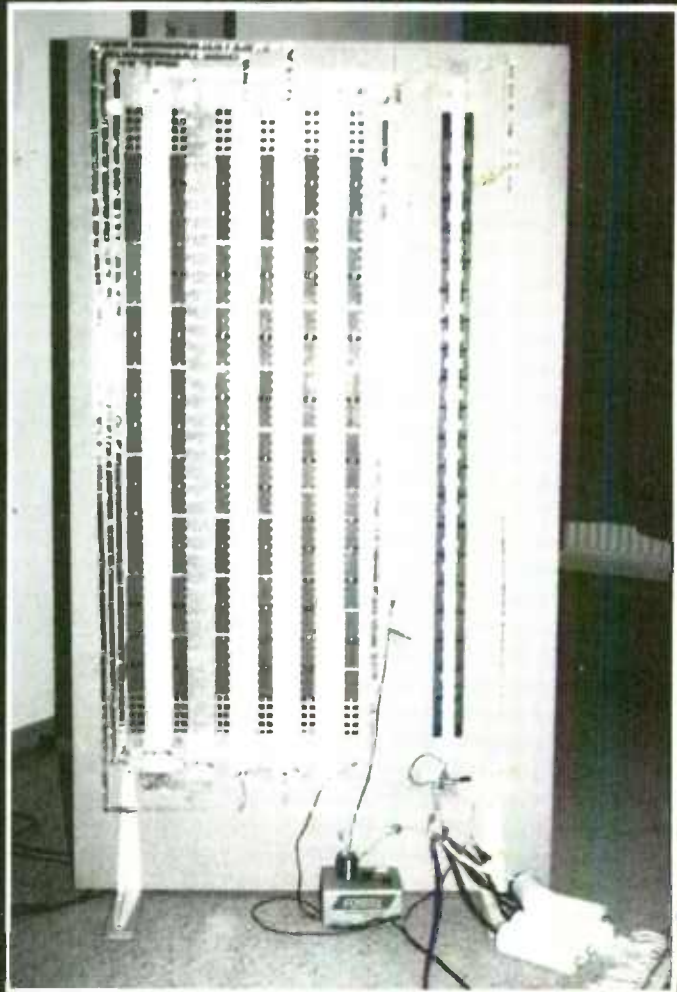
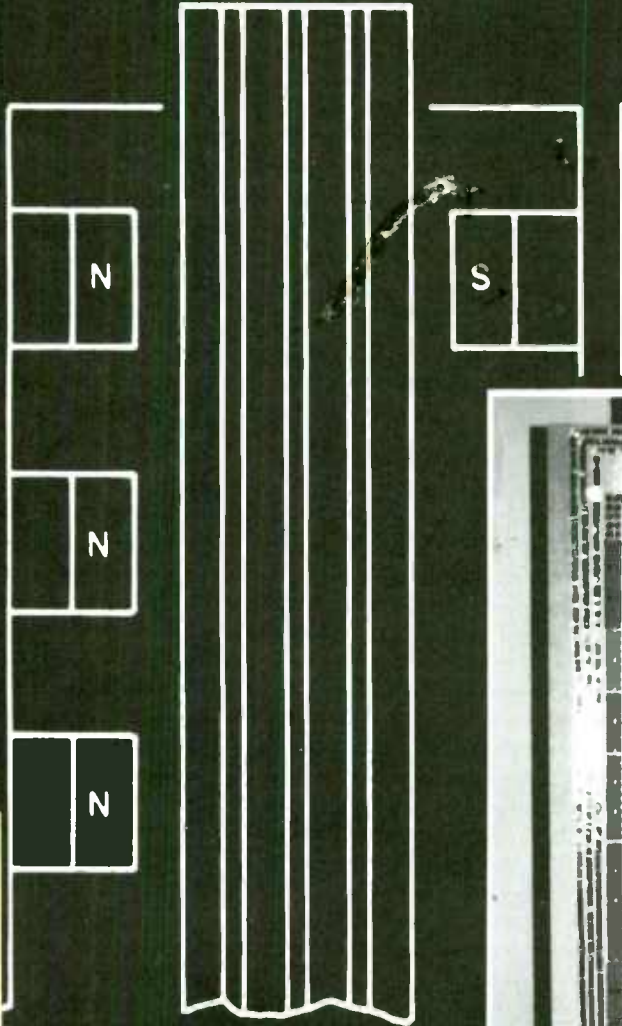


# Speaker Builder

THE LOUDSPEAKER JOURNAL

## KITCHEN BENCH RIBBON



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## Good News

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The new models include multiple drivers mounted in durable, carpet-covered cabinets with carrying handles and press-on connections. Designed for listening within the vehicle, or they can also be used anywhere for picnics or parties.

All models feature tuned, ported cabinets to insure full frequency response and deep bass. Three models (Hatchback, Pick-up, Samurai) are two-way systems with dual 8" polycarbon woofers and 3 3/4" piezo tweeters, and the fourth model is a bass augmentation system.

The UBC Hatchback is designed to fit a Camaro, Corvette, Trans-Am or Firebird, and is also recommended for Broncos, Blazers and station wagons. The UBC Pick-up is 6 1/2" deep, for behind-the-seat

placement in pickups and vans. The UBC Samurai is designed for a Suzuki Samurai. Prices range from \$239.95 to \$259.95.

For complete information contact Ul-

timate Sound, 19330 East San Jose Ave., City of Industry, CA 91748, (714) 594-2604.

**Fast Reply #EC25**



**NAKAMICHI** introduces three new auto loudspeakers with carbon-graphite reinforced polypropylene cones and a new

power adapter. The new speakers are the SP-35, a 3 1/2" full-range cutout replacement for many American and European

cars; the SP-65C, a two-way coaxial system (Nakamichi's first); and the SP-1010, an efficient subwoofer with a frequency response to 25Hz. The BA-50 Mobile Bridging adapter converts several of Nakamichi's stereo and four-channel power amplifiers to bridged operation and approximately triples their single-channel output rating.

The SP-65 features a new crossover design and a switchable attenuator to reduce tweeter levels by 2dB to suit installation conditions. The tweeter can also be removed from its mounting and placed elsewhere in the auto.

The subwoofer is a larger version of the SP-80, 10" in diameter, and can produce 113dB SPL.

The BA-50 is suggested to convert the Nakamichi PA-200, PA-300II and PA-350 to bridged operation. Two amplifier channels are driven in phase opposition and the loudspeaker is connected between their positive output terminals.

Suggested retail prices: SP-1010, \$179; SP-65C, \$299/pair; SP-35, \$69/pair; BA-



50, \$65. For more information contact Mr. Jun Sakamoto, (213) 538-8150; or in Canada, Mr. Howard Dickey, (604) 324-7535.

**ACOUSTAT** has developed the new Spectra loudspeaker line, a high dynamic range, wide dispersion, full range electrostatic.

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Spectra 3 last year, its "phantom curved" array controls dispersion for optimum high frequency and alignment under a variety of room conditions.

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The slender flat array is available in off-white or black fabric with standard dark oak finish for the hardwood veneer base (other finishes extra). The Spectra 22 is 22 by 2 by 66": \$1,850/pair. The Spectra 33 (33 by 2 by 66") is \$2,250/pair. Contact Acoustat for information: 3101 SW First Terrace, Fort Lauderdale, FL 33315, (305) 462-6700.

**Fast Reply #EC323**

**EJ JORDAN USA** announces the formation of the Owners Club for persons who own or have an interest in loudspeaker drivers made by EJ Jordan Designs. The intent is to form a network of sources and information to better serve customers with technical and design information and to also encourage members to share experience and knowledge.

The club plans a monthly newsletter and technical bulletin, complete kits, and discounts to club members. For full membership information, send a card with name, address, and phone to: EJ Jordan USA, Box 301, Suite 252, Building B, Princeton, NJ 08540.

