, wound around a core of length "c" and diameter "2c." The overall diameter of the flange is "4c." Given a coil of these dimensions, the inductance L in mH and the DC resistance R in ohms is predicted from the length of wire l in feet and the diameter of the wire d in inches. Also the number of turns N that will be needed to wrap the wire onto the core is predicted.

Table 1 gives the inductor form parameters for standard wire gauges, normalized to 0.1mH. For example, if an inductor of 0.8mH and 2.0Ω is needed, then X = 8 and by choosing 26-gauge wire (to achieve a DC resistance nearest to that desired),

$$R = (8)^{0.6}(0.541) = 1.88 \text{ ohms}$$

$$\ell = (8)^{0.6}(13.2) = 46 \text{ feet}$$

$$c = (8)^{0.2}(0.182) = 0.28 \text{ inches}$$

$$N = (8)^{0.4}(92.4) = 212 \text{ turns}$$

THIELE-SMALL CALCULATOR PROGRAMS

BY ROBERT M. BULLOCK

In previous articles I have presented alignment tables which facilitate the design and fabrication of vented speakers with flat response. However, the tables restrict the range of possibilities. A table derived system, though flat, may be undesirable to the designer. Changing parameters results in a speaker with unpredictable performance. Also, the adjustment phase can be extremely tedious and frustrating if you try to achieve a tabulated alignment with the flat response assured by the tables.

With the aid of a reasonably sophisticated programmable calculator, you can overcome this undue dependence on tables and tap the Thiele/Small model's full power. The heart of the model is a formula which expresses relative system output at a frequency, f, in terms of the basic system parameters. In other words, the formula will produce individual data points so you can plot the response curve of any vented system. By programming the formula into a calculator you acquire the capability of examining several response curves, each based on different design values, to determine their acceptability for your use. Then "acceptable" no longer will be a synonym for "tabulated" but will mean acceptable to you the designer.

I use such a program in my own work, and have found it to be invaluable. Since the Texas Instruments TI-58 and 59, and the Hewlett-Packard HP-97 and 67 are widely used, I will give a version for each brand which will run on either model.

The program's storage requirements rule out any calculators with less capacity than the TI-58 or HP-67. On the other hand, you should be able to translate the program easily for even the smallest home computer. If you would like to see a BASIC version, let the Editor know; I will be glad to write one if enough interest develops.

Both the HP and TI versions have the same structure and utilize the function buttons A, B and C with an optional calculation on D. After storing the Thiele/Small parameters in specified registers, pushing button A initializes the program for that system. To find the speaker's output at any given frequency, f, key in the frequency and push B if the system is fourth order (or B then C for sixth order). The system output is the number in the display. You can make a response plot by using the program to find frequency versus output values at selected points over the range of interest. Generally I do not go to all this trouble, but use a simple search to locate the system cutoff frequency and the places where response peaks and valleys occur. Usually this is enough information for me to decide if an alignment is acceptable.

I have also programmed the D button to calculate the system normalized cone displacement at any frequency. If you are familiar with Small's paper[1] button D calculates $|X(2\pi fj)|^2$ This quantity is used to determine maximum system output power as well as other large signal behavior. You may omit the programming for Button D if you wish, since I will deal only with small signal behavior in this article.

You will find complete information on the programs in boxes One, Two and Three. The first describes the parameters and formulas used in the programs so you can see exactly what is calculated. This material is especially useful if you wish to adapt the programs for more specific uses. The other boxes give the program details, including a complete documentation, showing what the storage registers contain at each step, as well as identifying what quantity is calculated in each block of program steps.

When you reach a bug-free copy, you can store it on one magnetic card (all except TI58). Old Colony will offer a correct copy on magnetic cards for both the TI and HP calculators.

SYSTEM OUTPUT. A few words are in order regarding the meaning of the output number calculated by the program. According to the Thiele/Small model, speakers resemble high pass filters since their responses are flat for all sufficiently high frequencies. This flat region is a reference level. Output above and below it is expressed as a fraction of this reference level. For example, an output of 0.5 means the power produced at that frequency is one half of the reference level power. The system cutoff frequency (f3) is the lowest frequency where the power is 0.5. An output of 4 indicates the power at that frequency is four times the reference level.

If you prefer to convert to dB outputs,

TABLE 1

Initial Parameters

Parameter	Driver 1	Driver 2
f_S	34.5	35.1
Q_{MS}	2.0	2.1
V_{AS}	4000	3850
Q_{ES}	.43	.44
Q_T	.366	.376

TABLE 2

T/S Alignment Data for EMS 803

Parameter	Driver 1	Driver 2
Q_L	7	7
Q_T	.37	.38
h	1.0834	1.0578
α	1.4905	1.3552
f_3/f_S	1.1651	1.1153
f_B	37.4	37.1
V_B	2684	2841
f_3	40.2	39.2

TABLE 3

Actual Parameters of Completed System

Parameter	Driver 1	Driver 2
f_{SB}	33.9	34.3
h	.96	.95
α	1.56	1.53
Q_T	.372	.385
Q_L	8.6	8.8

simply take ten times the logarithm of the output number. Thus an output of 0.5 is 10(log0.5) = −3.01dB. The cutoff frequency (f3) is a point where the output is 3dB down from the reference of 0dB. A response peak of 4 would be 6dB above.

PROGRAM USE. With the program you can examine the response of a particular driver and enclosure (vented box alignment) to see whether it will meet your performance criteria, whatever they may be. Generally, you will be concerned with cutoff frequency and the amount of deviation from flat response. For clearer understanding, you can plot the derived data on a response curve.

I use a shorthand method to get a quick impression of the alignment. I simply search for the cutoff point, and response peaks and dips. For example, I guess the cutoff frequency, f1. If the output is smaller than 0.5, I guess a higher point, f2, where the output is larger. Then I find the output at some frequency, f0, between f1 and f2. Now I have the cutoff point bracketed by f1–f0 or f0–f2 and can repeat this process on the smaller interval until I find an f3 between 0.49 and 0.51, which I call the cutoff frequency.

To test for response flatness, I search for peaks and valleys. After finding them I check the ratio of the highest peak to the lowest valley. If it is less than 1.12, the maximum variation will be less than 1/2dB, which I classify as acceptable.

Most of the time I use the program in conjunction with the tabulated alignments. I choose an appropriate table alignment for the driver and then build the system. At this point the measured system parameters usually do not agree with the table values. Without the program I would have to embark on an adjustment phase to hit a tabulated "target" alignment (*SB* 1/82). With the program, I can check the output after each adjustment and stop when I have an acceptable response, which usually involves much less work.

NEW ALIGNMENTS. You can use the program to create your own alignments independently of the tables. This is especially helpful when the tabulated alignment requires a box larger than you want to use. With the program, you have the freedom to choose an appropriate enclosure size and try out various vent tunings (h). Often you can find by trial and error a value of h which will give an acceptable system response. The best way to show you how I use the system is by example, through two of my past projects. As you work through the examples, you will see how to use the program for your own needs.

FOURTH ORDER SYSTEM. The object of this project was to build a precisely matched pair of vented woofers using EMS-803 drivers. After a break in period, I measured the parameters shown in *Table 1*. The Q_T values assume active crossovers, cable resistance of 0.1Ω, and an amplifier damping factor of 50. Using a tabulated alignment (from *SB* 4/80, p. 10, *Table 2*) gives the data in *Table 2* below.

I built enclosures of about 2850in³ and installed 8″ long 3″ diameter tubes. After mounting the drivers, I measured the actual performance of the two systems (*Table 3*), with Q_T adjusted for the box air load mass. Clearly α was too large and h too small. With the program I located the cutoff frequency (Button B). *Table 4* shows the "zeroing in" method of finding it described earlier.

I decided I wanted an f3 closer to 40Hz, so I trimmed about ½″ off the vent tubes and measured again (*Table 5*). Substituting these values in the program gave the outputs in *Table 6*. The f3 of both channels was now exactly where I wanted it. The maximum peaking of 0.15dB in channel 2 was inconsequential. The channels matched quite closely, with a maximum difference of only 0.20dB [10log (1.037/0.9854)] at 80Hz. I could scarcely improve on these figures and considered the alignment completed. Note that the alignment does not correspond to tabulated ones, or even to an interpolation between *Tables 2* and *3* in *SB* 4/80.

TABLE 4

Finding f_3 of EMS 803 System

Frequency	Output Driver 1	Output Driver 2
35	.3202	.3234
40	.4627	.4709
44	.5604	.5757
42	.5137	-
41.5	.5013	.5120
41.2		.5039

TABLE 5

System Parameters After Adjustment

Parameter	Driver 1	Driver 2
f_{SB}	33.9	34.3
h	1.05	1.04
α	1.56	1.53
Q_T	.372	.385
Q_L	8.8	9.1

TABLE 6

EMS-803 System Outputs After final Adjustment Frequency

Frequency	Output Driver 1	Output Driver 2
35	.3198	.3234
40	.5202	.5280
39.5 (= f_3)	.5009	.5080
45	.6873	.7060
50	.8024	.8337
80	.9854	1.0307
100	.9984	1.0333
120	1.0015	1.0280
150	1.0022	1.0203

TABLE 7

Measured Box Parameters of Completed Dual Alignment System

Parameter	Class I	Class II
Q_L	7.5	12.5
Q_T	.34	.34
h	.96	1.42
α	1.64	1.64
f_{SB}	23.5	23.5

TABLE 8

Box Only Output of Completed Class I and Class II Systems Compared to Table Predicted Output

FREQUENCY	OUTPUT CLASS I Table $Q_L = 7$	CLASS I Table $Q_L = 10$	CLASS I Actual	CLASS II Table $Q_L = 10$	CLASS II Table $Q_L = 15$	CLASS II Actual
15	.0195	.0211	.0213	.0026	.0030	.0029
20	.1042	.1134	.1222	.0196	.0025	.0234
25	.2554	.2730	.2962	.0946	.1097	.1252
30	.4092	.4291	.4495	.3408	.3937	.5101
35	.5329	.5513	.5588	.8717	.9680	1.3251
40	.6260	.6419	.6373	1.4155	1.4736	1.7972
45	.6956	.7091	.6961	1.6019	1.6001	1.7124
50	.7482	.7598	.7418	1.5584	1.5345	1.5308
55	.7888	.7987	.7781	1.4631	1.4371	1.3898

DUAL ALIGNED SUBWOOFER. In my article on sixth order alignments *(SB 1/82)* I mentioned that you can use drivers with Q_T between 0.3 and 0.4 in either a class I or class II alignment. I decided to design and build a system which could be converted from one alignment to the other by switching filters and vents, but using the same enclosure volume. Since the two alignments specify different enclosure volumes, I needed a means of dealing with non-tabulated alignments, and my calculator program was the perfect tool for this.

I chose Dalesford D100/300 bextrene drivers with the following parameters: $f_S = 24.3$, $Q_{ES} = 0.35$, $Q_{MS} = 2.7$, and $V_{AS} = 15000in^3$. To account for the probable driver moving mass increase in the box, I assumed $Q_T = 0.34$. Since I intended to use active filters and large gauge cable, any increase in Q_T beyond 0.34 would be negligible. From the $Q_L = 7$ tables *(SB 1/82, pp. 21-22)*, the α values for the class I and II alignments are 1.7838 and 1.9150, giving box volumes of $8409in^3$ and $7833in^3$. I decided to size the box at $8500in^3$, making α 1.76. In the completed

TABLE 9

Parameters for Completed Alignments Including Measured Filter Parameters

Parameter	Class I	Class II
Q_L	7.5	12.5
Q_T	.34	.34
h	.96	1.42
α	1.64	1.64
f_a/f_s	.790	1.59
A	.382	1.60
f_{SB}	23.5	23.5

TABLE 10

Total System Outputs for the Final Alignments in Table 9

Frequency	Output Class I	Output Class II
18	.4316	-
18.3	.5012	-
20	.8437	.0015
25	1.0516	.0173
30	1.0294	.1193
35	1.0024	.4511
35.6	-	.5018
40	.9850	.7987
45	.9758	.9199
50	.9717	.9423
60	.9709	.9449
70	.9737	.9488
80	.9772	.9549
100	.9832	.9665
125	.9882	.9766
150	.9914	.9830

Box One

Vented Box Parameters

- f_S Driver resonant frequency in air
- f_{SB} Driver resonant frequency in box
- Q_{ES} Driver electrical Q
- Q_{MS} Driver mechanical Q
- Q_{TS} Total driver Q
- Q_T Driver Q taking cable-crossover resistance, amplifier damping factor and enclosure airload mass into account
- Q_L Box loss parameter
- h f_B/f_{SB}, where f_B is the vent-box resonant frequency
- α V_{AS}/V_B, where V_{AS} is the volume equivalent driver compliance and V_B is the box volume
- f_a/f_s Ratio of filter characteristic frequency f_a to driver resonant frequency f_{SB} (sixth order alignment only)
- A Reciprocal of filter Q (sixth order alignments only)
- f Frequency at which relative output is desired

Vented Box Formulas

The initialization step (button A) calculates a_1, a_2, a_3, A_1, A_2, A_3 from

$$a_1 = (hQ_T + Q_L)/(Q_L Q_T h^{1/2})$$
$$a_2 = 1/(Q_L Q_T) + 1/h + \alpha/h + h$$
$$a_3 = (hQ_L + Q_T)/(Q_L Q_T h^{1/2})$$
$$A_1 = a_1^2 - 2a_2$$
$$A_2 = a_2^2 + 2 - 2a_1 a_3$$
$$A_3 = a_3^2 - 2a_2$$

a_1, a_2, a_3 are needed only to calculate A_1, A_2, A_3. Their storage registers become available after button A is used.

For a given input f, button B calculates

$$\omega = f/(f_{SB} h^{1/2}),$$

B = box output at f $= \omega^8/(\omega^8 + A_1\omega^6 + A_2\omega^4 + A_3\omega^2 + 1)$.
B is also stored for later use.

Button C gives the combined box-filter output for a sixth order alignment using the formulas:

$$\delta = (f/f_{SB})/(f_a/f_S) = f/f_a,$$

F = filter output at $f = \delta^4/[(\delta^2 - 1)^2 + (A\delta)^2]$,
C = combined output at f = BF.
Button D calculates the cone displacement D using

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

and

D = Bd for fourth order; Cd for sixth order

speakers, the drivers' Q_T actually did measure 0.34, so I used the table values of h = 0.9656 and 1.494 to design the vents. Measuring the parameters at this point gave the values in *Table 7.*

Rather than trying to adjust the values, I compared the "box only" response of the corresponding tabulated alignments *(Table 8)*. I used two table alignments to bracket the measured Q_L. My box responses are within 5% of the corresponding table alignment responses, so I also assumed I could use the tabulated filter parameters. I chose the $Q_L = 7$ class I filter parameters and interpolated halfway between $Q_L = 10$ and $Q = 15$ tables for the class II.

The measured parameter values of the filters I built were close to these values. *Table 9* shows the complete parameter set. I then checked the response of each alignment (including the filter) using *Table 9* values. The results are shown in *Table 10.*

The class II alignment was quite good, its gradually rising response reaching the reference level at 150Hz, my selected crossover frequency, with no peaks or valleys along the way. The class I system was a bit irregular, with a 0.35dB dif-

Details on ordering Old Colony encoded HP and TI mag cards are on page 43.

ference between the 25Hz peak and the 60Hz valley. The cutoff frequency of 18.3Hz was lower than I really wanted, but all things considered, I was pleased.

Comparing the total system output with the box alone *(Tables 8* and *10)* shows how the filter helps to create the alignments. A class II has a large peak in the box response, which is chopped off by the filter; a class I has a drooping response, lifted by a peaky filter. The class I's obvious advantage is the low cutoff frequency, ideal for pipe organ records. More importantly to me, this system sounds less restricted in the bass regardless of program material, so I use it most of the time. Its big drawback is that its maximum output is only 106dB on ordinary material, dropping to 98dB when the music has high energy levels at low frequencies *(i.e.* Telarc's *"1812")*, which means the driver will bottom occasionally even at normal volume settings. I can eliminate bottoming on everything but the *"1812"* by using a third order rumble filter set at 23.4Hz. Then the system produces 106dB at all frequencies and the cutoff frequency moves up to only 23Hz. I use the filter most of the time, but subjectively the sound is better without it.

In class II it plays louder than I can tolerate. I have calculated that it could produce 113dB at one meter regardless of the signal's spectral content. I can start the *"1812"* at a normal setting and the finale will be satisfactorily loud, but everything—including the cannon shots—will be reproduced clearly. I prefer the class I system and convert to class II only when the program material demands it. If you like rock music at extremely high levels, then a class II system probably would be your choice for regular listening. □

REFERENCES

1. R. Small, "Vented Box Loudspeaker Systems, Parts I and II," *Journal* of the AES, Vol. 21, June, and July/August, 1973.

Box Two

The TI-59 Program

To run the program, first store the required parameters in the following registers:

Parameter	Storage Register
f_{SB}	11
Q_L	12
Q_T	13
h	14
α	15
f_a/f_s (sixth order only)	16
A (sixth order only)	17

When you press button A, the following parameters are calculated and stored, in the listed steps.

Step Numbers	Parameter	Storage Register
002-027	a_1	18
028-051	a_2	19
052-066	a_3	20
067-075	A_3	23
076-091	A_2	22
092-102	A_1	21

At this point A_1 is in the display. Also, storage registers 18, 19, 20 are now free. Next, key in a frequency f. When you press B

Step Numbers	Parameter	Storage Register
106-107	f	10
108-117	ω	25
118-154	B	24

The display now contains B, the box output at f.

If the system is sixth order, then press C.

Step Numbers	Parameter	Storage Register
158-168	δ	26
169-189	F	-
190-195	FB(=C)	24

The display now reads the combined box-filter output C.

Now, you can key in a new frequency and press B (or B-C) again to calculate the output at this new frequency.

Alternatively, if you push D after B (fourth order) or after C (sixth order) then

Step Numbers	Parameter	Storage Register
199-227	d	-
228-231	Bd or Cd	-

The display now contains the normalized cone displacement at the frequency f.

000	76	LBL
001	11	A
002	43	RCL
003	14	14
004	65	×
005	43	RCL
006	13	13
007	85	+
008	43	RCL
009	12	12
010	95	=
011	55	÷
012	53	(
013	43	RCL
014	12	12
015	65	×
016	43	RCL
017	13	13
018	65	×
019	43	RCL
020	14	14
021	34	√X
022	54	)
023	42	STO
024	27	27
025	95	=
026	42	STO
027	18	18
028	43	RCL
029	15	15
030	85	+
031	01	1
032	85	+
033	43	RCL
034	14	14
035	33	X²
036	95	=
037	55	÷
038	43	RCL
039	14	14
040	85	+
041	53	(
042	43	RCL
043	12	12
044	65	×
045	43	RCL
046	13	13
047	54	)
048	35	1/X
049	95	=
050	42	STO
051	19	19
052	43	RCL
053	14	14
054	65	×
055	43	RCL
056	12	12
057	85	+
058	43	RCL
059	13	13
060	95	=
061	55	÷
062	43	RCL
063	27	27
064	95	=
065	42	STO
066	20	20
067	33	X²
068	75	-
069	02	2
070	65	×
071	43	RCL
072	19	19
073	95	=
074	42	STO
075	23	23
076	43	RCL
077	19	19
078	33	X²
079	85	+

Box Two—Continued

080	02	2	131	65	×	182	95	=
081	75	-	132	43	RCL	183	55	÷
082	02	2	133	25	25	184	43	RCL
083	65	×	134	45	Y^X	185	26	26
084	43	RCL	135	04	4	186	45	Y^X
085	18	18	136	85	+	187	04	4
086	65	×	137	43	RCL	188	95	=
087	43	RCL	138	23	23	189	35	1/X
088	20	20	139	65	×	190	65	×
089	95	=	140	43	RCL	191	43	RCL
090	42	STO	141	25	25	192	24	24
091	22	22	142	33	X^2	193	95	=
092	43	RCL	143	85	+	194	42	STO
093	18	18	144	01	1	195	24	24
094	33	X^2	145	95	=	196	91	R/S
095	75	-	146	55	÷	197	76	LBL
096	02	2	147	43	RCL	198	14	D
097	65	×	148	25	25	199	43	RCL
098	43	RCL	149	45	Y^X	200	25	25
099	19	19	150	08	8	201	33	X^2
100	95	=	151	95	=	202	55	÷
101	42	STO	152	35	1/X	203	43	RCL
102	21	21	153	42	STO	204	14	14
103	91	R/S	154	24	24	205	75	-
104	76	LBL	155	91	R/S	206	01	1
105	12	B	156	76	LBL	207	95	=
106	42	STO	157	13	C	208	33	X^2
107	10	10	158	43	RCL	209	85	+
108	55	÷	159	10	10	210	53	(
109	43	RCL	160	55	÷	211	43	RCL
110	11	11	161	43	RCL	212	25	25
111	55	÷	162	11	11	213	55	÷
112	43	RCL	163	55	÷	214	43	RCL
113	14	14	164	43	RCL	215	14	14
114	34	√X	165	16	16	216	55	÷
115	95	=	166	95	=	217	43	RCL
116	42	STO	167	42	STO	218	12	12
117	25	25	168	26	26	219	54	)
118	45	Y^X	169	33	X^2	220	33	X^2
119	08	8	170	75	-	221	95	=
120	85	+	171	01	1	222	55	÷
121	43	RCL	172	95	=	223	43	RCL
122	21	21	173	33	X^2	224	25	25
123	65	×	174	85	+	225	45	Y^X
124	43	RCL	175	43	RCL	226	08	8
125	25	25	176	26	26	227	95	=
126	45	Y^X	177	33	X^2	228	65	×
127	06	6	178	65	×	229	43	RCL
128	85	+	179	43	RCL	230	24	24
129	43	RCL	180	17	17	231	95	=
130	22	22	181	33	X^2	232	91	R/S

Box Three

The HP-97 Program

Before running, store the system parameters.

Parameter	Storage Register
Q_L	1
Q_T	2
h	3
α	4
f_o/f_S	5
A	6
f_{SB}	7

When you press Button A, the parameters are calculated and stored, in the listed steps.

Step Numbers	Parameter	Storage Register
002-014	a_1	9
015-028	a_2	A
029-041	a_3	B
042-048	A_1	C
049-059	A_2	D
060-066	A_3	E

At this point, A_3 is in the display. Also, storage registers 9, A, B are now free. Next, key in a frequency f and press B.

Step Numbers	Parameter	Storage Register
069-	f	0
070-075	ω	I
076-100	B	8

The display now contains B, the box output at f.

If the system is sixth order, then press C.

Step Numbers	Parameter	Storage Register
103-108	δ	0
109-123	F	-
124-126	FB(=C)	9

The display now reads the combined box-filter output of C.

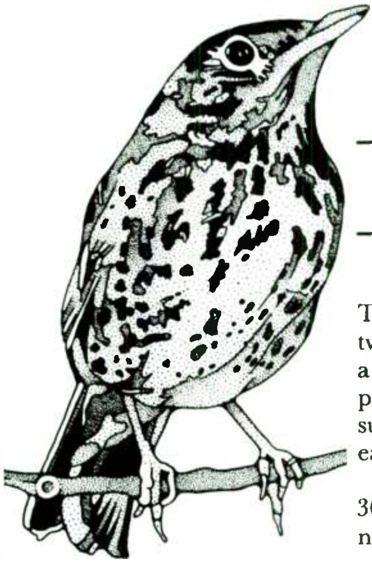
Now, you can key in a new frequency and press B (or B-C) again to calculate the output at the new frequency.

Alternatively, if you push D after B (fourth order) or after C (sixth order) then

Step Numbers	Parameter	Storage Register
129-144	d	-
145-146	Bd or Cd	-

The display now contains the normalized cone displacement at the frequency f.

```
001  *LBLA   21 11
002  RCL2    36 02
003  RCL3    36 03
004  ×         -35
005  RCL1    36 01
006  +         -55
007  RCL1    36 01
008  ÷         -24
009  RCL2    36 02
010  ÷         -24
011  RCL3    36 03
012  √X         54
013  ÷         -24
014  STO9    35 09
015  RCL4    36 04
016  1          01
017  +         -55
018  RCL3    36 03
019  X²         53
020  +         -55
021  RCL3    36 03
022  ÷         -24
023  RCL1    36 01
024  RCL2    36 02
025  ×         -35
026  1/X        52
027  +         -55
028  STOA    35 11
029  RCL1    36 01
030  RCL3    36 03
031  ×         -35
032  RCL2    36 02
033  +         -55
034  RCL1    36 01
035  ÷         -24
036  RCL2    36 02
037  ÷         -24
038  RCL3    36 03
039  √X         54
040  ÷         -24
041  STOB    35 12
042  RCL9    36 09
043  X²         53
044  RCLA    36 11
045  2          02
046  ×         -35
047  -         -45
048  STOC    35 13
049  RCLA    36 11
050  X²         53
051  2          02
052  +         -55
053  RCL9    36 09
054  RCLB    36 12
055  ×         -35
056  2          02
057  ×         -35
058  -         -45
059  STOD    35 14
060  RCLB    36 12
061  X²         53
062  RCLA    36 11
063  2          02
064  ×         -35
065  -         -45
066  STOE    35 15
067  RTN        24
068  *LBLB   21 12
069  STO0    35 00
070  RCL7    36 07
071  ÷         -24
072  RCL3    36 03
073  √X         54
074  ÷         -24
075  STOI    35 46
076  8          08
077  Y^X        31
078  ENT↑      -21
079  ENT↑      -21
080  RCLI    36 46
081  6          06
082  Y^X        31
083  RCLC    36 13
084  ×         -35
085  +         -55
086  RCLI    36 46
087  4          04
088  Y^X        31
089  RCLD    36 14
090  ×         -35
091  +         -55
092  RCLI    36 46
093  X²         53
094  RCLE    36 15
095  ×         -35
096  +         -55
097  1          01
098  +         -55
099  ÷         -24
100  STO8    35 08
101  RTN        24
102  *LBLC   21 13
103  RCL0    36 00
104  RCL7    36 07
105  ÷         -24
106  RCL5    36 05
107  ÷         -24
108  STO0    35 00
109  4          04
110  Y^X        31
111  ENT↑      -21
112  ENT↑      -21
113  RCL6    36 06
114  X²         53
115  2          02
116  -         -45
117  RCL0    36 00
118  X²         53
119  ×         -35
120  +         -55
121  1          01
122  +         -55
123  ÷         -24
124  RCL8    36 08
125  ×         -35
126  STO9    35 09
127  RTN        24
128  *LBLD   21 14
129  RCLI    36 46
130  X²         53
131  RCL3    36 03
132  ÷         -24
133  1          01
134  -         -45
135  X²         53
136  RCLI    36 46
137  RCL1    36 01
138  ÷         -24
139  RCL3    36 03
140  ÷         -24
141  X²         53
142  +         -55
143  RCLI    36 46
144  8          08
145  Y^X        31
146  ÷         -24
147  RCL9    36 09
148  ×         -35
149  RTN        24
150  R/S        51
```



OLD COLONY PRESENTS

DEVICES OF SPRING

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This versatile circuit began as a two channel 30Hz, 18dB/octave infrasonic filter. But you can adapt two of them for use as a single channel two-way electronic crossover simply by changing the values of a few resistors and capacitors. For three-way operation, add another pair of cards and change the parts values to move the crossover points to the appropriate frequencies. For further information on sub-woofer and 3-way crossovers, see *SB* 3/82, or *TAA* 4/75. Please specify **one** crossover point for each two-way crossover from the following frequencies: 60, 120, 250, 500, 1k, 2k, 5k or 10k.

Based on a simple op amp design, the crossovers typically have a frequency response of ±0.2dB 30Hz-160kHz. Output impedance is 10Ω non-inverted, input impedance is 50kΩ. Power supply needed should provide ±15V DC @ 10mA per card.

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The cable has extremely low capacitance, impedance, inductance, and eddy current effects. In the audio frequency range, impedance is virtually flat (see Nelson Pass' article on speaker cables in *SB* 2/80 for a discussion of these effects). Small improvements in low bass, extreme highs, imaging, depth, distortion, and amplifier damping all add up to audibly better sound and greater listening enjoyment—just one more way to remove some of the haze which prevents your system from sounding as clear as it should.

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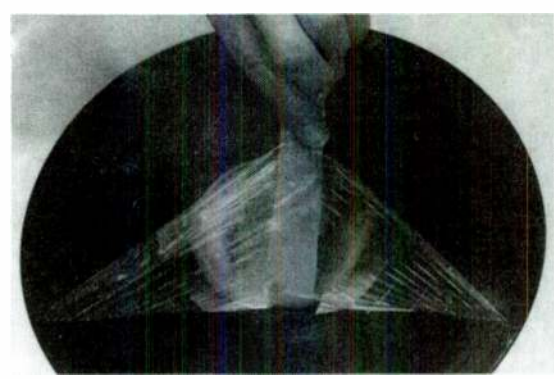

Developed by Reg Williamson, this two step system removes static charges from records virtually forever, and removes deep-down dirt thoroughly and safely. Static charges (as high as several *kilovolts)* lock dirt on the record and create annoying pops as the stylus traces over charged areas. The surfactant neutralizes those charges by supplying molecules with cationic ends to capture the negative ions.

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You supply distilled water, glycerin, isopropyl alcohol, an applicator and buffer pad. We supply ½ oz of de-static liquid (1000 treatments), and 4 oz of deep cleaner (80 disks). Regrettably, due to Postal Regulations, this cannot be shipped outside the US.

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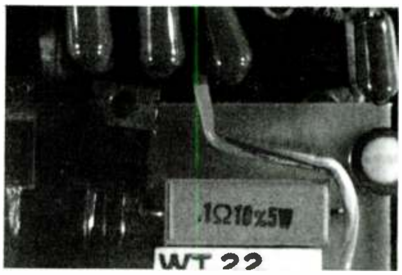
The headphone output on most amps usually is a large resistor in series with the output to knock the level down to what is suitable for driving headphones. The resistor reduces the amp's damping ability, leaving your headphone drivers less tightly controlled. You will also suffer the distortions produced by the resistor's particular nonlinearities. To solve these problems, Jim Boak has designed a high performance amp specifically for headphones. Built around the powerful 540 op amp, it features a circuit modification, derived from Walt Jung's work, which gives the op amp a highly linear transfer characteristic. The resulting distortion curve has that gentle rise associated with good tube amps, and a clean, wide open sound quality you will enjoy thoroughly every time you listen on headphones. To top it off, Boak gave it excellent power supply regulation. Each channel has independent power supplies using three-terminal regulators to deliver stable voltages across the entire audio range. The amp may be configured for driving either electrostatic or dynamic headphones, and parts for both are included.



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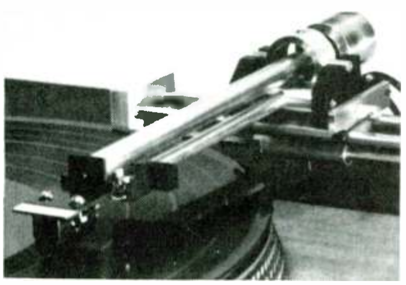

Here's your opportunity to own a tangential tracking tone arm—and have the fun of building it yourself. Rod Cooper's ingeniously simple design elegantly achieves the benefits long attributed to tangential arms. The kit has been sold in England for several years and has been praised for its high quality. The metal parts are precision-machined for a solid, tight-fitting assembly. Mount it on your choice of turntables, and you will have an outstanding piece of equipment which you can use and enjoy every day, for many years of listening enjoyment.

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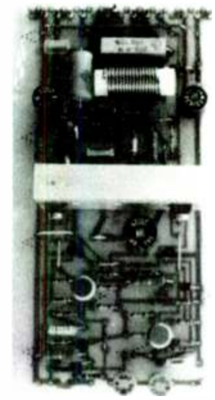

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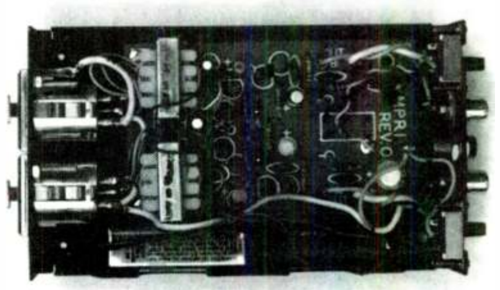
The kit includes audio grade capacitors and resistors, circuit board, and input transformers. You provide the case, chassis, appropriate input/output connectors, and power supply (which could be two 9V batteries, or if you have an Advent 201, use its built-in 18V output).

Construct this updated version of Advent's mike preamp and not only save money, but enjoy the full potential of your tape deck, while learning about recorded sound. You will hear your system with new ears after a few recording sessions.



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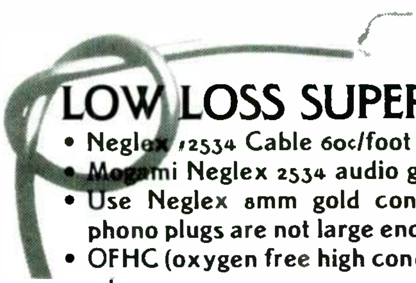

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HOW TO SELECT A PROGRAMMABLE CALCULATOR

BY L. R. PALOUNEK

Should you be interested in PPC's—Personal Programmable Calculators—even if you do not plan to learn programming? Because you are reading this magazine, the answer is: Yes, you should. You can benefit from the capabilities of a PPC by using programs written by others; recent developments in the field have made the distribution and use of such programs much easier than it used to be.

A PPC program can be written so the calculator display tells you in plain English what your next input should be. After the program calculates the result, it can identify each output in understandable form.

Nor do you have to key in the program: it can come to you recorded on a small magnetic card, or in a plug-in ROS—Read Only Storage—also known as a ROM—Read Only Memory—module, or, better yet, printed right here in this magazine.

The following tips will help you select the calculator that fits your individual requirements. I won't try to describe in detail what is available or give prices —these things change rapidly. Nor shall I mention some important "peripherals," such as printers/plotters, cassette tape recorder interfaces, etc. Rather, these tips will give you some insight and background information and direct you to sources of up-to-date details.

SOURCES. The two strongest contenders for the pocket programmable calculator market are Hewlett-Packard Company (HP) and Texas Instruments (TI). You can request technical information on their latest calculators, list prices, and dealers in your local area by calling toll free:

HP—(800) 547-3400
TI—(800) 858-1802

From outside the U.S.A., write to:

Hewlett-Packard Company, 1000 N.E. Circle Blvd., PO Box 3400, Corvallis, OR 97330 U.S.A.

Texas Instruments, PO Box 10508, Lubbock, TX 79408 U.S.A.

Some other sources are:

Sharp Electronics Corporation, 10 Keystone Place, Paramus, NJ 07652.

Casio, Inc., 15 Gardner Road, Fairfield, NJ 07006.

Radio Shack, 1300 One Tandy Center, Ft. Worth, TX 76102.

The information takes some time to arrive, so request it soon.

PROGRAMMABLE. Consider the availability of the following features when comparing PPC's. You will notice that HP and TI sometimes use different names for very similar features; I indicate this by either (HP) or (TI) after the term.

Keystroke programmable. You key in the program when you need it, and lose it when you turn off the calculator. Unless the calculator has a Continuous/Constant memory, you have to re-key the program and data to use it again.