**Fast Reply #EC553**

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Techart Associates *Drawings*

## Advertising Rates & Schedules

Rally Dennis

PO Box 494

Peterborough, NH 03458

(603) 924-6710

## Editorial and Circulation Offices

Post Office Box 494

Peterborough, New Hampshire 03458

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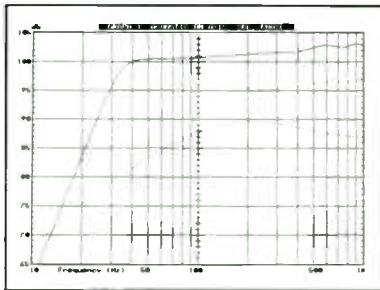
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## About This Issue

A fellow speaker builder from Copenhagen, Denmark leads off this first bi-monthly issue of *Speaker Builder* for 1988 with a fresh approach to hand-built ribbon drivers. **Ole Thofte** breaks new ground for *SB* since we have not had a construction piece on this technology previously. I trust it will inspire others to explore further. The prolific **John Cockcroft** is back with the shortest transmission line anyone has yet proposed (p. 18).

Taking his cue from Contributing Editor **Bruce Edgar's** coil winder in 1/87, **Fernando Viesca** offers a handy turns counter, starting on page 23, which includes boards to make construction simple. Winding neater and more precise coils should be easier with this gadget. **Wayne Cox** and **Bob Palmer**, Canadians both, decided they wanted a two-way system that would cover the whole spectrum, including the bass. The chronicle of their adventure begins on page 26.

Radio Shack's tiny Minimus 7 is, according to **William Hoffman**, more of a performer than its size or its low price would indicate. Starting on page 36 he outlines a carefully researched series of changes which turn it into a very respectable system that is low on fiscal drain. **David Davenport** gives us a report on dual voice-coil drivers starting on page 41 and **Jim Frane** relates his adventures with the VMPS woofer beginning on page 44.

We offer a new feature on page 47. *Vintage Designs* will resurrect older formats that may be of historic interest, and in some cases, viable projects some of you may want to try for the pleasure of it.

Our *Tools, Tips & Techniques* bin is bare and our supply of *Craftsman's Corner* items is too low, as well. Write up your own adventure, or send us a copy of that old cabinet plan from your files.

# Speaker Builder

THE LOUDSPEAKER JOURNAL

VOLUME 9 NUMBER 1

JANUARY 1988

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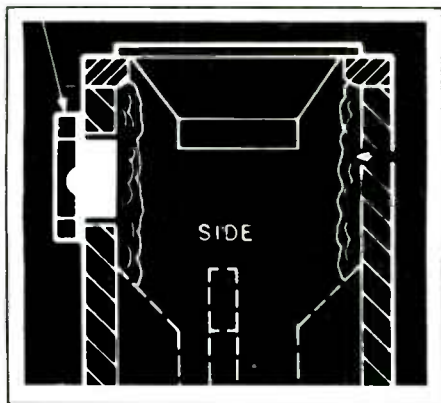
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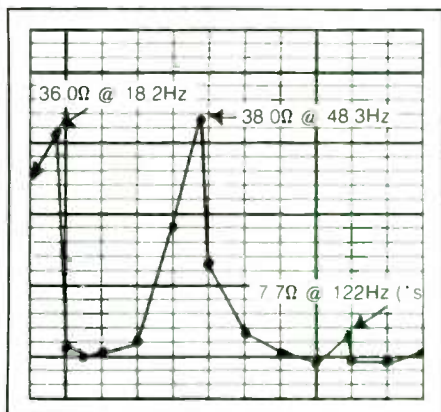
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## DRAGONS, DRIVERS and DISKS

When I heard that 1988 is the Chinese Year of the Dragon that seemed to fit well with the upbeat feeling around the town and around *SB's* office. Now we in the western hemisphere usually think of dragons as Medieval creatures who spent all their time devouring maidens or battling knights. St. George could scarcely have regarded his monster adversary as an amiable being. Those in the Orient, however, regard dragons as benign creatures, bringing good luck to any household where the traditional pair of dragon figures decorates the roof over the entry.

Persons born in a Dragon year, according to Chinese belief, are exceedingly fortunate and likely to be lucky throughout their lives. Reports from mainland China indicate that the government limit of one child per family is being flouted on a massive scale.

As we begin *Speaker Builder's* ninth year we are also feeling decidedly fortunate in that our fledgling magazine looks more and more like a dragon. Circulation renewals are at the highest level in our history. We are excited about publishing six issues, one every other month; an expansion many of you have asked for.

Advertising space orders are at the highest level ever and your response to advertisers' offerings is more enthusiastic than ever. Our advertisers also tell us that your response is making it possible for them to offer you a wider set of choices than ever before.

Your response to those offering goods in *SB's* pages is not merely by check or credit card. Many of you take the trouble to report back to the vendor on what happens when you use the drivers, crossovers, box stuffing, or wire in a project. Your suggestions have led to product improvements, to catching manufacturing errors or anomalies, and generally giving the vendors feedback that is vital to their ongoing development.

Some of you may be wondering why all that is good news. Well, the plain fact is that our loudspeaker systems won't get much better unless we have the best materials available. And unless someone can make a living out of finding and selling those materials: drivers, crossovers, coils, capacitors, wire, stuffing, computer design programs and the advice and technical information on specifications, which is probably the most valuable commodity of all, then this avocation will not

and cannot grow.

Your participation in the whole enterprise, support of and interaction with *Speaker Builder* and its advertisers is building a strong supporting structure which defines this hobby of speaker building.

We are at a wonderful stage of this avocation's development. We still have a lot of problems, but generally the atmosphere is one of strong growth, a remarkable amount of cooperation among vendors, and very few making a whole lot of money. The personal interest level of those in the business is still fairly high—and nobody is so busy that they can't do a good job.

The level of service many of you expect from dealers is very high. That's natural. And some of you are voicing some serious questions about that matter which need airing. Next time we will be doing a forum on customer support which may not make everyone happy, but it is a crucial and timely matter that needs attention.

Looking further afield, there is more dragon-like news on the horizon as we begin 1988. Sony Corporation has purchased CBS Records which is good news for several reasons. The new owners of CBS had earlier closed down the CBS Research Center in Stamford soon after they took over the company. As everyone realized, the purchasers were primarily interested in the TV Network part of the empire and were quite willing to sell off portions of the holdings in order to lower their debt load. Their cost cutting within the various segments of the network has been thoroughly aired. The cuts in the technical support for the recording efforts have not been so fully discussed. The Sony purchase of CBS Records will certainly restore to the record making portion of the company some of the world's more thorough and sophisticated technical development support.

The CBS Records executives were responsible for initiating and designing the Copycode Chip/anti-DAT legislation which has caused such an uproar among audiophiles. We can only suppose that one of Sony's reasons for purchasing the record division was to intervene in a process that was pushing the anti-DAT cause so vigorously.

*Continued on page 46*



# LA FOLIA: A KITCHEN BENCH RIBBON SPEAKER

BY OLE THOFTE

This is a description of how, with very simple means, financially motivated by the non-hi-fi needs of my family and helped by a certain anti-authoritarian disposition—I succeeded in building a pleasant sounding pair of ribbon speakers.

Since I'm no expert, there may be some risk in following my path, but I can promise a lot of fun. The expenses are minimal, if you are careful and don't short-circuit your amplifier. In Denmark, building the pair cost the equivalent of \$150–200 (US).

I took my main ideas from many different magnestatic speakers, such as Strathearn, Fostex, Magnepan and especially Apogee. I consulted Apogee's patent application in the Danish Patent Directorate (No. 804-1984); my construction does not have the sophistication of the Apogees, but is a simplified version using some of the same principles. I claim, despite many statements to the contrary, it is not that hard to make a ribbon speaker which sounds good.

Construction requires no special ability. You need to use a saw, drill and solder a little and have access to an ohmmeter (mind your amplifier). The impedance of the speakers is  $4\Omega$  and the impedance curve is almost a straight line. The efficiency is a drawback; your amplifier must be at least 100W and current happy.

I normally drive these speakers with a 150W hybrid/Moscode-like amplifier to high levels without problems and I have

tried a NAD 3020 as well. The result was very pleasing, but a little more power would be preferable. I had a very interesting session with a friend using his homemade original Futtermanns. Oh, what sweet sounds: crisp, mellow transparency. The speakers stood the test, neither blew up nor melted down. The sound level was as with the NAD, but since they "prefer" a much bigger impedance than  $4\Omega$ , I'm now rebuilding the speakers to an impedance of  $16\Omega$ .

The most time-consuming part of the project is collecting the materials. Building the speakers does not take a great deal of time, depending on how much you want to experiment. I strongly advise you to read and think through the construction before collecting the materials. Especially I want to emphasize this: just begin and save some of the speculations until later. My final piece of advice is: have a good time.

## COLLECTING THE MATERIALS.

**Baffle.** Cut two pieces of chipboard measuring 130cm by 75cm by 12mm. For fewer resonances you can use, for example, four of these boards, glue them together, and/or put sand between them. You can use thicker chipboard or denser types of board. A deluxe speaker could be made from acrylic board.

**Perforated sheet steel.** The sheet, 60 by 100cm by 1.25mm, will hold the woofer magnets. I used 50% perforation as a compromise between "magnet hold capacity" and airiness. The sheet was cut by a local smith with a hydraulic cutter. 1.25mm thickness appears to be too thin. 3mm is less resonance-prone and helps stiffen the baffle. Furthermore it acts as a better pole piece for the magnets, strengthening the forward directed magnetic field. You also need steel strips for the tweeter hole—background for the tweeter magnets.

**Magnets.** Use ceramic strontium-ferrite magnets. These are inexpensive and available in many sizes and forms. The magnets should be anisotropic—that is, magnetized through the flat side. The strontium types, which incidentally are no more radioactive than other post-industrial materials, are especially prone to resistant demagnetization in a strong magnetic field.

For each woofer I used 102 magnets measuring 42mm by 7.7mm by 9mm. For the tweeter magnets: 50 by 19 by 5mm. These were placed in double rows for greater force, 60 magnets per tweeter. Total cost of the magnets was approximately \$100.

Magnet prices are much lower when you buy large quantities so I suggest collective purchases when possible. Try low-cost types and arrange the conductor patterns after the magnet patterns. Bear in mind that the biggest magnets most often will be the strongest and you need a strong magnetic field to get a reasonable sensitivity from the speakers. The magnets I used were a bit too weak: I heard transparency, neutrality, and perspective in width and breadth, but the punch in the lower register was a little lazy. The sound became richer when I changed to a bigger magnet: 40 by 20 by 10mm. Unexpectedly, this size was about 40% lower in cost.<sup>1</sup>

**Membrane and conductor materials.** The woofer membrane was made from roasting film, available in bags and rolls. This film is a polyester product, very thin, resistant to stretching and withstands temperatures up to 425°F.

On the stretched film (110cm by 40cm) place a conductor pattern with

---

## ABOUT THE AUTHOR

*Ole Thofte has a degree in psychology from the University of Copenhagen and works with problems in the social/work environment. He has also done research on the psychology of "computers in the office." With no electronics background, Mr. Thofte is a true "kitchen bench" amateur.*

---

1. If you can't find a magnet dealer order at: Carbone, Teglvarksgade 37, DK2100, Copenhagen 0, Denmark.

adhesive aluminum tape.<sup>2</sup> This tape is used for burglar alarm systems in many shop windows. It should be available in rolls, for example, 50m by 9mm by 30 $\mu$ m. I used one roll for both speakers, which cost \$10, but buy two if you have a cat or children. My three year old son often punches the woofer with a curious finger. Otherwise these materials are tough. I don't think it is possible to burn them out by playing them too loud—I have used the tweeter often as a full-range speaker. It does a bit of pumping but no harm comes to it. Other methods to make membranes and conductor patterns will be discussed later.

**Tweeter membrane.** From the roasting film cut a ribbon 110 by 2cm. On this place four parallel conductors each measuring 110cm by 4.5mm. These are simply made by cutting the 9mm aluminum tape lengthwise.

**Stretching system.** By tuning the woofer membrane you can experiment with different bass resonance patterns, adjusting the speaker to the room and your taste. For a given longitudinal resonance, the trapezoid form of the membrane will spread the bass resonances and thereby boost the bass in almost a linear way. In this way the speaker can go much lower than the small baffle ordinarily makes possible. It should roll off with 6dB/octave from 100Hz, but it still has good output at 30Hz and lower, depending on the tuning of the membrane.

For the stretching system I used two aluminum L-brackets, 100 by 2 by 0.5cm; a 1m long thin wooden strip and 10 3mm bolts with screws.

**Crossover Network.** Woofer and tweeter both have an impedance of 3 $\Omega$ . I chose 500Hz as the crossover frequency to get the best possible dispersion from the woofer. As I wanted a 6dB/octave network, I calculated the coil in series with the woofer to 0.95mH and the capacitor in series with the tweeter to 105 $\mu$ F. I measured this to an overall impedance of 4 $\Omega$  and the impedance curve was almost flat.

Use the best possible components; I prefer open air coils and polypropylene capacitors. At first I used 100 $\mu$ F electrolytic capacitors in parallel with 4.7 $\mu$ F metal film and it worked well. Nevertheless, the result with the polypropylenes was so striking it justified the high price (\$65).

**Miscellaneous.** I used screws, washers, 3mm bolts with screws, solderlobes, thin foam rubber (baby washcloth), brackets to fasten the loudspeaker feet, and diffraction dampers such as felt

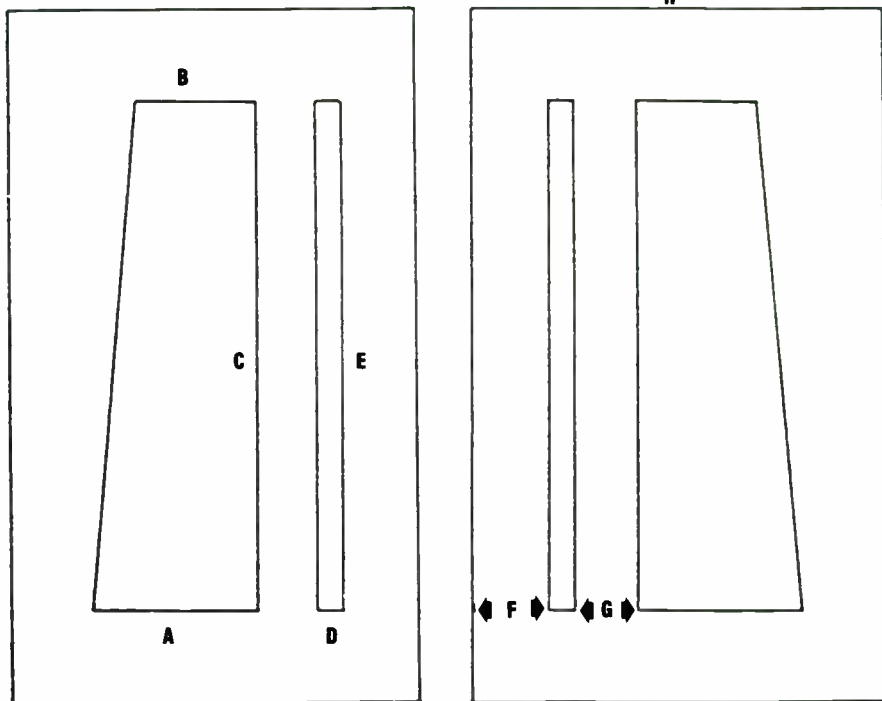


FIGURE 1: Cutout guide for chipboard. a = 30cm; b = 22cm; c = 95cm; d = 4.5cm; e = 95cm; f = 14.5cm; g = 11.5cm; h = 75cm; i = 130cm

or acoustic foam rubber. For the finish you might want speaker cloth.

**BUILDING THE SPEAKERS. Step 1.** Cut the chipboard (Fig. 1). Each must be a mirror image. I chose the dimensions more or less arbitrarily. You might want to add 5 to 10cm to the woofer to get a bigger surface. If you want a bigger (maybe much bigger) speaker, roughly use the same dimension ratio, a:b:c = 4:3:13.