Continuous (HP)/Constant (TI) Memory. The calculator remembers data and programs even after the power has been turned off. This eliminates the need to re-enter the program and constants, reduces mistakes, and saves time. If the memory is large enough, this feature eliminates for some users any need for other means of program input.

Magnetic Cards. Complex programs and data can be stored permanently on small magnetic cards approximately the size of a chewing gum stick. Prerecorded cards are available for a number of general applications, but rarely for specialized applications such as speaker design. The delicate card surface requires careful handling and storage. Some card readers have built-in translators; for example, the HP-41 card reader automatically translates cards written for the older HP-67 calculator into the HP-41 code.

Optical Wand. With this wand you can load long programs quickly by "reading" a bar code printed on paper. The program in this form can be copied on a high quality office machine; less expensive copiers may shrink the size of the bars so the wand cannot read the code. You can keep your program collection in a three-ring binder. (For more information on the PPC bar code, see McNeal's article in *BYTE*, January, 1981[3])

Application Pack Modules (HP)/Solid State Software (TI). Complete libraries of programs for specific applications, containing thousands of steps in a plug-in ROS module, are available for some calculators. Because programs in these modules use no memory space, they greatly increase a PPC's capabilities.

Custom modules are also available. Theoretically, you could order a single module for your specific application; but the cost would be unreasonably high. However, with an order of approximately 250 modules, the unit cost is close to that of a readymade module. Thus a group of people—such as the readers of this magazine—can write programs geared to their specific needs and have the special ROS module produced at a reasonable price.

MEMORY SIZE REQUIREMENTS. Programs written for an HP calculator generally require 40-50 percent fewer lines than comparable TI programs. See Bernfeld's article[4] for a comparison of a program from the audio field written for the older HP-29 and HP-67 calculators with one written for the TI-59 calculator.

Carbrey[2] describes a sample program comparing the relative performances of the TI-59 and HP-41 calculator. It requires a mixture of arithmetic, looping, and register operations, and is reasonably close to a typical program such as you may use. The sample needs 59 lines in the TI version, compared to 31 lines in the HP version. Expressed as a percentage of the memory available, the results are:

10.3% for the TI-59;
15.6 % for the HP-41C; and
3.1% for the HP-41CV.

SOFTWARE AVAILABILITY. Most manufacturers offer software support, *i.e.*, programs written for specific applications. As a rule, programs written in one manufacturer's logic system cannot be used in calculators made by other manufacturers without extensive, time-consuming changes.

HP and TI are far ahead of their competition in this area; HP's support is considered the best available. TI offers a plug-in solid state software module, "the RPN simulator," which translates some programs written in HP's RPN logic system into TI's logic system. This module makes available to TI-59 owners the vast support resources of the HP-67 calculator; but it cannot translate the HP-41 software.

The availability and quality of software support is extremely important. Using or adapting an existing program is much easier and faster than researching the application, programming the solution, and debugging the program.

PPC CLUBS. Important sources of software support are the independent user groups called PPC clubs. (Do not confuse them with the manufacturer-supported user program libraries and newsletters.) The first, the HP-65 User Club, formed in June, 1974 shortly after the world's first PPC, the HP-65, became available. Within a few years the HP-65 was joined by other HP and TI calculators. Because of the differences in HP and TI logic systems, the TI-oriented club spun off; later the names of the respective groups were changed.

For a special sample issue of the HP-oriented *PPC Journal*, send a self-addressed large (9" by 12") envelope with First Class U.S. postage for 2 oz. to PPC Journal, Richard J. Nelson, 2545 W. Camden Place, Santa Ana, CA 92704 (USA).

For information on the TI-oriented club, contact TI-PPC Notes, Maurice E.T. Swinnen, 9213 Lanham Seven Rd., Lanham, MD 20801 (USA).

HUMAN FACTORS. When evaluating different calculators, do not compare only technical parameters such as memory size, the repertoire of built-in functions, or the availability and capability of such peripherals as card readers. Pay close attention to the human factors such as display legibility and readability (commas make large numbers more readable—compare 278455552.6 with 278,455,552.6), keyboard layout, keyboard feel, etc.

SUGGESTED READING. Articles by Hayes[1] and Carbrey[2] contain good descriptions of the HP-41 calculator. Many consider this the standard to which other calculators should be compared. Although another PPC may be the best choice, you ought to become familiar with the standard. When these articles were published, HP's recent top-of-the-line PPC had not been announced. For details on the latest calculators, study the manufacturer's literature.

MAIL ORDER DISCOUNT HOUSES. Programmable calculators are available at discount. Compare prices and consider handling and shipping charges, state sales taxes, and delivery time. In the U.S.A., you can order by calling a toll-free number and charging the order to your bank credit card. Some retailers who have been in business for several years are: Tam's—(800) 421-5188; Elek-Tek—(800) 621-1269; Olympic—(800) 421-8045; Computique—(800) 854-0523. They and others frequently advertise in such magazines as *Scientific American* or such newspapers as *The Wall Street Journal.*

CALCULATORS, NOT COMPUTERS. We have been talking about hand-held personal programmable calculators, not about home or personal computers. Personal calculators are completely portable, battery operated, and usually much less expensive than personal computers. Calculators have limited display capability—one line as compared to the full TV-like screen of most personal computers—and limited memory as compared to a personal computer which can remember large tables of data or pages of text. But calculators are rich in instruc-

Continued on page 44

AN EASY PEAK POWER INDICATOR

BY A. L. NEWCOMB

While listening to your audio system during particularly dramatic moments, you may wonder how much of the available power reserve is being used. Many systems have power indicators, but they are usually on the amplifier, and not always convenient to watch. I will describe a simple, easy to construct indicator which you can install in or near the speaker system for less than $5.00 per channel.

The unit operates on less than 1% of the delivered power and, since it requires no additional power source, you can make it a permanent part of the speaker system while you are building it. The circuit is shown in *Fig. 1,* and an equivalent circuit for component calculations is in *Fig. 2.*

The full wave bridge converts the speaker input to an unfiltered DC. A divider (R1 and R2) drives the transistor when the base-emitter junction reaches about 0.65V. Resistance is fixed at 680Ω. R3 should be a value which will provide an LED drive current of about 5mA at 10W for 8Ω speakers, increasing to about 20mA at 100W. With medium to high brightness LED's, this provides a very adequate indication. Color is your option (red, orange, yellow or green), and lifetime is virtually unlimited.

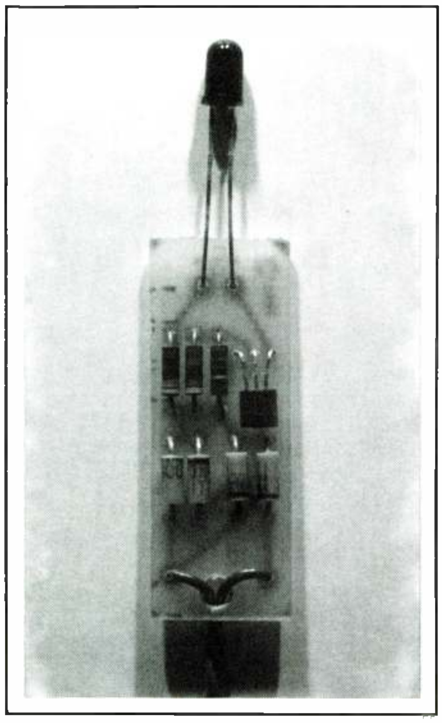


Table 1 shows resistor values for a number of convenient power levels. With 5% resistors, you get an accuracy within 1.5dB, or 20% power. Note that the circuit has a practical lower limit of about 5W at 8Ω, due to the minimal voltage needed to forward-bias the bridge, transistor, and LED.

To make a bar graph indicator, you could link several of these circuits together, placing the LED's next to each other. This would increase amplifier loading by only 10% (at highest levels), but the non-linear nature may put off some purists. However, when paralleled each unit becomes biased only at its threshold level, and has only an insignificant effect on lower level signals. Once a particular diode is triggered, the circuit is resistive in nature—no challenge for modern amplifiers. In most of the speakers where I have installed these, an indicator at 10W peak, or two at 5W and 50W peak have proven satisfactory.

If you want indicators for lower power levels, you can modify the circuit. The basic design is limited by the cumulative drops of the bridge, LED, transistor and current limit resistor. When set for much less than 2.5W RMS, 8Ω, the limit resistor may overload the LED at high levels when it is sized for adequate indication at turnon. You can add a current limit stage with two more transistors and a resistor *(Fig. 3).* Counting all the drops, total voltage for turnon now goes down

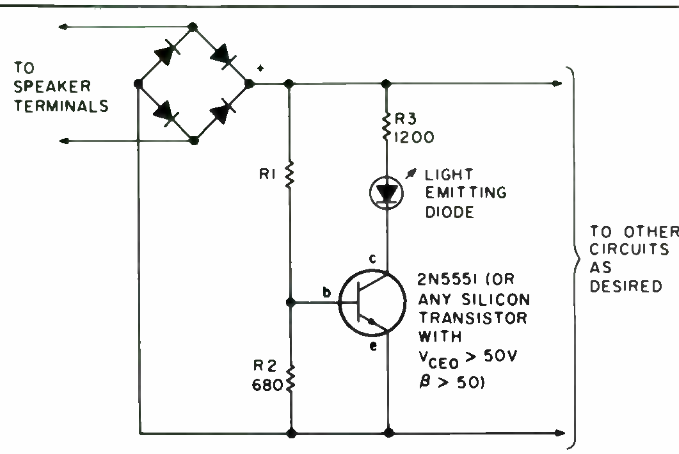


FIGURE 1: This is the wiring diagram for the simple version of the passive power indicator.

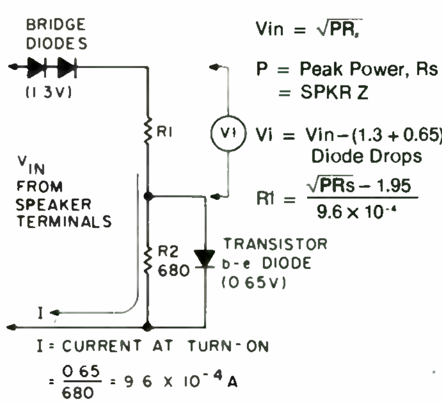


FIGURE 2: Use this equivalent circuit for calculating component values.

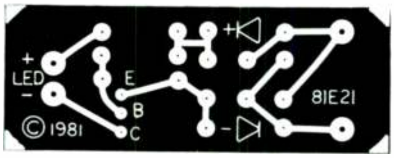


FIGURE 4a: The peak overload version uses this circuit board.

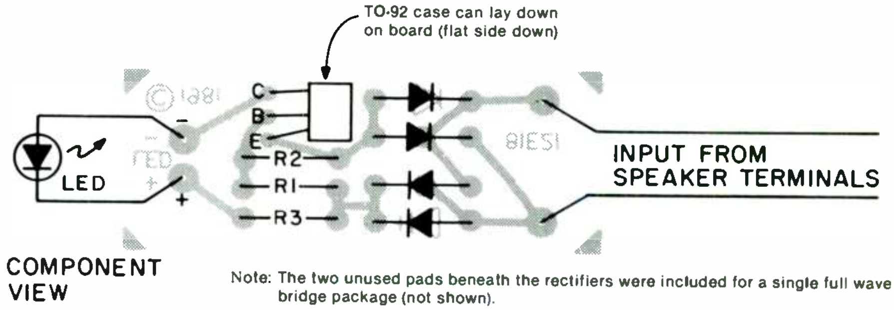


FIGURE 4b: The stuffing guide for the peak overload indicator shows its simplicity, low cost, and ease of construction.

to about 4.1V, which allows operation from 2W to 100W peak, where dissipation in Q3 reaches about ½W.

Indication is nearly instantaneous and some transient peaks may evade your eye's persistence of vision. To anticipate the next obvious thought, I will mention that storing enough energy to lengthen indication time significantly ("peak holding") requires quite a bit of capacitance. If you attempt to incorporate this feature (which is better reserved for active indicators), you will load your amplifier enough to degrade its performance noticeably.

This passive circuit is a simple, reliable and inexpensive way to indicate operating levels without affecting performance. The warning it gives of impending doom for your speakers is valuable. You can incorporate it into the design of your speakers, making it an integral part of the cabinet and electrical system, and improve their appearance while gaining the benefit of knowing at a glance when your system is operating at unsafe levels. □

TABLE I

POWER INPUT (Watts)		RI (kohms) for Speaker Nominal Impedance of:		
PEAK	RMS	4Ω	8Ω	16Ω
5	2.5		4.7	7.5
6.3	3.1	3.3	5.6	8.2
10	5	4.7	7.5	11.0
12.5	6.3	5.6	8.2	12
15	7.5	6.2	9.1	15
20	10	7.5	11.0	16
25	12.5	8.2	13	18
30	15	9.1	15	20
40	20	11.0	16	24
50	25	13	18	27
60	30	15	20	30
100	50	18	27	39

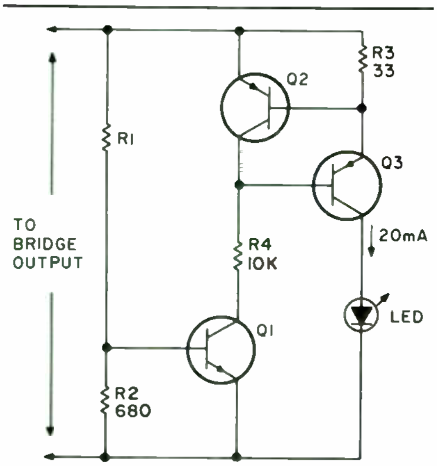


FIGURE 3: For the extended range version, two transistors and a resistor are added.

A strongly opinionated cautionary tale of one man's fifteen-year search for the ultimate home built speaker system

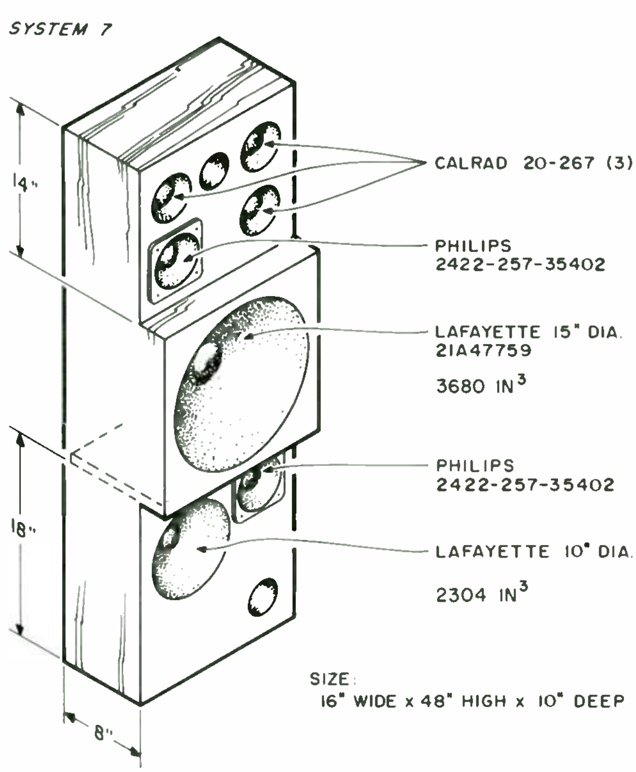
A SPEAKER BUILDER'S ODYSSEY: PART III

BY ROBERT CARLBERG

SYSTEM 7: THE MONSTERS. My next set, system seven, turned out to be not for myself, however, as another friend of "Boom Boxes" commissioned me. Not wanting to be outdone, he envisioned four large floor-standing cabinets. He was not particularly interested in a heavy thudding bass, but rather sheer volume—gut-wrenching, heavy-metal, peel-the-paint, rock-and-roll.

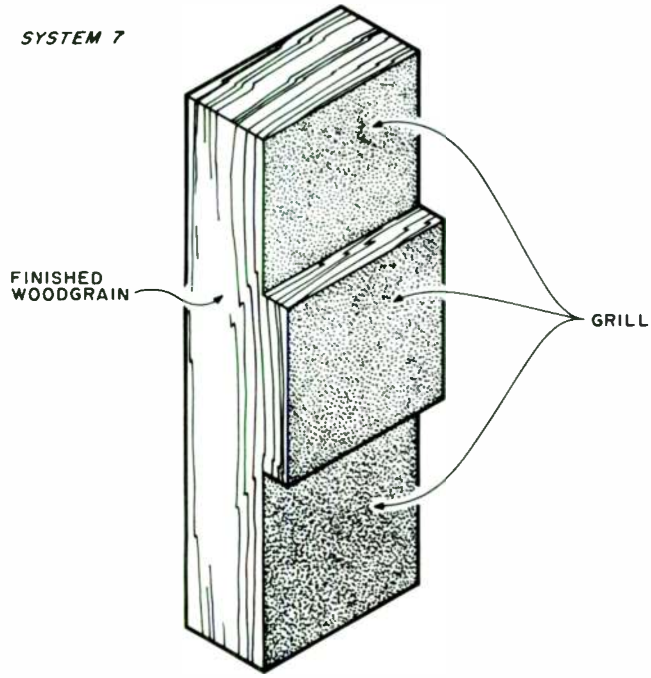
For the Monsters I knew I'd need a multiplicity of drivers to handle the power. We chose one 15″ and one 10″ Lafayette woofer, two Philips midranges, and three Calrad tweeters per cabinet—and there were four of them! As with the preceding systems, considerable shopping convinced me that these drivers were still the best value and sound on the market.