**Step 2.** Line the woofer hole with thin foam rubber (resonance damping) approximately 1cm into the chipboard. Use a thin layer of contact glue.

**Step 3.** Fasten the steel sheet with screws and washers on the back of the chipboards.

**Step 4.** The magnet pattern for the woofer is shown in Fig. 2. Place a row of north poles, then south poles, and so on. The poles point outward. You don't have to know the polarity but define the first row as "north" and continue from this assumption. The relative polarity is easily determined by holding a magnet and noticing attraction or repulsion.

The magnet pattern on one speaker should be a mirror image of the other. For the first row, the magnets on the right speaker must have the opposite polarity of the magnets on the left speaker, and the pattern continues. The magnets hold themselves to the steel

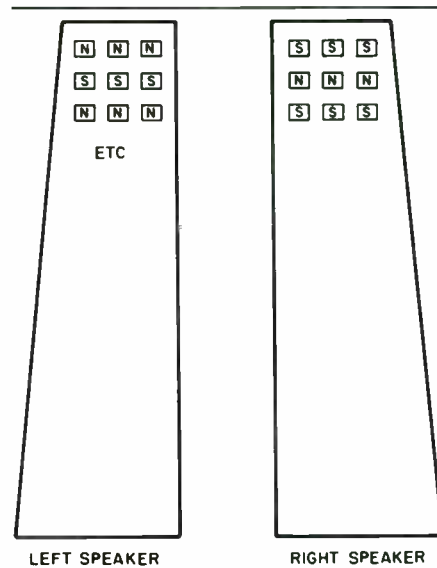


FIGURE 2: Magnet pattern for woofer.

sheet that functions as a pole piece. You can experiment with different patterns: more magnets in a row, less distance between the rows and so on. For permanent bonding, use a thin layer of contact glue to attach the magnets.

**Step 5.** Glue the roasting film membrane to three sides of the woofer hole,

2. If you can't find a dealer try: Age Nielsen, Sortedams Dossering 1, DK 2200 Copenhagen N, Denmark.

omitting the side with the stretching system (Fig. 3). Fasten loosely—the stretching is done with the stretching system. If the film slips from the glue when stretched later, screw it to a wooden strip lined with thin foam rubber.

Drill a suitable number of holes (for instance 8) in the L-bracket. Use these holes when screwing the bracket to the chipboard.

Drill 10 holes through the 5mm edge of the L-bracket. These holes must be evenly spaced, since they are used for the stretching bolts. Drill corresponding holes in the thin wooden strip and glue this to the roasting film. Line up the two rows of holes and screw the L-bracket to the chipboard approximately 3cm from the straight edge of the woofer hole. Fasten the 3mm bolts between the profile and wooden strip and the membrane is ready to be stretched.

**Step 6.** Line the inside of the tweeter hole with steel strips the same width as the thickness of the chipboard. These strips hold the tweeter magnets and help form the magnetic field. Again, you can glue the magnets to the strips but it isn't necessary.

**Step 7.** The magnet pattern for the tweeter is shown in Fig. 4. Let the left row of magnets on both the right and left tweeters have the same polarity as the top row of magnets on the left woofer. This ensures the left speaker is a reflected image of the right.

When you place the magnets close together on the metal strips, you will discover they repel each other. I left them further apart, thinking it might cause some diffraction problems that I could correct later by filling some material in the spaces. If you prefer the magnets close together, use contact glue or 3mm metal strips. In later experiments I achieved a stronger magnetic field by replacing the thin iron strips with thick strips (5-10mm), in Denmark called flat-iron and available in standard sizes at low cost.

**Step 8.** The conductor patterns use the basic rule learned in science class: place your right hand along the conductor with the fingers pointing in the direction of the current and with the magnetic field—going from north to south—at a right angle to your palm. Now the conductor will move in the direction of your little finger. In this design the rule has become a collective principle. Be certain the current flows in the same direction for all conductors in the same magnetic field, no matter how you plan your magnet and conductor patterns. And if the

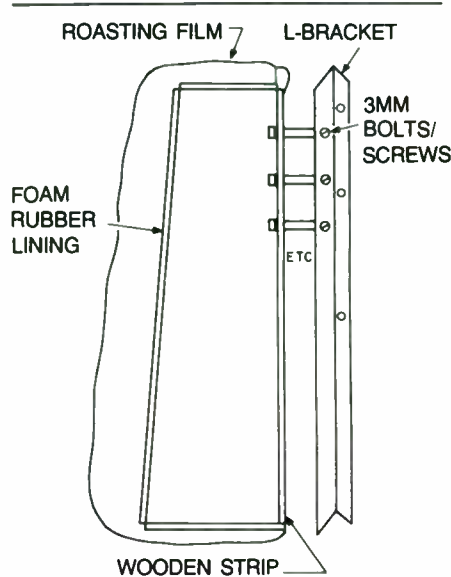


FIGURE 3: Fastening the membrane.

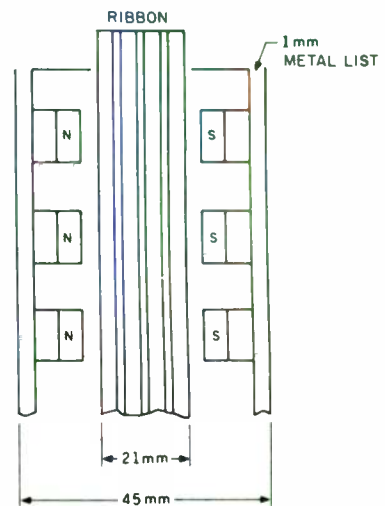


FIGURE 4: Magnet pattern for tweeter.

magnetic field changes, which happens for the woofer every time you cross the middle of every row of magnets, then the direction of the current for all the conductors within the field must also change.

For the woofer we want a continuous conductor twisting its way down the woofer membrane so the whole structure moves as a piston. You can do this in many ways depending on your materials. I placed the conductors as two patterns connected in series (Fig. 5), using 68 conductors at a distance of 4mm from each other. The pattern only covered two-thirds of the membrane. It would clearly be better to place the conductors closer to each other, which would have meant using more magnets (I just didn't have any more at the time). In all, the conductor was 18m long and had a resistance of  $3\Omega$ . I later connected the two patterns in parallel ( $0.75\Omega$ ). This was harder on the amplifier but was more efficient and had a better punch.

The conductor pattern of the tweeter used four conductors (Fig. 6) to increase impedance. For the same reason the return conductors placed outside the magnetic field are made of the same alutape. I'll admit it's a bit foolish to burn out energy where there is no use for it, but I solved this problem later. The tweeter conductor was 9m long and it had the same resistance as the woofer,  $3\Omega$ , since it was made by halving the woofer alutape.

Be precise when you make the ribbon. Cut a piece of roaster film 110 by 2.1cm. Fasten this with tape to your work table. Use plenty of light and something dark underneath. The outer conductors must

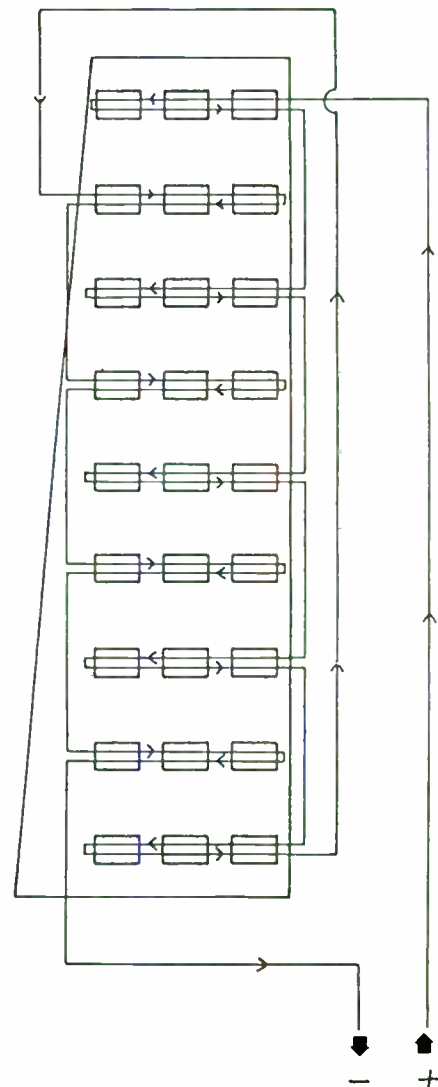


FIGURE 5: Woofer conductor.