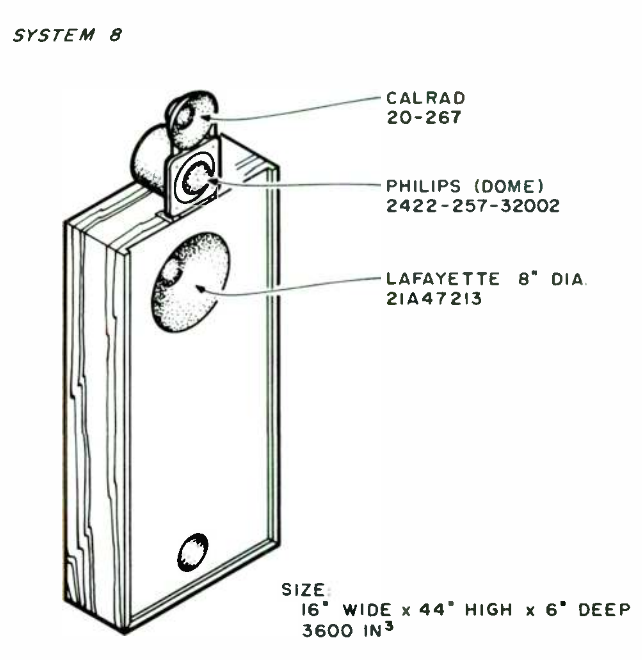
Each woofer was given its own separate air column to avoid intermodulation between them. Regardless of common practice, two woofers of unequal size will not move identically in a joint loading situation. I used the same proportions and geometries as before, and again rough-aligned the voice coils by eye (accounting for the very odd looking cabinets). As with the Towers, this proved less than satisfying to me—the commissioner was quite content with them.



Lafayette had by this time cut back local stocks considerably, and all eight woofers had to be ordered out of New York. In the 10 weeks or so before delivery, I had plenty of time in which to design and build, woofers unseen, the four 4-foot cabinets of about 140 pounds apiece. They were finished on all sides with rosewood-pattern laminate, and Radio-Shack foam-panel grille cloths were attached (exhausting the entire Seattle inventory). Unfortunately, when the woofers finally arrived, I only had time to mount them (they fit!) and deliver the finished products, so I was not able to experiment with the woofers. The commissioner however put them through their paces in short order. I heard a few weeks later that he was putting on "Dark Side Of The Moon," turning it up, and visiting a friend to enjoy the music four houses down the block!

SYSTEM 8: THREE PANELS. The experience of the last two systems convinced me I needed to do some basic research in driver alignment. Consequently, with the proceeds from the sale of my Towers, and the totally inadequate profits from The Monsters, I purchased two new Philips midranges using essentially the same basket, magnet, backcan, and surround as the cone mids, but with a dome driver and appropriately larger voice coil. They had better dispersion and slightly better clarity. I also selected one big expensive woofer—a JBL 124A, which had the largest voice coil (4″), the heaviest magnet (12 pounds of Alnico V) and the longest excursion (measuring about ±½″) of any I surveyed. I settled on the 12″ model because the cabinet size required for 15″ was ungainly, and no 15″ had larger control elements (voice coil and magnet) than this smaller 12″ unit. I





later read that 15″ woofers have inherently greater harmonic distortion due to cone breakup, but at the time it was just a lucky guess.

The woofer was quite expensive ($138), which was one of the reasons I decided to use only one of them, as a center-channel subwoofer. I also reasoned, though, that record cutting limitations make it necessary to mix all the low-frequency material into the center, so why not reproduce them where they stand? It seemed not only wasteful, but counterproductive to extrapolate the low-frequencies from the wings.

For my "wing speakers," I disassembled the Experimenters (goodbye old friends), mounting their 8″ woofers and Calrad tweeters in wide and flat floor-standing cabinets. I made them barely 6″ deep, just enough for clearance for the woofers (I was still playing around with this concept). On the top surface, I mounted the midranges and tweeters, using some steel strapping bent to an "L" shape. This way I could adjust the locations of the high-frequency drivers in relation to the woofers (or mid-woofers, actually).

Time-aligning the drivers produced a marked improvement, but alignment was: A. critical to within ⅛″, and B. not the same as visually aligning the voice coils. In fact, I found that a close but imperfect alignment sounds worse than one several inches off, probably due to the more noticeable phase cancellations. This alignment must be done by ear, moving the driver forward and back and listening for the point where the sound seems to come, not from two different drivers, but from a single full-range point-source between them.

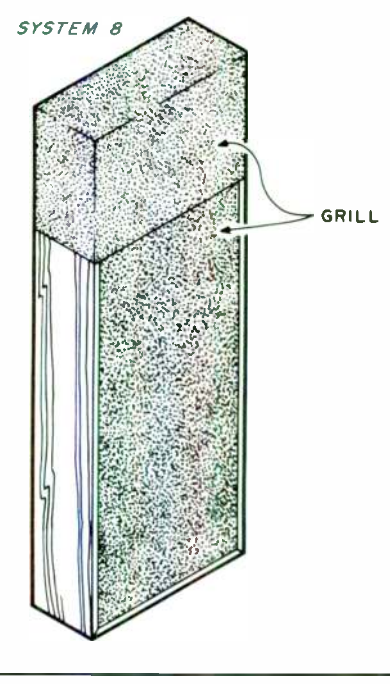
Once properly aligned, the studio-added reverberation, natural acoustic environment of the recording location, and inner detailing (such as breath tones, woodwind raspiness, and brass "bite") become as much a part of the sound as the basic tones. These phenomena of course depend on the harmonic structure, a subtle but important clue to our aural identification.

Contrary to some manufacturers' propaganda, I found the aligned image was not unduly sensitive to vertical listener motion, *i.e.* sitting down did not destroy it. The range of vertical motion in the typical listening room is somewhere in the range of 15 degrees, which is not a great variation. I have seen a large number of commercial systems that attempt to copy the Dahlquist Time-Aligned principle, without apparently understanding it—resulting in a great number of speakers with "little boxes" on top. One manufacturer, even puts the tweeters *ahead* of the woofer.

I made another discovery with the subwoofer cabinet, which was built wide and flat like its predecessors. I found its placement was also critical to within ½″ or so. All the speaker books tell us that low frequencies are non-directional, and your subwoofer can be placed anywhere in the room with equal result. *Not true.* At least in my front-facing direct-radiating design, there was a definite "best" alignment, where kick drums, snapping bass guitars, and orchestral tuttis took on visceral impact. Even a few inches off, and everything was considerably mushier.

After several months of evaluating and enjoying these speakers, I began to feel that I was really on to something.

NEXT ISSUE: FULL-RANGE PANELS



Kit Report

By Thomas Mosteller

One of the problems associated with being an audio amateur is that your ideas can outnumber your needs rather quickly. Having four independent stereo systems in the house means that, from a practical standpoint, I really had little need for another pair of speakers. However, reading *Speaker Builder* gave me a lot of good information on speaker construction, and I was anxious to try my hand at it.

My newly acquired brother-in-law stepped in at this point and our needs complemented each other perfectly. He needed a new set of speakers to replace his tiny XAM (EJ Korvette's house brand) bookshelf speakers. He was looking for either bookshelf or floor standing units—not too large in either case. A flyer from Universal Sound of Florida arrived, describing their small line of kit loudspeakers. The USA 61 seemed to fit his requirements nicely. Its size (28″H × 1¼″W × 10½″D) put it somewhere between the minitower and the bookshelf categories, and the price ($175 per pair) seemed reasonable for a kit which contained a Dalesford D163 polypropylene woofer and a Peerless K010DT dome tweeter, along with a crossover of unspecified slope, frequency, and alignment. However, the USA 61 was not available with an assembled enclosure. Suddenly, I was in the enclosure business.

With a $175 money order winging its way to Florida, we settled back for the tedious business of waiting. Bad news arrives. A capacitor is back ordered, and my patience would be appreciated. Well, these things happen. Six weeks later the package arrives.

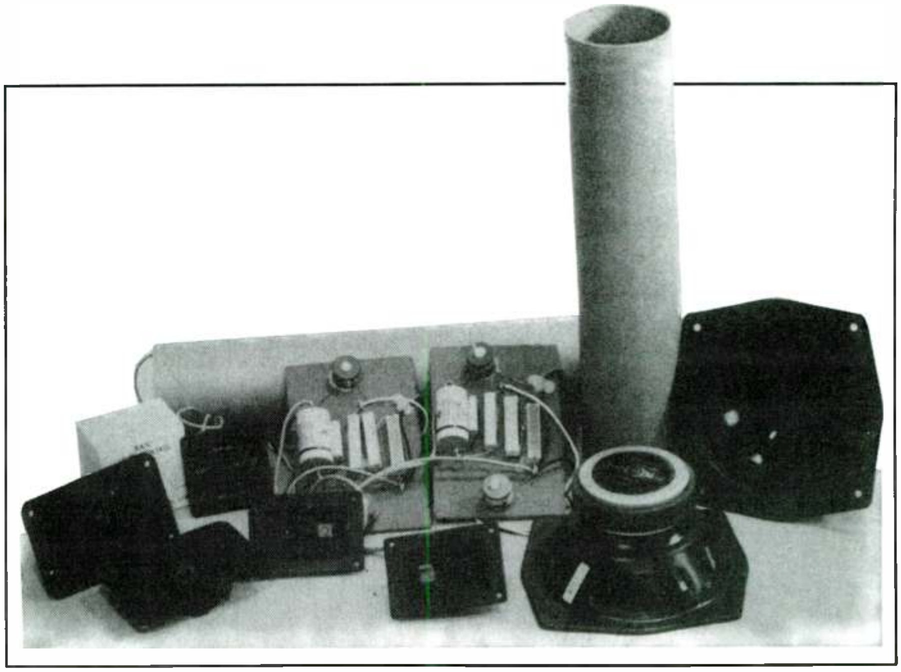


PHOTO 1: Universal Sound supplies all of these parts in the kit. The cabinet is up to you.

ASSEMBLING THE 61

The kit consists of the four drivers, the crossovers, L pads, tuning vents, cabinet plans, and a wiring diagram which was drawn by hand on a piece of notebook paper. The instructions were of adequate quality and clarity for even a semi-experienced person to build the cabinets, as long as he plans his actions carefully ahead of time.

The cabinet parts fit easily on a 4×8′ sheet of Novaply or other high density particle board. *Speaker Builder* is full of advice on building cabinets, so I won't belabor the details. Having had the particle board cut by the lumber yard where I bought it, I had no difficulty putting the panels together. I sprayed the interiors with auto undercoating and covered them with spun polyester batting. While the polyester may be less effective than wool as a damping material, it is much less expensive, easier to work with, stable, and in concert with the undercoating, seems to do a fine job. The front board, speakers, and crossover are all held in place with RTV in case removal is ever necessary. This came in handy later, as I will explain.

One worthwhile bit of information I got from Universal Sound is to use formica instead of veneer to finish the cabinets. I had my doubts about the appearance until I looked at all the various finishes available at the local kitchen remodeling store. We chose an elm burl pattern, which everyone who has seen admires. The total cost was about $15 for formica, $3 for the contact cement, and $12 for the router bit to trim the edges. Applying it really is as easy as everyone says. Spread the cement evenly on both surfaces, wait until dry, place a couple of nails on the cabinet edge and line up the formica. When you have it lined up, push the center of the formica onto the mating surface (which binds it permanently, so be sure it's where you want it before you make the contact). Remove the nails from betwen the two surfaces, and press the formica sheet into place, using hard pressure over the entire surface. Professionals use a special roller to set the sheet; I had good results with an auto windshield ice scraper. Trimming the sheet is easy with a router and a proper bit; the entire finishing job took me less than three hours.

The process of building these speakers took about two months of sporadic labor, borrowing of tools, and arranging for help. An experienced woodworker with all his own tools and free evenings and weekends should be able to complete the job in about two weeks.

FIRST SOUNDS

After all the work was completed, the "moment of truth" arrived. Early in the morning I hauled the speakers up from the basement to the living room, disconnected my Magnepan MG II's and hooked up the USA 61's.

The speakers played for a few minutes at a subdued volume (wife still asleep), and I was starting to form a positive impression when one of them started buzzing. Visions of construction errors filled my head as I examined the offending speaker. To my surprise, I found the Dalesford's surround had separated from the cone and was flopping in the breeze—certainly a rare occurence in a high quality driver like the Dalesford, but disconcerting nonetheless. A phone call to Universal brought a quick replacement, and no similar mishaps have occured since.

After I had installed the new woofer and checked it out, I began the serious business of evaluating the speakers. The extended bass and treble response was evident immediately. The bass at first seemed to be too heavy, but careful listening showed that this was just a matter of being accustomed to the Magnepans' characteristic sound. Judging by ear, I would estimate that the USA 61's response goes down at least one octave below the Magnepan's (which rolls off considerably at 50Hz). On the USA's, while playing passages with high amplitude low frequencies, you can see the woofer moving at least ±½". With such a highly compliant woofer in a vented cabinet, an infrasonic filter is an absolute must. Without one, you can watch as your woofer traces the warps on your records, stealing amplifier power from audible frequencies.

Although the low bass is flat, I detected a small hump at what I consider the very bottom of the male voice range *(ca* 70-80Hz). What I heard is not an obvious "tubbiness," but rather a slight sense of projection compared to a speaker with a flat bass. It is a definite aberration, but not a major one. Give the low end a 92 out of 100, with a special note of its extended range.

Midrange and treble reproduction are also of high caliber. The Dalesford's long suit is its midrange. Although the price is higher than other 6½" units, you get your money's worth. This driver would be at home as a midrange in any other system, because of its exemplary sound quality. Another slight hump in the system's response is revealed by a slight sense of projection in the upper midrange. Perhaps it has a slight dip above this point. With most program material, this is difficult to put your finger on, but I suspect the crossover may be the cause. The Peerless dome tweeter typically crosses over at 3-5kHz, which is just above the region where I think the problem lies. However, the Dalesford's ease and natural qualities are difficult to describe, except to say they are the equal of the Magnepans, which I prize for those qualities.

The Peerless tweeter itself is a remarkable unit for its low price. Response is extended, and dispersion is even, yielding a good stereo image. The tweeter level control, believe it or not, gave the best overall frequency balance at its 0dB setting. Cymbals had an especially crisp, tight sound that is far more bright than the MG II's—but that may be condemning with faint praise.

The USA 61's imaging sounds best when they are pointed inward about 10°. Setting them straight gives a slight hole in the middle. But even toed in, the imaging does not open up. A constricted quality keeps the soundfield limited in its breadth and height. After a little experimentation, though, I found an easy cure for this. The cabinets' height falls into a no man's land—too tall for a bookshelf, and too short for a tower. Putting a 12" table under them made a world of difference. The image extended above and below them in a gratifying way. When you build your own cabinets, you have the flexibility to do things like adding 12" to the base of the enclosure. You could angle the baffle board back a few degrees, or even angle it inward, to improve the imaging. You should add some weight to the base to make it tip resistant.

PHOTO 2: Adding a 12" base to the USA 61's cabinet improves the imaging. You could use the space for a power amp.

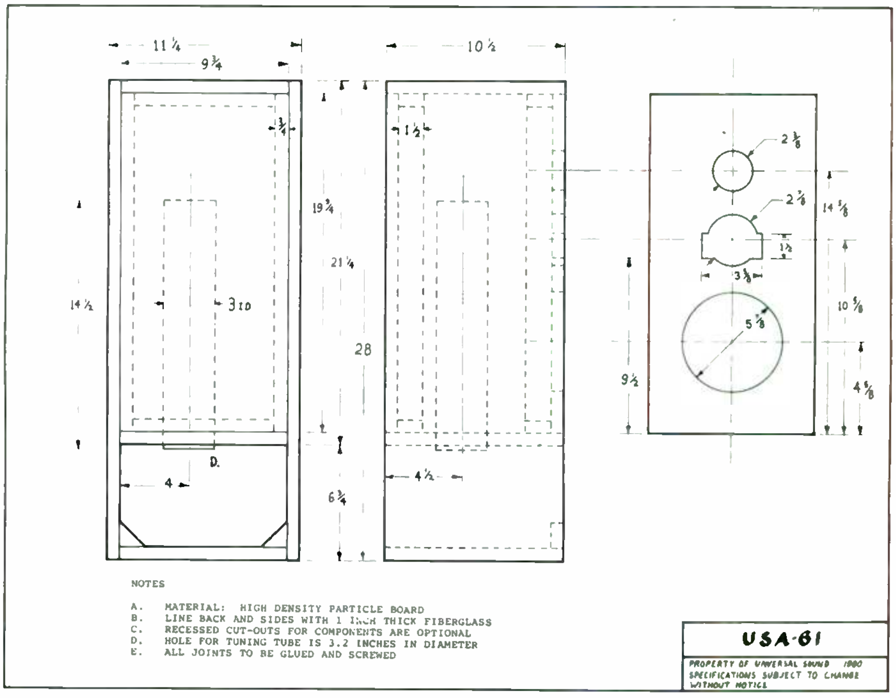
USING THE USA 61

Power handling capability is good but not exceptional. The recommended 100W per channel is a reasonable guideline. With my 300W Leach Double Barreled Amplifier I had excellent results—and I'm not noted for restraint. If I were to use this combination permanently, I would consider a speaker fuse prudent.

A good set of electronics for this speaker is the Hafler DH101/DH200. I managed to borrow this equipment and the sound was excellent. The DH200 has plenty of power for the USA 61's, and the combination has an open, spacious sound which certainly belies the amount of money invested in the system. The only real difference I could find between the Leach and the Hafler was a slight diminution in the bass. The 32Hz organ note at the beginning of *Also Sprach Zarathustra*, for example, almost disappeared with the DH200. The Leach's extra power gave it an almost palpable effect. However, this kind of bass information is not present on most recordings, and certainly not on FM, so it usually would not be missed. Remember to defeat the infrasonic filter. I should note that the Hafler equipment was unmodified; quite possibly its response could be improved. For $750, you would have a hard time matching the sound quality of this preamp/amp/speaker combination.