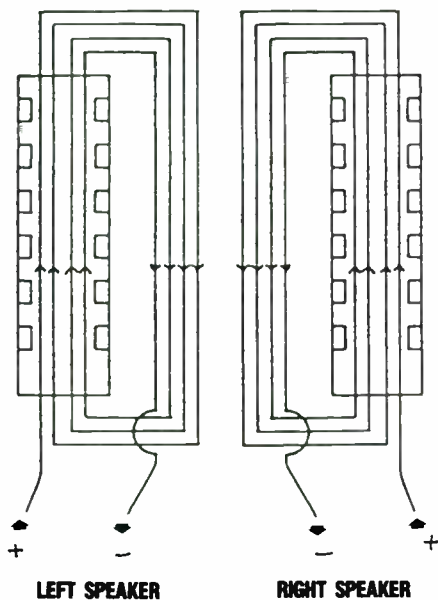


FIGURE 6: Tweeter conductor.

follow the edges of the ribbon, leaving room for 1mm between the conductors. No overlapping equals no short circuits. Next waveform, or corrugate the ribbon. I have run the ribbon between two pieces of corrugated paper, which makes big waves. I have also used, with better results, small plastic tubes with ruffles—from a toy set. Smaller waves are better. The corrugation is important since it makes the ribbon stiffer and eliminates rattling and buzzing.

The same applies for the woofer. Remember, the corrugation shortens the membrane about 10%, and you must make the conductor pattern on the work table and corrugate it before gluing the three sides to the chipboard. Never stretch a corrugated membrane. Let it hang loose.

Fasten the ribbon with contact glue in the tweeter hole about 2cm into the chipboard at the top and bottom. Be careful when you place it and make sure it does not touch the magnets or buzzing and rattling will result.

Connect the four conductors with four return conductors on the chipboard. Make sure the current flows in the same direction for all conductors. Make the connections with small screws and washers (solderlobes) to press the alutape ends together. You cannot solder aluminum. [With the proper flux, aluminum is solderable but the author's screws are an easier answer.—Ed.]

**Step 9.** The woofer and tweeter must be connected parallel to each other. Otherwise the tweeter will play as a full tone element. The coil (0.95mH) is in

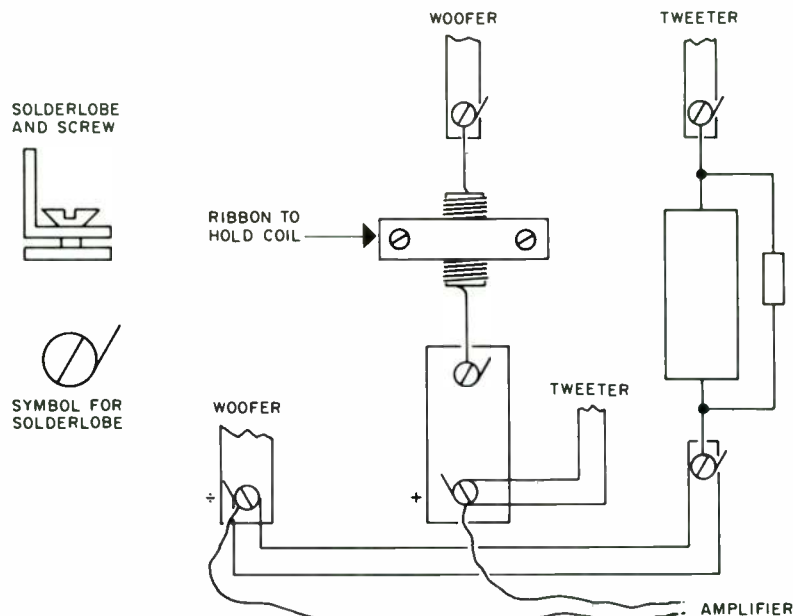


FIGURE 7: Crossover network and speaker terminals.

series with the woofer and the capacitor (105μF) is placed in series with the tweeter (Fig. 7). This makes the crossover frequency 500Hz.

**Step 10.** The loudspeaker feet were made from leftover pieces of chipboard, halved and fastened to the baffle with small brackets (Fig. 8). Experiment with foam rubber on the back of the baffle to diminish diffractions from the board itself and from the stretching system. I have tried acustilux (synthetic wadding) but it only muffled the sound. I haven't tried foam rubber or felt, but both are highly recommended with dynamic speaker construction.

If you don't like the decidedly functional look of the speakers, you may cover the baffle with cloth. I bought a synthetic, airy, inexpensive type in a dress store—"chamyse" as it is called in Denmark.

**Step 11.** Check for short circuits or faulty connections with an ohmmeter. The resistance measured over the main speaker terminals should be 3.5Ω.

**SYSTEM TESTING.** Connect the amplifier when everything is checked. If you haven't built solidly enough or if the membrane is closer than 4mm to the magnets, everything starts rattling. Go through the construction again and continue on.

Check the absolute phase and change the amplifier cables until the stereo is centered. Check woofer and tweeter for phase in relation to each other: use a 1.5V battery and connect to the corresponding speaker terminals. Remember

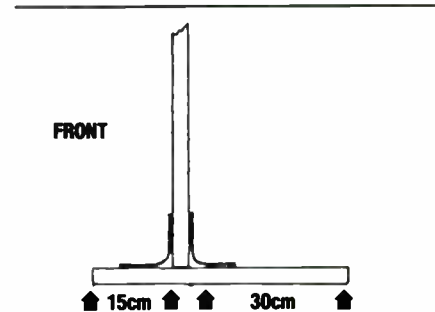


FIGURE 8: Speaker foot.

to disconnect the amplifier and bypass the crossover filter. When you follow this procedure both speakers should move in the same direction. If you don't see the movement, the woofer is stretched too tight. Also check the magnets for correct placement.

It is difficult to place bipolar radiating speakers optimally, because they need lots of surrounding space. My listening room is 6 by 4 by 2.5m. I placed the speakers 2m from the back wall and 0.75m from the side walls. Experiment and try angling and tilting the speakers. This can produce amazing differences in tone quality, perspective and so on. If one of the speakers sounds louder, you can "tune" them by adding or deleting magnets.

**FURTHER EXPERIMENTS.** I previously suggested some modifications, but will now elaborate and let my imagination go a bit—hoping to inspire you to do the same.

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1. Improving mechanical stability. For a heavier baffle use thicker chipboard, glue several thinner boards together, make sandwich constructions with sand in between, use marble, and so on. Try wooden strips to stiffen the construction across the back of the baffle, or build a stiffening "scaffolding" behind the speaker.

You could let the steel sheet cover the entire back of the speaker. This adds stiffness and also functions as a pole piece to the tweeter magnets. You could glue thin perforated sheets together (resonance damping) or use a thicker sheet (3mm). The feet could be bigger and heavier using sand again. You might want to try a different fastening system when you angle the speakers in the vertical plane.

2. Stronger magnetic systems. More and bigger magnets in the woofer and tweeter will make the speaker more efficient. I don't know where the optimal relation lies between number of magnets and airiness in the woofer. Remember the conductor pattern must follow the magnet pattern and the alutape might limit your possibilities, therefore you might consider other ways to make the conductors.

Later I experimented with "paths and bridges" at strategic places to strengthen the magnetic field. Use iron strips (*Step 7*) to line the tweeter hole and continue the lining at the top and bottom of the hole. This way the magnet force lines from the backs of the magnets are conducted better, which strengthens the fields in the gap.

U-formed bridges from the left side to the right side of the tweeter hole add further strength. (Remember the old horse-shoe magnets? Consult the literature for explanations.) Do not place the bridges so the magnets touch the iron, since this will short circuit the magnetic field: N and S touching the same piece of iron. Instead the magnet should touch the iron with the flat sides.

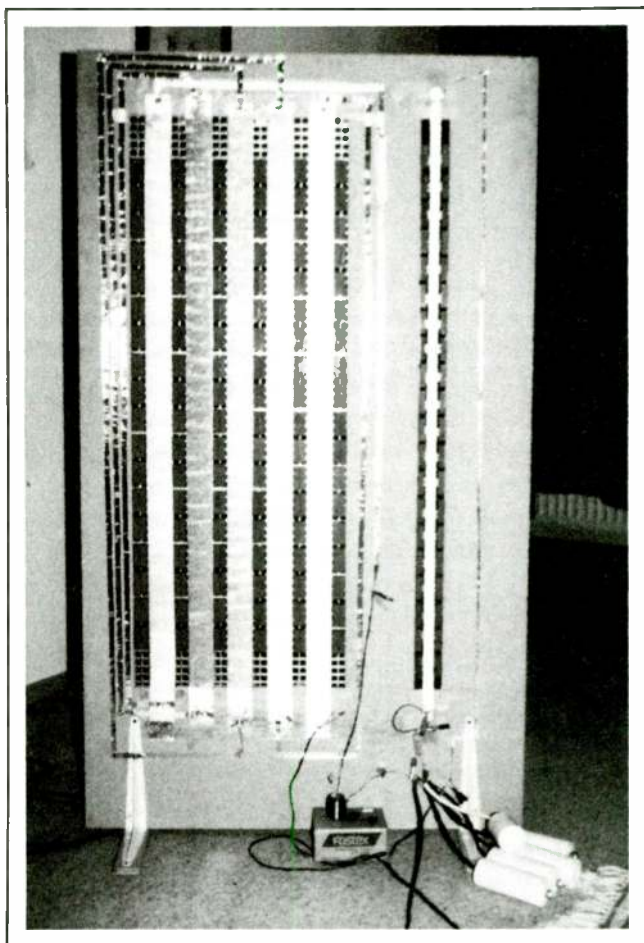
Don't make too many bridges because they cause reflections and resonances. I think the Magnepan ribbon has too much resonance-causing material behind it, for example.

3. Alternative conductors. The simplest way to make the woofer conductor is one conductor for each row of magnets (*Fig. 9*). The split between the magnets should be placed above the middle of the magnets (*Fig. 10*). Think it through. The pattern is easily made with alutape and 42 by 7.7 by 9mm magnets. If you use larger (40 by 20 by 10mm) magnets, place them closer to-

## Design Alterations

Since this article first appeared in the Danish *High Fidelity* I have been inspired to work on a true two-way ribbon speaker with a ribbon woofer instead of the usual planar woofer. I don't know of any commercially available true ribbon speaker. However, the magnetic field between two opposing magnets is more homogeneous than the magnetic field behind the planar woofer. Therefore I decided to try it. The present results are promising (*Photo 1*) but there is still some interesting work to do.

The speaker is very easy to build. In principle it is just a row of ribbon tweeters placed on a piece of chipboard. I just dismantled the planar woofer of the speaker I had already built, and widened the woofer hole to 35 by 95cm. The perforated steel sheet remained. The ribbon tweeter remained. Then I took 216 magnets per speaker, 40 by 20 by 10mm, and placed them



two by two in six long vertical rows and the steel sheet, approximately 5½cm apart. The magnets were now "standing" on end. The steel sheet had to be at least 2mm thick or the whole system would collapse like dominos. (My son found that great fun at first.) Placing the magnets this way short circuits them and I should have used flat pieces of thick iron as vertical magnet holders, but this was much easier to work with and more economical since the right side of one magnet system could function as the left side of the next magnet system.

The ribbons, five for the woofer and one for the tweeter, were cut from ordinary kitchen aluminum foil (11µm). I took 10 layers of foil with a little water between to moisten, a very sharp hobby knife held as horizontally as possible and voila: all the ribbons in one cut. Woofer ribbons were 4 by 120cm

(extra to allow for corrugation), and 1.2g. The tweeter ribbon was 1.5 by 120cm and 0.5g; a 6.5g moving membrane—very light indeed.

I corrugated the ribbons with the riffled tube and fastened it to the chipboard with tape, slightly stretched between the magnets. It's important that the ribbons can move freely; measurements indicate fastening the sides to increase mechanical stability also introduces distortion. Return conductors were made from burglar alarm tape and connected to the ribbons with one screw and washers.

Woofer impedance was  $0.6\Omega$ ; return conductors, approximately  $2\Omega$ ; tweeter impedance,  $0.4\Omega$  and conductor  $0.7\Omega$ . Since the tweeter was much more efficient than the woofer I damped the tweeter 18dB with a  $1.2\Omega$  resistor. I used a simple 6dB crossover network: coil,  $0.40\text{mH}$ ; capacitor,  $136\mu\text{F}$  (polypropylene); crossover point 800Hz.

**CONCLUSIONS.** My most merciless critic, my wife, and I agree there is almost no coloration from resonances in the baffle, because the ribbons don't pull very much compared to the "sail" of the planar woofer. So the thin chipboard is quite stiff enough. There is air, openness, perspective, fast transients, a world of inner details and a very clean bottom.

There are some drawbacks. These speakers are horribly inefficient. It hasn't been measured, but subtracting 18dB from the speakers (about 75dB) is probably close. The very low impedance makes it hard on the amplifier. I have found my amplifier, Audio Mirror, constructed by Karsten Svendsen, a tube MOSFET design of 150W, can easily cope.

Furthermore, these speakers cannot play very loud, but are quite sufficient at "normal" listening levels in my listening room. If I increase volume the ribbons move outside the controlling magnetic field. I should add, I prefer chamber music and music with acoustic instruments. Orchestral music does not sound as well with these speakers, so far.

Finally, they *are* easy to build, but need some maintenance. The corrugation on the woofer ribbons stretch because of the movements and must be redone after approximately 100 hours of play. Otherwise the sound tends to break up, rattle and buzz in a rather nonmusical and commanding way. This can be done without removing the ribbons from the chipboard, with care.

**FURTHER WORK.** Do not place the woofer magnets on the steel sheet but use the horseshoe method described previously. Experiment with less distance between the magnets, and narrow the width of the woofer ribbons. This makes the magnets more prone to twitch and turn while working; find some compromise.

Inner damping is essential to avoid rattling and buzzing. A thicker aluminum foil, up to  $20\mu\text{m}$ , might work better. The burglar alarm tape might be good for the ribbons because the inner damping seems very good when it works as tweeter, but I haven't tried it yet as a woofer. It is almost  $50\mu\text{m}$  when placed on the roasting film. You might want to work with the laminates. The  $9\mu\text{m}$  aluminum laminate had a tendency to lose its corrugation too quickly, when working as a woofer.

These line source speakers don't spread the sound very well; horizontally better than vertically. If you stand up in the listening position in front of the speakers the higher frequencies disappear. You can avoid this by making the ribbons taller. Horizontally you have to avoid "beaming," when the sound does not spread from a wavelength equal to the width of the ribbon (or the combined width of the woofer ribbons). With the 1.5cm tweeter, beaming should not occur before 20kHz. The woofer is 32cm wide and beaming is expected from 1kHz. The crossover point was chosen below the beaming point, however the woofer rolls off from 800Hz with 6dB/octave and isn't exactly silent beyond the beaming point.

You might want to experiment with the position of the woofer ribbons relative to each other. The Martin Logan electrostatic speakers could inspire more ideas. The ribbons could be angled relative to each other to form an approximation of a section of a large cylinder. This ought to help on the beaming problem. If you want to make a one-way ribbon speaker and avoid the crossover network this angling is essential. I haven't tried it yet but it's on the agenda.