The USA 61 is a clean and natural sounding system, due mainly to the Dalesford woofer. The extended bass response is notable and draws frequent compliments from listeners. Sheffield's *Track Record* is especially dynamic and exciting on this system. I know of no commercial speakers selling for $250 a pair that come close to the 61's. Clearly kits have a cost advantage, and this one illustrates well what exceptional sound quality you can achieve for a low cost.

As a final note, I think a good way to use the space under the speaker is to build an amplifier into it. With just a 6" increase in height, a Williamson 40/40 would fit in very nicely, and a nice hefty transformer would help solve any tipping problems.



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Books

Designing, Building & Testing Your Own Speaker System, With Projects

David B. Weems, author
Tab Books, $8.95

Reviewed by Ronald H. Miller

My previous comments on this useful book were buried in the middle of a series of brief notes. Having read almost two years of *Speaker Builder*, I am even more convinced of the usefulness of Weems' work. This detailed, clear book should enable anyone to design and build an enclosure which would get the best sound possible out of a woofer found by the side of the road with no specifications.

In his chapter on testing Weems shows how to measure for the data needed to set design limits; then in chapters on various types of enclosures he helps the reader through the computations necessary to design the most desirable enclosure. His construction suggestions should enable any woodworker/cabinet maker to build boxes which will give good results and look reasonable.

After introductory chapters on the characteristics of loudspeakers, and a discussion of how to test drivers and finished systems, Weems devotes separate chapters to closed box systems, reflex systems, and labyrinths and transmission lines. He covers things like omnidirectional speakers, miscellaneous arrays, and unusual enclosures. The final chapters include contemporary trends in speaker systems, notes on using your speaker systems, rainy day projects (simple ways to improve your present speakers), and details for building the 16 systems which are his design examples.

No book can take the place of hands-on experience when learning a craft/hobby; nevertheless, this is a handy place to begin your reading. The theory is applied to concrete variables of real speakers; even if you can no longer find the specific drivers used in an example, Weems gives enough theory to help with the necessary adjustments. I recommend it for the way theory is brought side-by-side with practice.

Somewhat later, Weems published *21 Custom Speaker Enclosure Projects You Can Build* (Tab, $7.95). This is best thought of as the second part of a larger opus which began with the book above. It contains less theory and more detailed information about building specific systems (which are not the same as those in the previous book). You may or may not find this useful.

Each of the 21 projects has full construction details: dimensions of the lumber for enclosures, specific drivers, crossover details, and finishing suggestions. Weems also makes sketchy comments about sound. For example, Project 13, "The Doppelganger," pp. 142ff. (10" woofer, 12" passive radiator with midrange and piezoelectric tweeter) is described thus:

> Construction: Easy! Wiring: Home made crossover; Comments: Deep, fat, bass, 4 Ohms. This system has several novel features, all adopted for the purpose of getting the best possible sound at a low cost. It has a full-bodied bass response without the one-note imitation bass that some speakers produce. While the full bass response is noticeable, the system will accept bass boost without an annoying middle bass boom. This is evidence that the slightly plump bass occurs at a comfortably low frequency. As with any reflex speaker you should use an amplifier or receiver that has an infrasonic filter." (P. 142)

This is certainly clearer than the blurbs in speaker ads.

For those who are starting to learn to build speakers from scratch this book is a useful supplement to Weems' other one. Even if you don't choose to build a Weems system, his approach and practical advice can be helpful.

DUTCH TREATS

Report from Eindhoven

BY JOHANNES M. DIDDEN

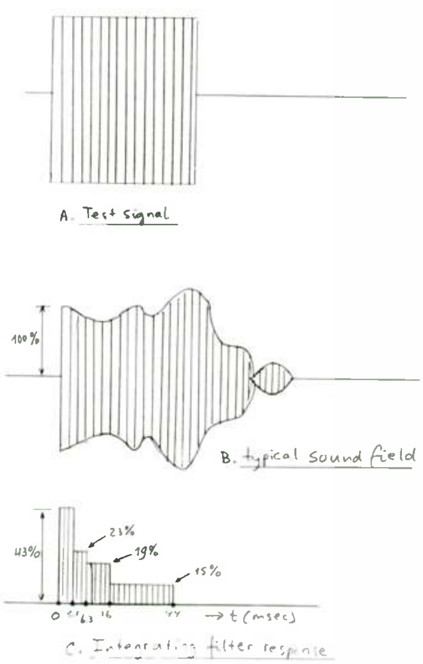
The 73rd AES convention, held in March at Eindhoven, The Netherlands, offered a smorgasbord of audio topics. Of course, Digital Audio Disk was written all over the convention, since Eindhoven is the home of Philips, one of the principal developers of the system. In fact, the convention center is only a few hundred meters from the still-existing building where Anton and Gerard Philips started manufacturing light bulbs in 1891.

Philips demonstrated their Compact Disk in an A/B test against the master tape, running on a Sony professional digital recorder. I could detect no difference, although the test periods were too short to be determinative. The catalog of available CD titles contains several hundred entries and is growing at the rate of 15 per month.

I was impressed with the effort given to digital cassette machines, using normal audio cassettes. The Japanese seem to be the most active in this field. Imagine a stack of 12 superthin heads, with tracks 120 micrometers apart, on 3/20" tape, 24 tracks interleaved for recording on both sides. The specs looked as fantastic as those of the CD. We can expect some big improvements in home audio quality from both media for a relatively low price. When you compare the price and performance of CD with the cost of a top-notch analog turntable, tonearm, cartridge, head amp if needed, and audiophile pressings, CD becomes a real bargain.

Perhaps the most immediately interesting sessions for *SB* readers were on loudspeakers. Philips showed that a speaker's transient distortion is closely related to the cone's shape. They found a flat plane is best, and domes are a good second. Concave and convex cones have inherently limited transient capabilities.

B&W presented a method of determining a speaker's overall power output. The sound pressure measured near the cone's surface is not related linearly to the actual acoustic power output, primarily because of the cone structure's nonlinear behavior from point to point. If you use a miniature mike for motional feedback, the results will depend on its specific location and will not be optimal. B&W used both a mike and an accelero meter on the cone. The phase difference between the two signals indicates the speaker's load factor (just as the phase shift between current and voltage in a resistor-capacitor combination indicates the "real" power dissipated by the resistor). B&W uses this phase shift technique to equalize the total power output, rather than just the SPL at the mike position.



Several papers were concerned with finding measurement techniques which would substantiate subjective listening tests. Henrik Staffeldt of the Danish Engineering Academy described a method of measuring frequency response with a miniature microphone at the listener's ear canal entrance. In this way, room and listener reflections, and body diffractions are included in the measurements. He reported that the data correlated well with subjective tests. Someone should do an A/B test with speakers equalized for identical ear canal response.

Researchers Salmi and Weckstroem from Finland approached the problem from a different angle. Noting that the first arriving wavefront has the greatest influence on the perceived loudness, they devised a test filter that gives progressively less "weight" to sound arriving after the first front *(Fig. 1)*. They found that this way of measuring speaker response eliminated room properties from the collected data, indicating the speaker's "true" response. The results correlated well with subjective tests.

Most impressive from a physical point of view was a speaker presented by the Swiss Acoustic R&D Corporation. It was developed for production studio monitoring of digital masters, and they claim a uniform polar and frequency response for levels between 10 and 120dB. Each system is about seven feet high, and four feet wide and deep. A Quad ESL 63 is the midrange, supplemented by three woofers, and a six element leaf tweeter strip. Six built-in 200W amps dissipate their heat through several square feet of heatsinks on the rear. Although no price was given, it is no doubt as impressive as the size.

At the post-presentation sessions, you have the opportunity to engage in informal discussion with audio personalities. Mr. van den Hul explained his new stylus tip geometry, and it all sounded so obvious, I wondered why no one had thought of it before. Researchers from Leuven University in Belgium presented a single chip RIAA preamp, with all the necessary equalization components incorporated into the chip. To realize the various capacitors and resistors, they used switched capacitor techniques, which yield precise component ratios and assure a tight equalization curve.

As you can see, the AES conventions are stimulating for the audio amateur as well as the professional engineer. They really are a meeting place for anyone who is involved in audio, from all over the world, and probably beyond, since a note on the message board said, "ET call home." □

Old Colony RECORDINGS INDEX

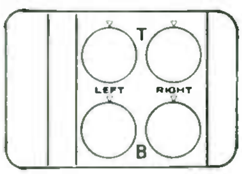
WHEN OUR COLLECTION of recordings passed the 200 mark my wife remarked to a friend that I was the only one who could find anything. When they passed the 400 mark, neither of us could. Our solution to the problem became the *Old Colony Recordings Index System*.

Of course, if each long play disc contained only one piece of music, we would not need an index. That's how it was in the pre 1948 days of the 78s. We just arranged our heavy albums in order from Albeniz to Wieniawski. Today a single disc may contain both these and eight others in between. The spine of the average 12'' package is a little over 3/16'' wide and 12½'' long. Even a list of composers on that spine is difficult—and the compositions outright impossible.

What is possible is a serial number for each package. A way to put it on the spine of the recording package is the heart of the Old Colony Recordings Index. To aid you in making a simple, useful index of your recorded music we offer the basic makings which you are not likely to find available locally. The system is simple, inexpensive, and flexible.

The OLD COLONY RECORDINGS INDEX has three main components:

COMPONENT 1



A wraparound, pressure sensitive, adhesive label for the sleeve or box of the recording. It has a place for stamping a serial number for the recording in three places.

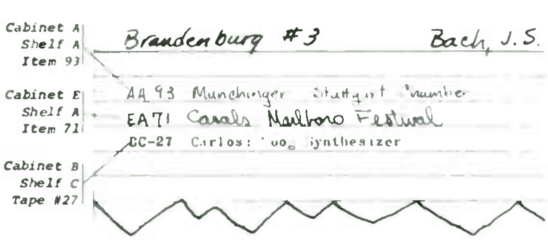
When wrapped around the typical disc's sleeve, the number appears on front, back, and spine of the package. On multi-disc boxes or tapes the serial appears on the spine and front. The glue on the labels is permanent and does not age or deteriorate. Four small tone control knob symbols on the label may be marked to note preferred settings for listening to the indexed recording.

COMPONENT 2

Is a special adjustable, five-band rubber stamp. Its characters are turned 90 degrees so they appear vertically rather than horizontally. This makes the five character serial number easy to read on the narrow edge of the sleeve spine when it is stored on the shelf.

The first two bands of the stamp are the letters A to K (omitting I) and the last three are the numerals 0 to 9. These provide plenty of flexibility in coding. The two letters can be used to designate cabinets and their shelves; the numerals consecutive serial numbers on those shelves.

COMPONENT 3



A 3x5 (or larger if you prefer) file with guides for each composer (and some performers) arranged in alphabetical order. Each card represents one work of that composer in your recordings collection.

The name of the work is listed on the top line. The serial numbers of the discs and tapes where this work may be found are listed below with the main performers noted as well.

HIGH FIDELITY

". . . The Old Colony record filing system provides what appears to be by far the best solution to date.... The convenience of the...system to the user is likely to increase arithmetically as the size of his record collection increases; so the larger the collection, the better this investment will be."

the stereophile

". . . We have tried several different filing systems ourselves as our tape and disc collections grew, but it has become clear to us that the only sensible way of doing it is in conjunction with a file of catalog cards. We never pursued the matter much beyond that point. The originator of The Old Colony Sound Lab *system did, and the result is a filing system that seems to be foolproof, is easy to use, and is about as versatile as you wish to make it."*

J. Gordon Holt, in
THE STEREOPHILE,
Winter, 4-68, p. 15
Box 49, Elwyn PA 19063

A number of users have found the system ideal for indexing slides. The stamp is used directly on the slide mount, with two letters and one numeral indicating the slide storage package and the remaining numerals the slide number in the set. A 3x5'' index file is set up by category: "Flower gardens" "Fountains" "Uncle Fred" etc.

The Old Colony starter kit includes a set of printed sheets containing some 250 composers' names (and their birth and death dates). Cut out with scissors, these fit standard ½-cut 3x5'' file guides, available from any good stationer for a few cents each. A tiny dot of white glue holds the names in place on the guide while it is being covered with Scotch magic mending tape (¾'') for a durable finish.

In addition to the starter kit you will need to purchase locally: 3x5 file cards, 3x5 file guides (½-cut), a file box or drawer, an inked stamp pad (cloth, not foam, permanent black ink) white glue, and Scotch magic mending tape (¾''). Your only added cost for a collection of more than 250 recordings is for labels and index cards. The system works equally well for tapes, multi-record sleeves and boxes, cassettes, and video tapes.

THE OLD COLONY RECORDINGS INDEX makes it possible to index your recordings as you acquire them, regardless of size or content. The sooner you start indexing, the easier it will be to keep up with what you own. Radio stations, university libraries, and hundreds of serious collectors are enthusiastic users of the Old Colony system.

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Please make check or money order payable to OLD COLONY SOUND LAB. *No C.O.D.s. MasterCharge and Visa(BAC) acceptable. All orders postpaid in the USA. Add postage for 1 lb. for starter kit to foreign address. All remittances must be in USA funds.*

Designer's Corner

A Satellite/Subwoofer System

My interest in active loudspeakers first became aroused seriously when the Linkwitz three-box design appeared in *SB*. I decided to build my own active system based on my existing equipment. At that time I had two subwoofers bi-amped to two pirate LS3/5A monitors. To go fully active seemed a logical step.

I have always believed that the speakers are by far the most important factor governing sound quality and realism (a good recording is essential too). Unfortunately, some audiophiles are preoccupied with the "sound" of turntables, amps, preamps, and cables, overlooking the importance of advanced speaker design.

My subwoofers use old enclosures originally built for Goodmans Axiom 301 twelve inch full range drivers (a clue to their age, as well as my own). I modified them with extensive bracing and also coated the inside with roofing bitumen. The enclosure walls are 18mm chipboard with 5mm teak finish plywood. Black cloth on a frame provides an unobtrusive grille. The new drivers are KEF B139's and the vented box alignment (thanks to Bullock's articles) produces fine results.

By contrast, the two satellites, which originally were LS3/5A copies, use 10mm plywood, damped internally with 12mm high density bitumen felt. The exterior is teak veneered all over and the front is flush, with no grille. I used washed long fiber wool well teased and evenly distributed (I have found no equal to long hair wool).

The drivers are the KEF B110 (SP1057) and the Dynaudio D28 fabric dome modified to incorporate a flat aluminum mounting plate. I suspended the satellites from the ceiling with two strands of monofilament nylon, which is entirely satisfactory and aesthetically pleasing.

The active crossover points are 100Hz and 1500Hz, and the circuits incorporate delay for the tweeter relative to the midrange and for the midrange relative

PHOTO 2. The satellite speakers are small enough to be suspended from the ceiling. Damped with long hair wool and coated internally with bitumen, they use Dynaudio dome tweeters, and KEF midranges.

PHOTO 1. The two subwoofers use KEF drivers and a Thiele/Small vented box alignment.

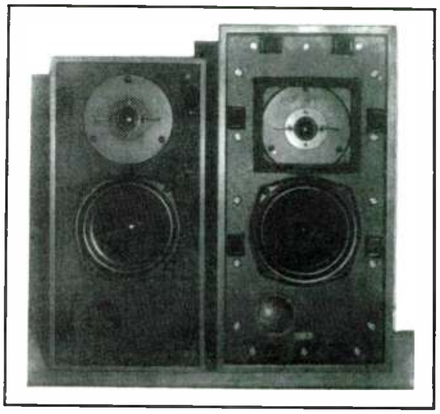

PHOTO 3. These speakers are used in other rooms of the house and have handmade crossovers based on the KEF computer assisted design.

to the subwoofer. To achieve the best sound, I had to balance the levels of the three drivers carefully (improper adjustment results in noticeably colored sound). The finished system sounds truly excellent. The unique acoustics of each recording are now quite obvious, and depth and imaging are superb.

For other rooms of the house, I built two small vented box systems (13 and 18 liters) with B110 and T27 drivers. The crossovers are home built to the KEF CS1A specifications, and the results are superior to the pirate LS3/5A crossover. The KEF design is computer optimized as is their practice now for all their work based on "target function design." I deviated slightly from the enclosure dimensions given in the KEF design. The frequency response of small speakers is sensitive to front panel dimensions and driver placement, but the sound of both of these systems is quite good. The new crossover sounds smooth and uncolored, especially in the crossover region.

John Kasowicz
Melbourne, Australia

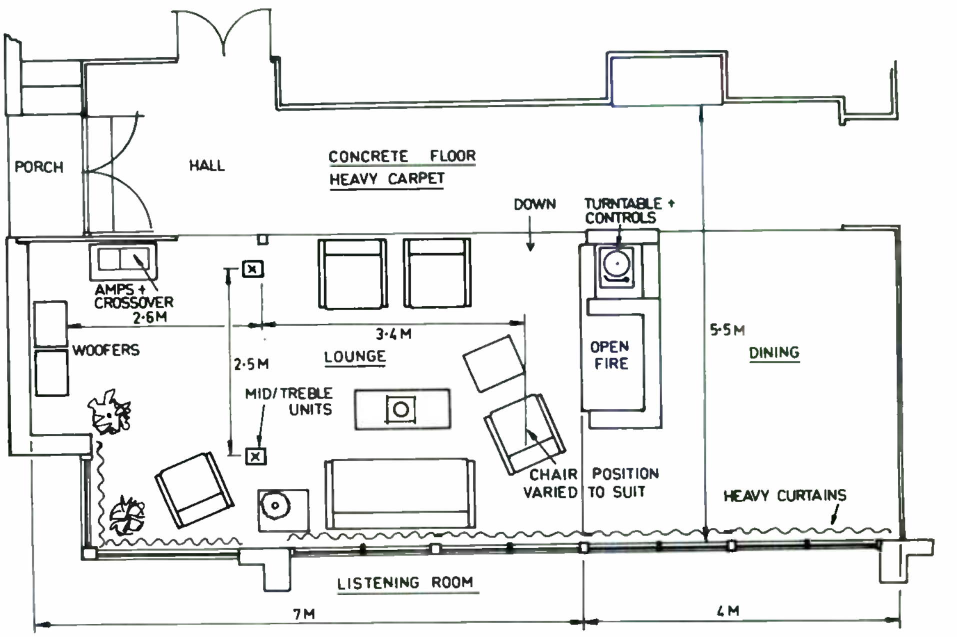

FIGURE 1. The arrangement of the satellites and subwoofers requires adding suitable amounts of delay to the signals for the upper drivers.