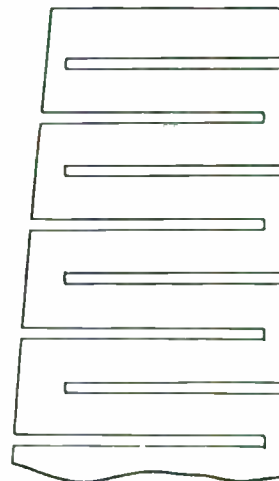


FIGURE 9: Alternative conductor 1.

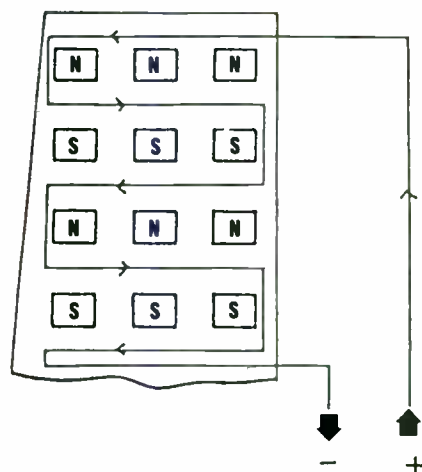


FIGURE 10: Alternative conductor 2.

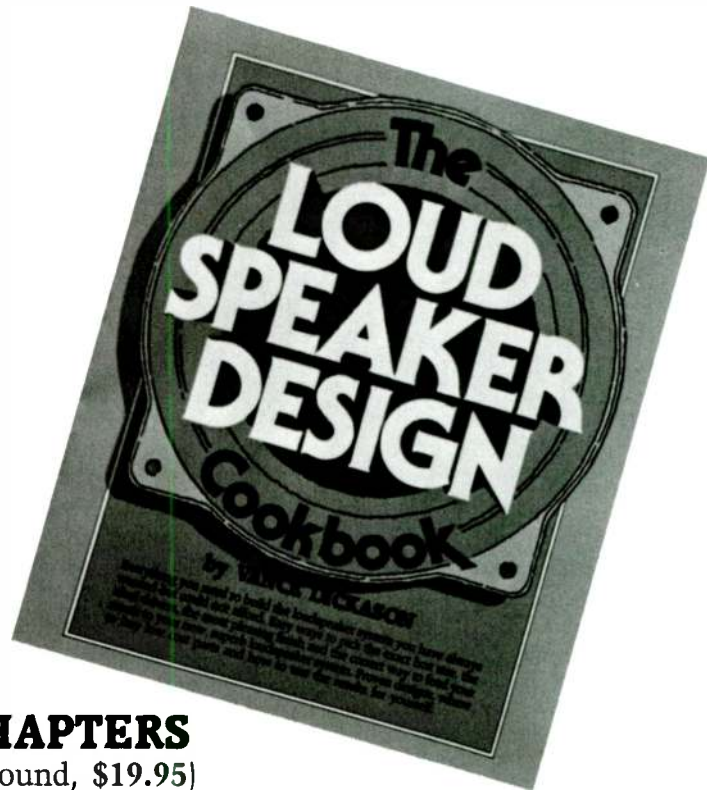
gether and use 3mm sheet steel to keep the magnets apart. If you leave the magnets further apart you must place, for instance, four alutape conductors between two rows of magnets, all having the current flowing in the same direction and all changing when the magnetic field changes. The conductors must be placed on the membrane and the "turnings" must be kept at a distance from the magnets.

You can also make your own tape by cutting strips from ordinary kitchen aluminum foil and gluing the strips to the membrane with thinned contact glue or spray glue (Photomount from 3M, for example—with adequate ventilation).

A third possibility is to etch the conductor pattern on a laminate of polyester and aluminum foil. These industrial laminates are used for wrapping candy, coffee bags, and so on. They might be

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difficult to buy. I managed to obtain a suitable supply: 12 $\mu$ m polyester, 2 $\mu$ m glue and 9 $\mu$ m aluminum foil.

The etching follows ordinary "print technique." Cover the conductors with tape, and ink or paint whatever is not attacked by the etching fluid. Use a thin solution of ferric chloride, one-third of the strength used for copper print plates (ask a local electronics dealer). Stretch the membrane on a piece of chipboard with wooden strips around the edges, seal the inside and pour a thin layer of solution on the membrane. Move it a bit and your conductor pattern will be ready in one hour.

As another possibility, cut slices across the laminate or foil to split the conductors. Close the slice with thin tape (tape recording splicing tape). The laminates are easy to work with; foil is more delicate.

4. Cable connections. It is advisable to use cable instead of aluminum tape outside the magnetic field. Keep in mind when you change the conductor pattern—the impedance, and consequently the crossover frequency compared to the original loudspeaker change when you use cable. Therefore you have to change the component values in the crossover network. At the same time the efficiency of the loudspeaker improves since it draws more current from the amplifier when the impedance is lower:

$$\text{capacitor} = 157 \div (\text{Hz} \times \text{tweeter impedance})$$

$$\text{coil} = \text{woofer impedance} \div (6.28 \times \text{Hz})$$

It is not a good idea to make the impedance more than 4 $\Omega$ , since most amplifiers lose power, except in exotic cases such as the Futtermann, where 16-30 $\Omega$  is preferable. Since the loudspeaker has no ugly phase shifts, it is easy to drive.

5. It's a good idea to arrange the system of magnets so you can experiment with the distance between the magnets and the membranes, especially the woofer membrane.

**FINAL HINTS.** Try to find a better stretching system. Mine has a tendency to lift the membrane where it is fastened.

Experiment with the distance between the woofer and tweeter and any phase problems. I have noticed a small valley in the frequency curve, 2-3dB, in the 2kHz-5kHz region.

I implied a rule of thumb regarding the resistance in aluminum foil: 18m by 9mm by 30 $\mu$ m has a resistance of 3 $\Omega$ . Since the resistance is directly proportional to length (L) and inversely proportional to width (W) and thickness (T),

you can calculate the resistance of any conductor made from aluminum foil. For example, using a conductor on the woofer, 10m by 4cm by 11 $\mu$ m, your resistance is now:

$$(L2 \div L1) \times (W1 \div W2) \times (T1 \div T2) \times 3 =$$

$$(10 \div 18) \times (0.9 \div 4) \times (30 \div 11) \times 3 = 1\Omega$$

Different size speakers can be built by keeping the same rough proportions of the woofer, 3 by 4 by 13. Bigger speakers are probably more efficient. The proportions and trapezoid form are open to experiment. Does the speaker have to be flat? Why not cone shaped, cylinder shaped, or a broad ring hanging from a ceiling? You can use different sized rib-

bons or a few or several single ribbons. These ideas are open for experimenting. You can use the same magnets in endless rebuildings.

An interesting possibility is using the planar woofer as a subwoofer for other speakers, for example Quad ESL 63, since this planar woofer matches the 63's sound quality better than do dynamic woofers.

#### ACKNOWLEDGEMENTS

*I would like to thank my good hifi friend, wizard-of-the-tubes, Karsten Svendsen, who besides building amplifiers that survive playing into 0.1 $\Omega$ , has advised me throughout this project.*

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# THE SHORTLINE: A HYBRID TRANSMISSION LINE

BY JOHN COCKROFT

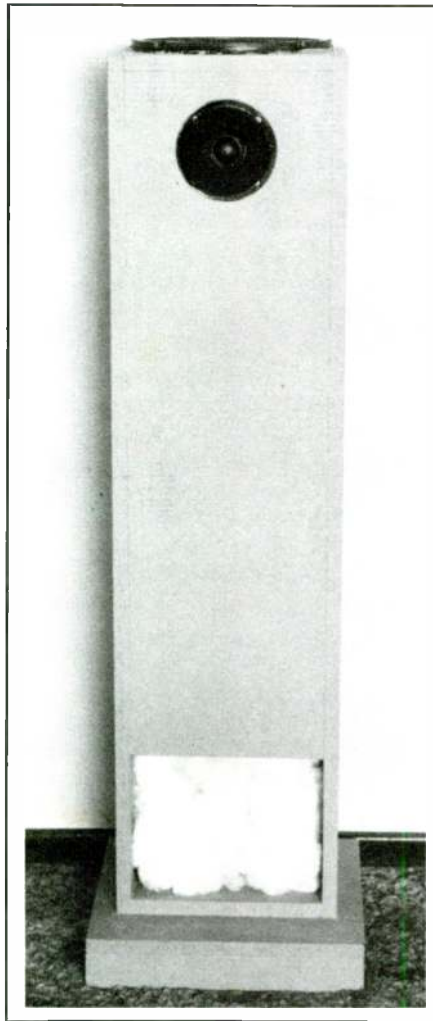
The Shortline (Photo 1) is a variant transmission line loudspeaker system designed to compete directly with typical box systems, both in size and in frequency response. In the eyes of most people, the transmission line speaker system represents a large, bulky structure capable of delivering extended, low bass. This is by no means the only form that a transmission line speaker may take, even though it is the ultimate presentation. Aside from producing deep bass response, the transmission line is justly known for its smooth, uncolored response in the upper bass regions and its excellent transient response, due to its essentially non-ringing enclosure.