All these valuable back issues of *Audio Amateur* are still available

1970 "Price, Time and Value" surveys nine years of the fortunes of used equipment. An all silicon, complementary output, 20W per channel amplifier, fail-safe overload protected by Reg. Williamson. A high efficiency bookshelf speaker by Peter J. Baxandall. How to update and improve your Dynaco PAT-4 preamp. A visit to the Heath Co.

1971 A superb, simple, high quality preamplifier by Reg Williamson; A 4+4 mike mixer, using four ICs in a compact chassis, with eight inputs and two-channel output. A four channel decoder for adding a new dimension to listening: cost to build: $12.50. Two four-channel encoders, one with microphone preamps, to put four signals on two tape tracks. Three voltage/current regulated power supplies for better power amp performance.

1972 A nine octave graphic equalizer with slide pots by Reg Williamson. A 10½" reel tape transport, a full-range electrostatic loudspeaker and a 900W tube amplifier for driving the electrostatic panels directly. A high quality op amp preamp, Heath AR15/AR1500 modifications. A new type A + B, low cost 35W amp, electronic crossovers for bi- and tri-amplifier operation. All about microphones, and tuning bass speakers for lowest distortion.

1973 Construction: Five transmission line speakers: 8" to 24" drivers, peak reading meter, dynamic hiss filter, tone arm, disc washer, electrostatic amplifier II, and customized Dyna MkII and Advent 101 Dolby. How to photograph sound, power doubling, mikes, Jung on op amps, Williamson on matching and phono equalization.

1974 A perfectionist's mod of the Dynaco PAS tube preamp, a mid/high range horn speaker, wall-mounted speaker system, IC preamp/console mixer by Dick Kunc, a family of regulated current limited power supplies, switch & jack panel for home audio, grounding fundamentals, low-level phono/tape preamp with adjustable response, IC checker, lab type ± 15V regulated supply. A series on op amps by Walt Jung. Kit reports: electret microphone, Class A headphone amp.

1975 Building the superb Webb transmission line, how to test speakers, a test bench set of filters, variable frequency equalizer, building and testing Ampzilla, power amp clipping indicator, a compact tower omni speaker, controls for two systems in three rooms. Visit to Audio Research Corp. Ultra low distortion oscillator, all about filters by Walt Jung, universal filter for either audio garbage or crossovers. Electrostatic speaker and schematics for Audio Research Corp.'s SP-3A-1 preamp, Heath's XO-1 and Marantz' electronic crossovers.

1976 Three mixers by Ed Gately, a vacuum system for cleaning discs, a 60W per channel amp for electrostatic speakers, a silent phono base, a perfectionist's tonearm, re-mods for Dyna's PAS preamp, Jung on active filters, a white noise generator/pink filter, tape deck set-up by Craig Stark, modifying the Rabco SL-8E, a high efficiency speaker system for Altec's 604-8G, uses for the Signetics Compandor IC, modifying Heath's IM (tube) analyzer, simple mods for Dyna's Stereo 70 amp, a tall mike stand. Kit reports: Ace preamp, Heath's 200W/channel amp, Aries synthesizer, Heath's IO-4550 oscilloscope.

1977 Walt Jung's landmark series on slewing induced distortion, a wood/paper/epoxy horn, Reg Williamson's Super Quad-pod, experiments with passive radiator speakers, a high efficiency electrostatic speaker with matching low-power direct-drive amplifier, modifying the AR turntable for other arms, Heil air motion speakers, a $10 Yagi FM antenna, Ed Gately's 16-in/two out micromixer, the speaker saver: complete system protection. Audio Research modifies the Dyna Stereo 70; the super output buffer, a 101dB precision attenuator.

1978 Modular equipment packaging, PAT-5 preamp mod, radio system for Hospitals, supply regulation for Dyna's MkIII, B.J. Webb on phono interfacing and record cleaning, 24" common bass woofer, TV sound extractor, modifying the Formula 4 tonearm, phono disc storage cabinet, Jung on IC performance and noise control, visit to Peter Walker's Quad factory, small horn enclosure, audio activated power switch, the Nelson Pass 40W class A amplifier, a thermal primer, capacitor tester, recording with crossed cardioids. Kit reports: Heath IC 1272 audio generator, Heath's IM5258 distortion analyzer, Hafler preamp, Dynaco's octave equalizer, West Side Electronics pink noise generator.

1979 A space-age IC preamp by Lampton-Zukauckas; scientific evaluation of listening tests. Room testing oscillator, Advent mike preamp, three preamp construction projects compared, basic issues of record manufacture, a primer on soldering, a variable frequency tube electronic crossover, a re-mod of Dynaco's PAT-5 preamp. A noise reduction system, Williamson's 40W power amp, a LED power meter, and an interview with Peter Baxandall. Kit reports included: The Integrex Dolby, Heath's audio load, IG1275 sweep generator and their Technician's training course. Classic circuitry included a 1936 GE console, the Marantz 8B, Dynaco PAS-3 and Audio Research SP-6.

1980 Regulated power amp power supplies, dynamic range and clipping indicator, Precise, Inverse RIAA Network, Interview: Peter Baxandall Pt. II, Golden ears? Power supply regulator for op amp preamps, Timerless tone burst generator, Filters outside the audio band, Intensity Stereo primer, Upgrading FM tuners, Choosing & Installing an FM antenna, Passively equalized phono preamp, Soldering practice, Modifying the Hafler DH-101 preamp, Analog phase meter, Audio equipment rack, AD7110 Digital attenuator, Capacitor Dielectric absorption, Tube RIAA equalization, Review: Hafler DH-200, SWPTC Tigersaurus 210A, Heath AP-1615 Preamp, Logical Systems 318 Silencer, Heath AA-1600 power amp, Heath AD-1701 Output indicator.

1981 Audio Research SP6 mods; Revising preamp power regulators; Home built heatsinks; Marantz 7C mods; Nelson Pass' MOSFET rebuild of HK's Citation 12; Williamson on Record Care: destaticizing and deep cleaning; An audio measuring system: Part 1: A Swept Function Generator, Part 2: A Logarithmic Amplifier; Modifying Dynaco's ST-150 amp and regulating its supplies; Adding a tower for FM; Microphoning, a heretic's view; Super uses for **Cramolin**, De-ringing transformers; Jung and Marsh upgrade the Hafler DH-200 with clues for all amps, Greening the ReVox A-77, Evaluating Dolby-C.

1982 MC pre-preamp, two-tone IM measurements, double-blind testing and its alternatives, Heath IM-25 and IM-16 meter upgrades, phased array recording, adapting surplus meters to your needs, Borbely 60W MOSFET amp, Rabco ST-4 tonearm upgrade, sophisticated preamp switching with minimum contacts, NiCad battery charger, sweep marker adder, Boak op amp electrostatic and dynamic headphone amps, DC servo loops for amps, Advent mike preamp update, double-blind testing, tangential tracking tone arm, building a plate reverb, selecting and evaluating interconnect cables, the last word on Dyna PAS tube preamp mods, distortion analyzer, stepped attenuator, tape deck testing and calibration device. Kit and Test Reports: VSM's stereo demodulator, Radio Shack's coincident mike, Fluke 8050A multimeter, Heath AA1800 amp. Phoenix CX decoder. Plus reviews, classic circuits, and audio aids.

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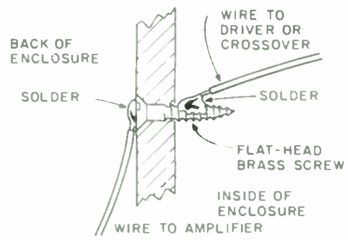

Over many years of building speakers, I have settled on one method for bringing out the leads from the enclosure. This is completely airtight, low cost, fast, easy and low in resistance. Cable can be connected or disconnected quickly with a touch of the soldering iron.

Roy C. Koeppe
Tulare, CA 93274

Tunable Vent for T/S Systems

Thiele/Small vented box designs are sensitive to vent tuning—especially the higher order, assisted alignments, which are the most beneficial. After constructing one, you may want to adjust the vent tuning to compensate for individual differences in drivers. You may also want to retune for a different driver *(i.e.* if you damage one or replace it with a better model, or want to compensate for changes in compliance with age). This is not always easy to do after the enclosure is glued, nailed, and sealed and the finish applied. With this method, you will have a vent which you can remove easily and tune outside the enclosure.

Fabricate the vent from a section of PVC or ABS sanitary drain pipe. This type of pipe usually is 3/16″ thick or greater (the thinner walled varieties often used for water supply lines are not suitable). PVC or ABS pipe is available in 1½ to 3″ inside diameters. Although more expensive than a cardboard tube, it is ideal for a vent because it is inherently nonresonant, does not deteriorate, and the smooth inner surface reduces breathing noises (making smaller diameters more practical). Vents longer than the enclosure depth are easy to make with elbows and other typical plumbing hardware.

My method is as follows:

1. Cut a hole in the baffle board the same size as the pipe's outside dimension. The hole can be slightly out of round and slightly larger than the pipe, because you will seal it later.
2. Cut a length of pipe a bit longer than required and square the ends with sandpaper.
3. Using a router with a straight bit and center arbor, cut a ¼″ deep by ¼″ wide ring around the hole in the baffle board. The exact depth and width are not crucial.
4. Make three screw holes in the pipe's outside wall. Using the same depth setting, use the router to cut three equally spaced notches, about three-quarters of the way through, at one end of the plastic pipe. The router's base plate rests on the pipe's open end to make these cuts.
5. Insert the pipe into the baffle board, flush with the surface and mark the center of each notch cut on the baffle in step 4.
6. Remove the pipe, and using a thin blade, make a vertical scarf (a shallow groove) inside the hole in the baffle in each of the locations marked. Do not make the scarfs more than 1/16″ deep.
7. Insert the pipe flush with the baffle, and align the notches in the pipe with the scarfs in the baffle. Insert a 1/12″ #8 or #10 pan head sheet metal screw into each scarf and screw in. The screws will thread themselves into the wood and plastic pipe, and cause the surfaces to fit together.
8. Tightly pack the routed area with Mortite.

To shorten the vent, simply remove the Mortite and the three screws, remove the vent, shorten it and replace. If you must use a long vent requiring an elbow, arrange it so you can take it in and out without disturbing the driver.

I have used this technique on several speakers and have experienced no problems. I always use high density 1⅜″ par-

Tools, Tips & Techniques

ticle board for my baffle boards, and usually for the entire enclosure. This material is strong enough not to require bracing to damp panel vibrations for small to medium size enclosures. Panel resonances which do occur are usually an octave lower than with ¾″ particle board. I recommend the double thickness particle board for all woofer boards. Lumber yards carry it on special order.

John Bandel
Nanuet, NY 10954

Caribbean Bass

I would like to share this project with other readers. Due to the requests of friends, I have purposely left out electrical formulas for the benefit of those who do not understand them and get bored because they only want to build and play the speaker. For this reason I will be short and to the point to please my lawyer, banker, accountant, joiner and mechanic friends. I would, however, invite those who want more details to write to me.

The speaker is a bass reflex, or if you prefer, vented type, with a separate enclosure for the midrange and treble units. The entire speaker is constructed of ¾″ high density particle board. The internal measurement of the larger box is 39″ × 11½″ × 15″ and the smaller enclosure is 11″ × 6½″ × 5″. The vent, which is constructed of ½″ particle board, is square in shape and has internal measurements of 3″ × 3″ × 7″ with the 7″ length measured from the outside of the baffle to the end of the duct.

There is a 2″ × 2″ brace that runs from the front baffle to the back of the cabinet and is positioned between the bass driver and the vent. This brace is most important, as is the brace that runs 4″ behind the magnet of the B139 II from side to side of the cabinet.

I suggest that you construct both boxes as follows. Attach the smaller box to the top of the main enclosure. Assemble the top and bottom to the side panels, then add the back. Lastly attach the front baffle, which serves both enclosures. Use thick white glue and 1½ × 7 or 8 screws to ensure that the cabinets are airtight and do not rattle. Paint all internal surfaces with four coats of auto undercoating and stuff the boxes with well teased long fibre wool (or fibreglass) at a rate of seven ounces per cubic foot.

The 3″ base shown in the diagram serves two purposes. One is to move the duct 9″ off the floor (a distance determined by trial and error to be best), and the other is to provide easy access for assembling the crossover. The best crossover network for this speaker is the KEF T27 used in the KEF 104AB and can be ordered from Falcon Acoustics, Tabour House, Norwich Road, Mulbarton, Norfolk NR 14 8JT, England as kit number 22, along with the midrange and bass drivers. The 8mH inductor used in the B139 circuit must be a high power, low loss type.

This speaker can be driven comfortably by a 60W per channel amp. The bottom end is as good as you could ever want it and is really the strong point of the speaker. I hope readers will try this inexpensive and simple home project.

Bernard Georges
Dominica, West Indies

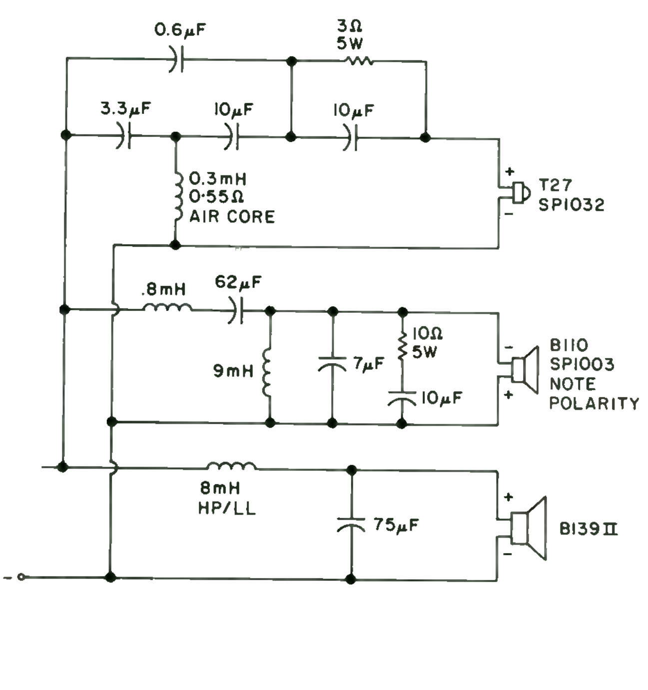

FIGURE 1: This is the crossover network for the three-way, vented, double-enclosure system designed by Georges.

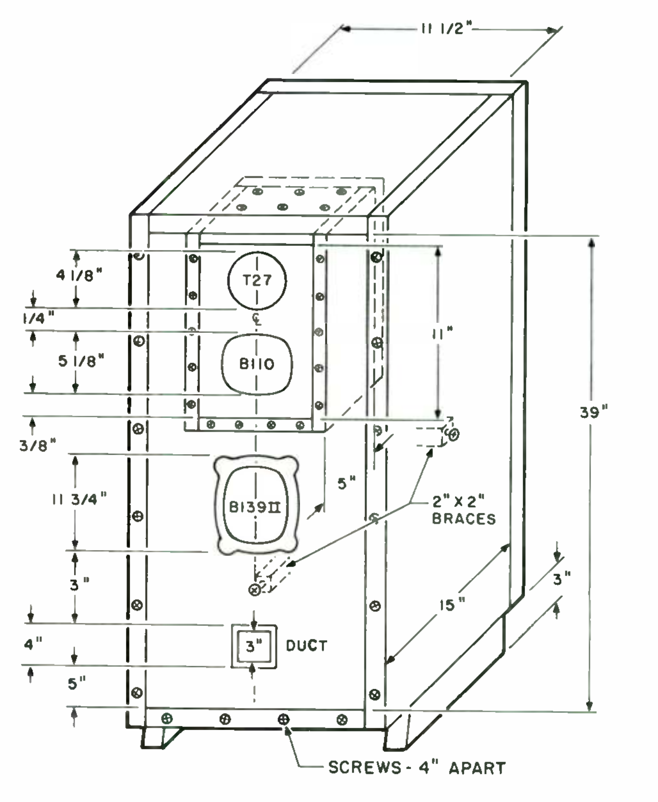

FIGURE 2: The diagram does not include a front baffle. The enclosure uses a square vent and inner enclosure for upper drivers.

SB Mailbox

D'APPOLITO CORRECTION

Three errors appeared in my letter (4/82, p. 41). The first equation for V_{AS} on p. 42 might be more readable in this form:

$$V_{AS} = V_B \left[\frac{(f_H^2 - f_B^2)(f_B^2 - f_L^2)}{f_H^2 f_L^2} \right]$$

In the equation for V_{AS} at the bottom of that page, a square bracket should enclose all terms following V_b. On page 44, near the bottom of the middle column, the square root of 1 + 2 should be the square root of 1 + alpha.

Joseph D'Appolito
Andover, MA 01810

TIGER PAUSES PERMANENTLY

Many readers, including myself (as evidenced by my attempt to order some parts), may not be aware that SWTPC (Southwest Technical Products Corporation) is moving out of the audio business. The enclosed letter from them should tell the story.

Neil Shattles
Decatur, GA 30035

SWTPC's reply to Mr. Shattles:

Effective November 17, 1982 Southwest Technical no longer accepts orders for spare parts for audio equipment and kits. Our entire inventory of these items has been liquidated.

We have been phasing out the audio and kit line gradually. At this time only a small quantity of these items remains in stock.

We now manufacture and distribute assembled business computers.
Sales Dept.
Southwest Technical Products Corp.
San Antonio, TX 78216

BALLARD CORRECTIONS

The author has specified recently that the trimpots for the phase shift circuits (R3 and R37) should be ±10% of the nominal value (or 20% of the nominal value as a maximum). Therefore R3 should be 2k ohm in all cases; R37 should be 1k ohm in all cases. Larger values cause nonlinear frequency response.

In Part I of "An Active Crossover With Phase Correctors," (3/82, p. 14) some errors appeared. On p. 14, column three, the phrase *"Figure 6A* shows that..." should refer to *Fig. 6B."* Near the bottom of that column, *"Figures 6C* thru *6F* show that..." should read, *"Figures 6D* through *6F*..." On p. 15, column three, "speakers" should be "speakers." On p. 16, near the bottom of the third column, "10" should be "10%."

INDUCTOR RESPONSE

I would like to comment on Daniel Coyle's article on winding inductors in the 3/82 issue.

We should not give preference to air core inductors (even for high power applications) solely because a ferrous core can be saturated. Air core inductors have the disadvantages of higher resistance, weight and size, and both have their uses. A ferrous core inductor saturates only if you are careless with the core's size. If we compare the two types with equal inductances and resistances to suit a specific current, we can resolve the issue.

The article repeats once again two popular fallacies: 1. using the impedance of the driver at the crossover frequency to determine crossover component values, and 2. subtracting the voice coil inductance from the calculated crossover inductance.

So far as I can judge, the former is made without consideration of the consequences, while the latter seems to have arisen to maintain the "constant resistance" property of a pair of filters (H and L), which these days is of little consequence. My article, "Loudspeaker Networks," in 2/82 shows why the first is incorrect. It also illustrates that rather than trying to reduce the value of the inductor, you should (in some circumstances) *increase* it to compensate for the voice coil inductance.

Wilfred F. Harms
East Sussex, England

WARNING: MEKPO FOR HEIL HORNS

I happened to find a warning about MEKPO catalyst in an old issue of *Railroad Model Craftsman.* Readers who are building the horns described by Ken Rauen (3-4/82) should be aware of the possible dangers to the eyes in using this compound. They refer to an article in American Airlines' *Flight Deck* about a safety conference in Vancouver, BC. An eye specialist said that even one drop of MEKPO will cause *serious eye damage* unless you wash it out immediately (within four seconds). It will destroy eye tissue progressively and result in permanent blindness. The damage cannot be reversed. You should wear protective goggles and have a ready supply of clear water available when working with MEKPO.

Marc Nowakowski
Hunt Woods, MI 48070

Mr. Rauen replies:

I was not aware of any toxicological properties of this compound. I regret I do not know a substitute for MEKPO. Boat shops will know of safer alternatives. The precautions listed in Railroad Model Craftsman *are good to follow. As a general rule, any*

SB *Mailbox*

chemical you are exposed to, other than in quantities naturally encountered, should be treated as a threat to health and life. Do not use rubber gloves as some will absorb the materials used in the horns. Wipe your hands with a rag and wash your hands with soap and warm water immediately.

Good safety practices in the workshop include the use of safety glasses even for cutting wood and soldering.

Don't forget: accidents happen when you least expect them.

WOOFER POSITIONS

Are any speaker Q's altered when the driver fires downward or at an angle, as in coffee table style subwoofers? In production subwoofers I see drivers mounted anywhere from two to ten inches from the reflecting surface. What "rules of thumb" might help find the best distance?

Doug Cabaniss
Sullivan, IN 47882

ALTEC COAX MODS

Owners of Altec coaxial drivers such as the 604B, C and D, and the 8G may be interested in one of the modifications available. Good background on this design was provided by Lampton and Boyer in *TAA* 3/76. The modifications increase the lower range of the treble horn to 800Hz, and use a time-aligned crossover to delay the signal to the woofer. These changes result in smoother response and improved off-axis response. UREI has incorporated them into one of their studio monitors.

Changes to the horn do not necessitate dismantling the speaker or disturbing the woofer cone. All you need do is remove the 2×3 multicellular plastic horn and install a ceramic extended horn. UREI (8460 San Fernando Rd., Sun Valley, CA 91352) sells the ceramic extensions, but their crossover is no longer available. However, Electro-Voice does have a suitable network at a reasonable price.

The construction of an active network incorporating the correct delay would be a good project for those interested *(see Bob Ballard's phase correcting crossover in*

3-4/82 for ideas—Ed.). My personal experience in attempting to build passive versions has been unrewarding. One of the best kept "secrets" of the industry is how important the crossover network is to the speaker's sound quality.

Charlie Howlett
Lake Wylie, SC 29710

MORE ON COYLE

I read the article on winding inductors (3/82). Although I like the systematic methodology of Coyle's technique, having wound a few coils myself over the years, I have some comments and questions. First, he recommends using a former which you can disassemble. In my experience removing the top and bottom plates usually results in a few turns unwinding from both ends. I have found that securing the ends to the core is much safer. I prefer to use 6-32 nylon bolts since they also can be used to secure the finished coil to the circuit board.

He recommends cutting the wire to length before winding. In practice, unwinding the wire from the supply reel without simultaneously winding it onto the former produces a costly mess. The wire snags and kinks, and as anyone who has used magnet wire can tell you, once kinked, you can never straighten the wire again.

Secondly, I would like to know how he derives the time constant, To, for the networks. For 500Hz, his formula yields a To of 318 micro sec. Inverting this yields a frequency of 3144Hz. Finally, in following his formula, I designed a coil for an inductance of 1.27mH. I used 0.7 ohm as my DC resistance, having a commercially wound coil of approximately these same parameters on hand. By Coyle's formula, this required 98.8ft. of 16 gauge wire. According to the table, 16AWG has a resistance of 4.016 ohm per thousand feet. Substituting these values into the formula, 98.8ft gives a DC resistance of about 0.4 ohm, the value recommended in the article. The commercial coil's 0.7 ohm is about 50% higher than the desired 5% of voice coil impedance.

Scott Ellis
Ocean Springs, MS 39564

THE DIGITAL DECISION

Continued from page 6

have anything to hope for from that quarter, unfortunately.

On the other hand, Philips has invested untold quantities of development money, as have Sony and others, in bringing the CD to market. The oddest fact, in my mind, is that the CD system is a "higher end" item. Ask yourself how many kids are going to plunk down $800 for a CD player to listen to rock music or pay $17.95 for a disk, however cute or indestructible it may be.

The answer is that, like VCR's, the prices will go down. Well, VCR's began at $1400 and now are in the $300-$500 range, discounted. But even if CD players drop to $200, they will still require at least another $50 worth of electronics to use the device.

It becomes obvious then that the makers of the CD are obliged to sell the machines to audiophiles first while the manufacturing is streamlined to lower costs.

We will do well to remember that the audiophile has power. He sank four channel without a trace. We may hope the well deserved demise of that sonic deformity will not ruin permanently the acceptance at some future time of the Ambisonic proposal or of some matrixed ambient system we can all agree to use.

But unless the CD makes it among knowledgeable audiophiles and music lovers, it may not make it at all. That puts a responsibility on us all to listen critically and to talk to one another with candor.

The worst scenario possible on the digital issue is one where we all choose up sides and fling mud at each other. Let us be clear about what is opinion and what is fact. Opinion is important and can be evaluated. It has a rightful place in this decision and will be welcome in these pages. Doctrinaire opinions about the value of opinions are not helpful. Positive criticism of opinion is welcome. The more shared experience and insight we can pool the better. I welcome as much light with as little heat as possible.

Double blind test results will be most welcome if we can have some idea of the tested hearing acuity, experience, and qualifications as auditors of those participating. I think it is clear by now that listening tests of random samples drawn from the general population are nearly useless.

The digital proposal is a highly important one worthy of the best efforts the audiophile community can make to evaluate it. Let's do our work conscientiously, fairly, and vigorously with pleasure. —E.T.D.

PERSONAL CALCULATOR

Continued from page 25

tions: trigonometrical, statistical, and other functions are built-in, whereas you have to program them into most computers. However, some new features put the top calculators somewhere on the increasingly gray border between programmable calculators and hand-held personal computers. □

REFERENCES

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OPEN REEL TAPES from studio masters. Philips, Argo, Telefunken, Vanguard, Unicorn. Catalogue $1.00. ***BARCLAY-CROCKER,*** Room 1470-L, 11 Broadway, NYC 10004. TTF

THE DB-3XL SWITCHABLE CROSSOVER is a 2-Way 18dB Butterworth with switching for frequencies of 50, 70, 100 and 150Hz. Features include: front panel level controls, additional common bass, mute and bypass switches, built in power supply and five year warranty. The DB-3XL was designed to be a demonstration model and is now available new for $575 in limited number. For complete technical information write: ***DB SYSTEMS,*** Main St., Rindge Ctr., NH 03461 (603) 899-5121. T1/83

ESL TRANSFORMERS, $42. Mylar 48″ x 30″ $10. 12″ Dynaudio woofers for T.L., $99. Post Paid. ***SANDERS SYSTEMS,*** 1578 Austin St., Atwater, CA 95301. T4/83

AUDIO CONCEPTS: Strathearn full range ribbons, AC acoustic foam, Technics ribbons, polypropylene caps, oak-walnut enclsoures .1—2.5ft³, Shadow Engineering electronic kits, Falcon and AC speaker kits. Moving coils from Audax, Dalesford, Dynaudio, Kef, Peerless etc. Much more. Informed, helpful service. Fast delivery at guaranteed lowest prices. Demos by appointment. MC/Visa phone (608) 788-0366 9:00-5:00 CST M-F. Catalogue $1.00, 1919 S. 19th St., LaCrosse, WI 54601. 3/83

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NEW GOLD PLATED PHONO JACK. Rear mount, gold plated, solid brass jack w/gold plated ground flag and hardware, $1.75 ea. Will interchange with Audio Research SP3A-1's phono jacks. Gold plated solid brass shielded phono plugs, $2.00 ea. Send stamped self addressed envelope for flyer and order form. Minimum order $10.00. ***OLD COLONY PARTS,*** PO Box 243, Peterborough, NH 03458.

SAVE 50%. Build your own speaker system. Write: ***McGEE RADIO ELECTRONICS,*** 1901 McGee Street, Kansas City, MO 64108. T4/83

WE ARE ONE OF the largest independent manufacturers of crossover networks and speaker system accessories in the U.K., supplying manufacturers, retailers and export. We have a growing number of outlets in the U.S.A. and Canada. Your guarantee is the trust our manufacturing customers put in the quality and reliability of our networks. If you have supply problems, please send for details: $2 bill Air, $1 bill Surface, to our mail order retail outlet: ***FALCON ELECTRONICS,*** Tabor House, Norwich Road, Mulbarton, Norfolk, England. T2/84

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GOLD PLATED BANANAS. DBP-9AU, eight solderless (set screw) plugs for up to 12 gauge wire, $14.95. DBP-9H, four red and four black bakelite plug handles, $5.50. DBP-9J, 5-way dual binding post rated 30A at 1000V, gold plated hardware included, package of two, $15.95. DBP-8, 12 gauge speaker wire, $45.95 for 100 feet. **NEW**: DBP-14, Gold Plated Spade Lugs solder or crimp, takes 10-12 ga., $5.95 per 8 pack. Include $2.50 handling charge for orders under $45. ***DB SYSTEMS,*** Main St., Rindge, NH 03461. T3/83

STEREO SPEAKERS, KITS, COMPONENTS. Mylar Film capacitors, crossovers, coils, cabinets. Polypropylene woofers, midranges. Dome and Ribbon tweeters. Discount prices. Catalog $1.00 ***SPEAKER COMPONENTS,*** Box 297, Marlborough, CT 06447. T3/83

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SPEAKER BIBLE. Vital information, plans, kits, transmission lines, modified Panasonic Leaf Tweeters and more. Send $2.00 to ***NEW YORK ACOUSTICS,*** 578 Nepperhan Ave., Yonkers, NY 10701. T1/83

FREE SPEAKER KIT CATALOG. Kits include phase alignment, computer optimized plans, JBL, EV, SEAS, Audax components. Also available: Thiele data, specifications of 200 components, including KEF, polypropylene woofers, $2 refundable. ***GOLD SOUND,*** Box 141SB, Englewood, CO 80151. (303) 789-5310. T1/83

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METAL FILM RESISTORS, RN55, 0.35 watt, 107 values from 10 ohms to 1 Meg., 25¢ ea., 10 per value/$1.80, 50 per value/$7.50. Send stamped self addressed envelope for list of values and order form. New gold plated brass rear mount phono jack, $1.75 ea. Gold plated shielded RCA type phono plugs, $2.00 ea. Minimum order $10.00, quantity discounts available. ***OLD COLONY PARTS,*** Dept. SB, PO Box 243, Peterborough, NH 03458.

TESLA TWEETER: At last, a very efficient 8 ohm 40W round horn tweeter. Designed and produced by ***TESLA ELECTRIC COMPANY.*** None finer for under $40.00. Free brochure, 1029 Marles Drive, Santa Ana, CA 92706. T4/83

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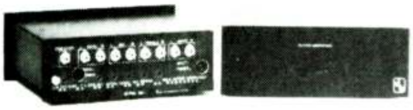
BUILD WITH THE BEST! ElectroVoice speaker components and our engineering staff. Free catalog packed with information and great deals! Try our consult by mail plan. ***S&S ELECTRONICS,*** 1005 Market St. #207, San Francisco, CA 94103, (415) 864-8205. Visa, Mastercard. T4/83

RAW DRIVERS, ACCESSORIES, and lotsa help! Catalog 25¢. ***MENISCUS SYSTEMS,*** 3275 Gladiola, Wyoming, MI 49509. T3/83

CABLE TV CONVERTERS & DESCRAMBLERS. Plans and parts. Build or buy. For more information send $2 to ***C & D ELECTRONICS INC.,*** PO Box 21, Jenison, MI 49428. T3/84

SERIOUS AUDIOPHILES interested in a central Colorado group (Denver, Boulder, Ft. Collins, Greeley area) contact James S. Upton, 2631 17th Ave, Greeley, CO 80631.

MINNESOTA AUDIO SOCIETY. Monthly programs, newsletter, special events, yearly equipment sale. Write: PO Box 3341, Traffic Station, Minneapolis, MN 55402.



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Custom made DB-3 ACTIVE CROSSOVERS are available in 2-Way and 3-Way with 6, 12, 18 and 24 dB per octave slopes. THD less than 0.0008%, five year warranty. Send for our free literature on crossover applications.

SPEAKER GASKETS: Finest quality neoprene for air-tight seals. Size & price each: 3½" Dome Tweeter $1.30. 2×6" Horn Tweeter $1.40. Midrange and Woofers 5"-$1.50, 5½"-$1.60, 6½"-$1.70, 6×9"-$1.80, 8"-$1.90, 10"-$2.00, 12"-$2.25, 15"-2.50. Send payment with order to ***TESLA ELECTRIC COMPANY,*** 1029 Marles Drive, Santa Ana, CA 92706. T4/83

GOLD PLATED phono jacks $1.20, plugs 90¢ ea., $1.00 handling. Also custom 1% capacitors, 0.5% resistors. Details SASE. ***REFERENCE AUDIO,*** Box 368M, Rindge, NH 03461. T4/83

CLUBS

Space in this section is available to audio clubs and societies everywhere free of charge to aid the work of the organization. Copy must be provided by a designated officer of the club or society who will be responsible for keeping it current. Send notices marked Audio Clubs in care of the magazine.

SAINT LOUIS AUDIO SOCIETY meets monthly for discussion and equipment audition. For information sheet send a stamped, self-addressed envelope to SLAS, 7435 Cornell, Saint Louis, MO 63130.

Southeastern Michigan Woofer and Tweeter Marching Society

Detroit area audio construction club.

CONTACT DAVE CARLSTROM 10155 Lincoln Huntington Woods, Michigan 48070 313-54-48453

A CLUB FOR FM AND TV DXers, offering antenna, equipment and technique discussions, plus updates from FCC on new station data. Monthly publication "VHF—UHF Digest." Annual convention in August. For more info: Worldwide TV-FM DX Association, PO Box 97, Calumet City, IL 60409.

PACIFIC NORTHWEST AUDIO SOCIETY (PAS) consists of 50 audio enthusiasts meeting monthly, second Wednesdays, 7:30 to 9:30 PM at 4545 Island Crest Way, Mercer Island, WA. Be our guest, write Box 435 Mercer Island, WA 98040 or call Bob McDonald (206) 232-8130.

THE BOSTON AUDIO SOCIETY INVITES you to join and receive the monthly B.A.S. SPEAKER with reviews, debates, scientific analyses, summaries of lectures by major engineers. The BAS was the first to publish info on TIM, effects of capacitors, tonearm damping, tuner IM dist., Holman's and Carver's designs, etc. Sample issue $1, sub, $16/yr. P.O. Box 7, Boston, MA 02215.

THE COLORADO AUDIO SOCIETY is a group of audio enthusiasts dedicated to the pursuit of music and audiophile arts in the Rocky Mountain region. We offer a comprehensive quarterly journal plus participation in meetings and lectures. Membership fee is $10 per year. For more information, send SASE to: CAS, 6225 Snowbird Dr., Colorado Springs, CO 80918.

THE NEW YORK AUDIO SOCIETY meets monthly with prominent guest speakers, discussions and demonstrations of the latest equipment. Its $20 annual membership dues include a subscription to S/N, the society's quarterly publication. For a free invitation to our next meeting, call (212) 544-1222, (212) 289-2788 or (201) 647-2788 or write us at PO Box 125, Whitestone, NY 11357.

QUAD OWNERS CLUB. We have joined together to share information, set up modifications and make the best speaker better. Special research projects and tests. For information write: Quad Owners Club, 33 No. Riverside Ave., Croton-on-Hudson, NY 10520.

SARASOTA AUDIOPHILES interested in forming a club—write: Mark Woodruff, 5700 N. Tamiami, Box 539, Sarasota, FL 33580.

AUDIOPHILES INTERESTED IN FORMING an audio club in the Washington, D.C. area please contact: Joseph Kmetz, 9861 Goodluck Rd., Apt. #10, Lanham, Maryland 20706 or call days (301) 794-7296, eves. (301) 585-3186.

SAN FRANCISCO BAY AREA AUDIOPHILES, Audio Constructors society for the active, serious music lover. We are dedicated, inventive and competent. Join us in sharing energy, interest, expertise, and resources. Send self-addressed stamped envelope to S. Marovich, 300 E. O'Keefe St., Palo Alto, CA 94303 for newsletter.

THE AUDIO SOCIETY OF HONOLULU cordially invites you to attend one of our monthly meetings and meet others like yourself who are interested in the how's and why's of audio. Each meeting consists of a lively discussion topic and equipment demonstrations. For information on meeting dates and location contact Bob Keaulani at 1902 South King Street, Honolulu, HI 96826. (808) 941-1060.

CONNECTICUT AUDIO SOCIETY WANTED. Serious audiophiles in Conn., or Putnam or Dutchess Co., NY, contact John J. McBride, 33 Perry Dr., New Milford, CT 06776, (203) 355-2032.

PRIVATE FOR SALE

Karlsen Enclosures: 2 available for 12" speaker. Teak veneer. 2 12" University 312 spkrs; Dynaco Stereo 70 tube amp. SASE for description, prices, pics of Karlsens. R. L. Pittman, PO Box 24, Gulfport, Miss., 39501.

Polk Audio mini monitor speakers, mint, $125/pr., Rod Cooper tangential tracking tonearm kit, all parts plus teflon bearings, $100. Empire 698 turntable, $40. Joseph Kmetz, 9861 Good Luck Rd., #10, Lanham, Maryland 20706, (301) 794-7296.

For sale or trade: CTS 18" woofer(s), M&K milk-x, crossover, Radio Shack SPL meter, AD0160T8 tweeter(s), electronic crossover (300-1200Hz Variable). All negotiable. (717) 738-1622.

Fluke 8024-B DMM 11 function w/peak hold, in box w/all manual & paperwork, latest model, $175. Dale 4Ω 250W non-inductive resistors .01% gold finned w/hardware. New, $16 each. B&K freq. counter 1801 6 digit, ex. cond, w/manual, $125. Sprague 3100 μF @ 450V caps, $25 ea., 4 for $100. N. Palladino, 33 Village Rd. North, Brooklyn, NY 11223, (212) 996-2252.

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One pr. subwoofers, built from art. in August '76 *Audio* magazine, JBL 2213 drivers. $450 pr. Norris Shave, SRI, Box 173AA, Toano, VA 23168, (804) 564-8513.

Bruel & Kjaer 4134 ½ condenser mike, 4619 FET preamp, 2801 pwr supply. All like new, $950. General Radio 1521-B graphic level chart recorder. General Radio 1304-B beat frequency audio oscillator, manual, link unit. General Radio 1564-A vibration analyzer, case, 1521-B drives either unit. All like new, $1500. Hewlett-Packard 120AR scope, rack mtg., exc., $145. Tektronix R561-B scope with 3A7 and 3B1, rack mtg., exc., $450. Roger H. Russell, 7 Normandy Court, Binghamton, NY 13903.

½″ diaphragm Nakamichi CM-700 laboratory microphone meeting all ANSI S1-4-1971 specifications for acoustical measurements, omni & cardiod capsules, both calibrated for frequency & phase by the Nicholet FFT system, FET preamp & electret construction for accurate impulse measurements, slim, non-diffractive body, used *only* for occasional lab measurements, $285 (U.S.) includes shipping, insurance, calibration curves. S. Clark, 9 Armandale Ave., Toronto, Canada M6S 3W7.

Fried Drivers: One pair of 10″ damped bextrenes from Fried model O woofers. Dalesford made. Excellent condition. Also JVC AM-FM tuner, model JT-V31. Great specs and sound. Both to best offer. Doak Wattigney, 2448 Oakmere Dr., Harvey, LA 70058, (504) 341-2575.

Hartley Concertmasters—pair, walnut cabinet 41″ high by 29″ wide by 18″ deep. Drivers consist of: a 218-HS 18″ woofer, a 220-MSG 10″ midrange, a 207-MSG 7″ tweeter, and a DT/8 super tweeter. Excellent condition, original shipping cartons, $1,500/pair (originally $3,000/pair). Ken—Cleveland, Ohio, (216) 338-8252 evenings.

Ace subsonic filter, 18dB at 20Hz, $50. 4 Speakerlab W1208R woofers, $30 ea. 4 Phillips 2″ domes, 16 oz mags, $10 ea. 2 15″ CTS woofers, 20 oz mags, $15 ea. 2 TO125 poly woof/mids, $10 ea. All excellent. Take all for $200. George, (516) 588-5550, days.

Technics ST-8600 AM-FM tuner. Functions new, looks new. Complete with manuals. $125, includes shipping (USA) and insured. Doug Cabaniss, 225 S. Section, Sullivan, IN 47882, (812) 268-5642.

Pair Clestion HF2000 tweeters, excellent condition. Best offer. Neil K. Disney, 414½ W. Mansion, Marshall, MI 49068, (616) 781-6156 (evenings).

Altec N800E-800Hz crossover, Altec H-811-E horn, Altec 802D driver, needs diaphragm, $95 for all. 2 Dynaco A-420 output transformers, used but in perfect condition, $35 ea. Alex Michailoff, 3637 Dorney Park Rd., Allentown, PA 18104, (215) 398-0823.

2 JBL #2350 horns, huge, 2″ throat, $200 plus shipping for the pair. Glenn Behrle, PO Box 5147, Woodmont Station, Milford, CT 06460, (203) 878-0558.

Acoustech III amp, IV preamp, both $200. Ampex 755 tape deck, $125. All are original mint, complete with factory manuals and schematics. Wayne Barkus, 623 N. Ashbury Ave., Bolingbrook, IL 60439, (312) 739-0061.

Jordan 50mm modules, $70 ea. Jordan design manual, $5. GAS Thoebe, mint, $260. GAS Grandson (metered), $195. GATA820 8″ polyprop woofers, $30 ea. Foster ribbons, $25 ea. Long fibre wool, $.50/oz. Panasonic 2900 AM/FM/3 band SW receiver with digital display, $175. Bearcat 220, 20 chan. scanner, $205. Sumo Charlie, $340. Commodore N60 flight computer and manual, $57. Dynaco PAT 5, works but needs tweak, $65. PASSA40, all parts except ECB's Kent, $130. Call Russ (415) 494-2700 Calif. wk. or write PO Drawer H, Foresthill, CA 95631.

10μF 135V AC electrocube metallized polypropylene caps, great for quality crossovers, $5 each. J. Carlblom, 2774 Doresto Road, San Marino, CA 91108. (213) 441-1318.

Dynaudio 21W54 MPS (plastic cone) woofers, $95/pr., Morel MDT-28 tweeters, $39/pr. Dynaudio Variovents, $5 ea. Crossover for above drive units, $13/pr. SEAS H107, $20/pr. Peerless PHT-25, $20/pr. 3-way (600/5000Hz) 12dB crossover, $10/pr. Also, acoustic foam for dampening walls and enclosures. Eric, (216) 524-6684 evenings & weekends.

SHY AUTHORS
SEND YOUR LETTER TO THEM VIA US—with your STAMPED ENVELOPE

8 ft. transline subwoofers of 1″ high density particle board with 10″ Dalesford D100/250s, $300 pr., new Jordan modules, $140/pr., new Apature/JVC ribbons, $35/pr., used KEF B110's, $65/pr., used Audax HD1Z.9D25A domes, $20/pr. Call Wayne at (617) 593-5937 between 8 and 10 pm EST weekday evenings, or on weekends.

Sanders ESL components—transformers, mylar, power supplies, crossover—invested $225, want $150. Also stator components (not shippable) $50; Marantz 120 tuner $275; Van-Alstine metered MOSFET 150, $550; SUPERFET preamp, $425. Wally Kowalski, POB 205, Sumas, WA 98295, or (604) 792-6353 home; 792-0794 work.

PRIVATE WANTED

Ionovac-type tweeter or construction info on same. Hafler DH500, DH110, Carver TX-11 tuner also wanted. Wally Kowalski, POB 205, Sumas, WA 98295, or (604) 792-6353 home; 792-0794 work.

Newcomer to hi fi audio seeks reasonably priced gear—generator, scope, etc.—to determine parameters of speakers and systems a la Thiele, Bullock, etc. C. Burger, 848 Barber Rd., Southern Pines, NC 28387.

dbx model 224 wanted. Will pay reasonable price. David Baran, 24 Wickham Ave., Hamilton, Ontario, Canada L8H 7E9.

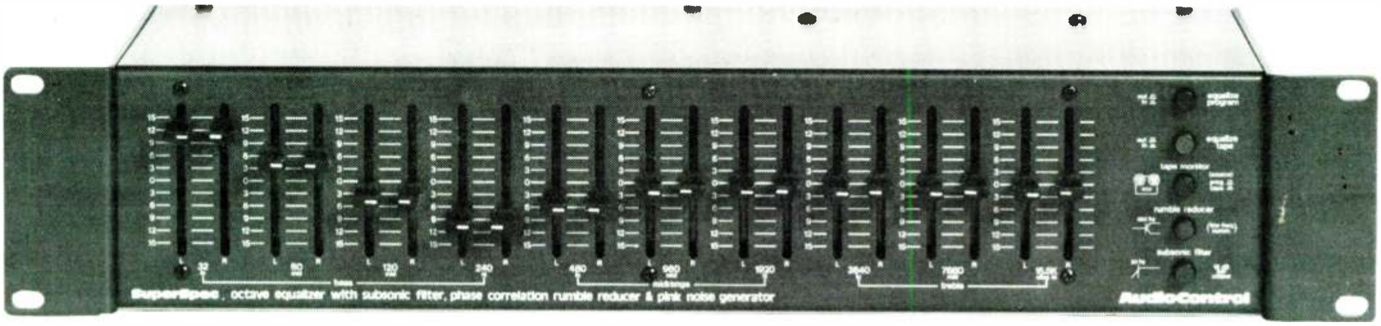
Converse, correspond with live recording enthusiasts using grand old tube machines; recommendations for the best recording electronics and heads, solid state or tube; feedback from persons scratch-building or modifying tube record electronics, especially cascode, constant current, etc. Neil Shattles, 2243 Emerald Castle Dr., Decatur, GA 30035 (404) 289-5374.

I'm looking for 1 pr. Strathearn ribbons & Dalesford D100/200 in good condition. Jay Hageman, 515 Postoffice St., Galveston, TX 77550, (713) 762-0511.

Wanted: the group purchasing power of the people who want to build the Absolute Sound QRS 1-D Reference system or modify their system to sound more like it. Contact Michael Marks, 448-206 Westover Hills Blvd., Richmond, VA 23225, or call (804) 233-7041.

Advertising Index

WHY WE'RE OFFERING YOU A $299 EQUALIZER FOR $129.



Our neighbors here in Lynnwood make some of the finest equalizers and analyzers in the world: Audio Control Corporation.

But once in a while the engineering department gets the best of the marketing department and a product emerges that's too esoteric for the rank and file consumer.

THE SUPER-SPEC C-25 WITH PINK NOISE GENERATOR.

A few years ago, when Audio Control's C-22 Octave Equalizer was beginning to really take off, the engineering department said, "Why don't we make a version with even better specs and add a laboratory-grade pink noise generator for the experimenter?" Sounded ike a great idea: .009% THD, 102dB signal-to noise, pink noise generator ±.5dB 20-20kHz. So they did it.

C-25 Specifications:

DISTORTION (at 1 volt from 20Hz to 20kHz): less then .009%. **FREQUENCY RESPONSE:** From 3Hz to 100kHz, plus or minus 1dB. **HUM AND NOISE:** (10kHz band-width): minus 96dB re 1 volt, minus 102dB re 2 volts. **MAXIMUM INPUT:** 7 volts. **MAXIMUM OUTPUT:** 7 volts. **INPUT IMPEDANCE:** 100K ohms. **OUTPUT IMPEDANCE:** 680 ohms. **CONTROL CENTERS:** 32, 60, 120, 480, 960, 1920, 3840, 7680, 15.5kHz. **CONTROL BANDWITH:** "Q": 2.5 **CONTROL RANGE:** Plus or minus 15dB. **SUBSONIC FILTER:** 18dB per octave Tchebychev alignment. **SUBSONIC ROLLOFF:** Minus 1dB at 25Hz, minus 3dB at 20Hz, minus 21dB at 10Hz. **SIZE:** 19" (48.2cm) W, 3.5" (8.9cm) H, 6.5" (16.5cm) D. (standard EIA rack mount). **WEIGHT:** 6.75 pounds (3.2kg). **PINK NOISE GENERATORS:** ± 1dB 20-20kHz. **BACK ELECTRET MICROPHONE:** ±1.5 dB 20-20kHz **WARRANTY:** 2 years.

Unfortunately, the vast majority of dealers just didn't understand the whole point and Audio Control ended up with a pile of superb equalizers. They languished until we noticed them on the back shelf and made Audio Control a deal they couldn't refuse.

THEIR LOSS IS YOUR GAIN.

We're not talking about a cheapo imported knock-off here. Audio Control lavished the best components and design into the C-25.

Fiberglass boards. Precision resistors and capacitors. Silky-smooth pots and superb specs. Frankly, there's probably $129 worth of materials in each C-25.

LAB-GRADE PINK NOISE GENERATOR.

Anybody who reads this publication knows how useful pink noise is in evaluating and adjusting speakers. Even if you don't have a measurement instrument, pink noise lets you do considerable adjustment by ear. In conjuction with a handheld spectrum analyzer it opens up a whole world of interactive EQ testing.

When we got the shipment of C-25's from Audio Control, Accessoterica benchtested it's pink noise generator against a B & K Model 1405 Noise Generator. The Audio Control C-25 was more accurate.

So even if you just use the C-25 as a pink noise generator, it's a great buy.

TWO SPECIAL CIRCUITS FOR HOME HI-FI.

Audio Control is a great believer in solving real-world audio problems. So they added an 18dB/octave Tchebychev subsonic filter circuit and a Rumble Reduction circuit to the C-25.

Subsonic filter is down 1dB at 25 Hz, down 3dB at 20 Hz and down 21dB at 10 Hz. If you bought or built vented or transmission line speakers, you know how important a circuit like this is, especially if you like a healthy 40Hz boost in your program material the way we do.

The Rumble Reduction circuit mono's bass below 200Hz to combat rumble, mechanical feedback, warped records and resonances. Vertical groove components are effectively cancelled without losing stereo speparation. If you don't agree with this approach, the circuit comes out with the touch of a button.

THE $549 C-101 FOR $299!

We also grabbed up a few packaged C-101 Octave Equalizers with 101-LED Realtime Spectrum Analyzer, measurement microphone pink noise generator. All units are 100% guaranteed, electronically and cosmetically. They're not repairs, but demo units returned by dealers. Some manufacturer's would just sell them back as new, but Audio Control made a deal with Accessoterica to clear them out at cost. You couldn't do better if you bought a brand new C-101 at retail. Same features and specs as the C-25 with 10-band Spectrum Analyzer with 2 & 4dB range, slow and fast decay, SPL mode and microphone on 20-ft cord with ± .1.5dB 20-20K specs. A steal, while they last at $299. Full 2-year warranty from the factory.

PAIRED SLIDERS FOR EASY ADJUSTMENT.

Audio Control is the only company that puts left and right channels next to each other. Doesn't seem like much until you start adjusting an equalizer frequently. As you probably know, a difference of as little as 3dB in the midrange bands can smear sound imaging. (A lot of bias against equalizers stems from this adjustment problem which is solved simply by putting left and right controls near each other so you don't have to build two curves.)

THE RIGHT STUFF.

Of course, the C-25 has an extra tape monitor loop, a program switch for comparison (especially useful in conjuction with the pink noise generator and your trusty ear for quick speakers EQ's), and an EQ-tape circuit which lets you equalize tapes without repatching C-25. It's packaged in a standard 19" rackmount chassis with RCA-type inputs and outputs on the back--including two for the pink noise generator. We even talked a pile of C-22 manuals out of Audio Control, although you're on your own concerning the pink noise generator. But then you wouldn't be reading this page if we didn't think you'll know what to do with pink noise.

VERY LIMITED SUPPLY.

Order your C-25 right now since we have a very finite supply. Order it toll-free with a bankcard and get it within seven days. Mail us a money order for two-week service or a personal check (which we have to let clear) for three to four week delivery. WE PAY FREIGHT via U.P.S. on all orders! Whether you need a pink noise generator, a great octave EQ or just a sharp subsonic filter, $129 is a superb deal on a great unit.

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