Because I live in a small apartment complex, a large enclosure with ultra-low bass is not the most practical musical solution. Having become entranced with the sound of transmission lines, however, I was not ready to give up. The solution to my dilemma was the Shortline.

**DESIGNING THE SYSTEM.** In a normal transmission line system, the damping material is usually installed at a density of about ½ pound/cubic foot. I decided that if I wanted to shorten the line, I would have to increase the density of the material to achieve a similar attenuation of the backwave.

I arbitrarily decided on a 3-foot enclosure to be set on a base that would hold the necessary crossover parts and prevent the tall slim enclosure from tipping over. To couple the speaker to the room, I applied Roy Allison's principle<sup>1</sup> of using an upward facing speaker close to the rear wall (as exemplified in his models 4, 6, 7 and 8). This design concept produces an extremely smooth and substantial bass line, further enhancing the transmission line's inherent qualities of smoothness and depth.

The Shortline enclosure has a center-



**PHOTO 1:** Notice the Shortline's proximity to the rear wall. This is necessary to achieve the proper interface between the speaker and the room.

line length of 36⅞ inches. This is considerably shorter than most lines I am aware of. Because of the Allison configuration, the rear face of the Shortline must be as close to the rear wall of the room as possible, about ¼ to ½ inch.

Because of this, you should examine the proposed location of the system to make sure no high baseboards, or other obstructions prevent meeting this condition. In extreme cases, you may have to redesign the base of the enclosure to allow the speaker back to be close to the wall.

It recently occurred to me that these short lines, which incorporate higher-density acoustic damping material, might function as a hybrid manifestation of A.R. Bailey's transmission line<sup>2</sup> and aperiodic, pressure-relief enclosures such as the old Dynaco A-25 and more recently Irving Fried's Beta and Studio IV systems. My short lines (I have a Microline that is even shorter than the Shortline) perform like stuffed boxes with the bottoms left off, but they sound like true transmission lines, with a smooth, extended bass and without the midbass hump so characteristic of boxes.

**SHORTLINE vs. COX TRANSMISSION LINE.** Because the line lengths were similar, I compared the Shortline to Thomas Cox's experimental 39-inch line ("An Experimental Transmission Line," *SB* 4/85, p. 9). For this purpose, I installed a Radio Shack 40-1011 6½-inch speaker in the Shortline because the Cox line used 6½-inch speakers. This particular 40-1011 has a free-air resonance of 44Hz at 59.8Ω, similar to that of two of the speakers Cox tested. The measured  $Q_{fs}$  was 0.66.

Cox used a stuffing density of 0.5 pounds/cubic foot, while I used a density of 0.957 pounds/cubic foot. He obtained the following impedance peaks which he termed (Ph) "upper peak" and "lower peak" (Pl). For the two speakers closest to mine, the Peerless TP165F and the Speakerlab W618P, he obtained Pl=37Hz, Ph=98Hz and Pl=43Hz, Ph=

100Hz, respectively. The Shortline has a Ph of 71Hz, with a magnitude of 15Ω. I couldn't locate a lower peak. The Shortline also seems to have done better than the Madisound 6102, which had a Pl of 26Hz and a Ph of 93Hz. [This speaker had an Fsa of 31Hz and a Qtc of 0.39.]

To see whether I could find a lower peak, I removed some fiberfill, about the size of a volleyball. I found a lower peak at 27Hz which measured 22Ω. The upper peak moved to 81Hz. (I forgot to record the impedance.) I then replaced the fiberfill, as I liked the sound better with it installed.

Cox does not mention the impedance of his peaks, but based on their location only, the Shortline seems to have a slight edge (in this particular test). I have no idea how this test relates to the actual sound of a transmission line speaker system on program material.

I then compared the Shortline to the 54" Cox line. The Peerless speaker had peaks of 37Hz and 70Hz, while the Speakerlab unit showed peaks of 38Hz and 75Hz. The Shortline still appeared to be in good company, so I looked at the 71" Cox line (SB 4/85, p.11). Here I was getting in up to my shoulders. The Peerless unit peaked at 33Hz and 58Hz, giving way to the Speakerlab unit, which sported a disappearing lower peak and a Ph of 64Hz. The Madisound speaker peaked at 22Hz and at 54Hz.

I then put the 8" speaker back into the Shortline (Radio Shack 40-1021) and ran the same tests with it. I obtained an impedance peak of 7.9Ω at 76Hz. Since the general impedance around this point was 6.5Ω to 6.8Ω, it seems silly to call it a peak. I could not locate a lower peak. By removing 153 grams of fiberfill (about 5.4 ounces), I noted a rise to 7.1Ω at 22Hz, or 23Hz, up from a general level of 6.9Ω in the 10Hz-30Hz range. Ph rose to 86Hz at 7.8Ω.

I replaced all the fiberfill except 62 grams (2.2 ounces). I decided to try the Shortline with an even 16 ounces of fiberfill to see whether I could eliminate the troublesome chore of weighing out the stuffing. (Fiberfill comes in 12-ounce or 16-ounce bags. Make sure you get a 16-ounce one.) This gives a density of 0.84 pounds/cubic foot in the Shortline. To calculate the density, merely divide the weight of the stuffing by the volume of the enclosure, in cubic feet. The internal volume of the Shortline is about 1.19 cubic feet. With this density, I again could find no lower peak; Ph was 83Hz at 8.1Ω.

Elsewhere in his article, Cox states that he attempted to match his speakers to

an optimum line length based on the speed of sound. Since the purpose of the line is to attenuate the backwave of the speaker and to damp the impedance peaks, it seems to me that the line with the lowest impedance for the peaks would be the one that approaches the optimum.

**DISTINCTIVE SOUND and LOOK.** I am sure most people who are familiar with and enjoy live music will find the Shortline to their liking. If it is lacking in the deepest bass, this certainly is not noticeable on most material. In fact, the few Telarc CDs I have (mostly organ music) sound quite authentic. I found the last two movements of the Berlioz "Symphonie Fantastique" particularly impressive. The Shortline is right at home with large musical masses, both orchestral and choral. It is definitely a musical speaker.

I do not know what rock 'n' rollers will think about it. It does not have the hump in the midbass or the sizzling highs of the "California sound" type of speaker. It will, however, record ver-

batim the built-in distortions of the music as it is played, without adding any additional distortion of its own.

Aside from its reasonable size and fine musical qualities, the Shortline has a distinctive look that takes it out of the "just another box" class. The straight line (except for the final 5 inches, or so) creates a minimum of reflection problems, while the generous cross-section of the line minimizes back pressure, even with the increased density of the acoustic material. The straight design also makes it relatively easy for you to reach in and adjust the packing.

It is quite unusual for such a sophisticated system to offer such simple construction and to be so kind to the pocket-book. A Shortline could be constructed from scratch for as little as \$70.

**CONSTRUCTION DETAILS.** The construction of the Shortline is simplicity itself. The material used is 5/8 inch particle board shelf material from K-Mart and white glue. Cut out all the pieces, including the stiffeners and the base parts, before assembly (Figs. 1 and 2). It

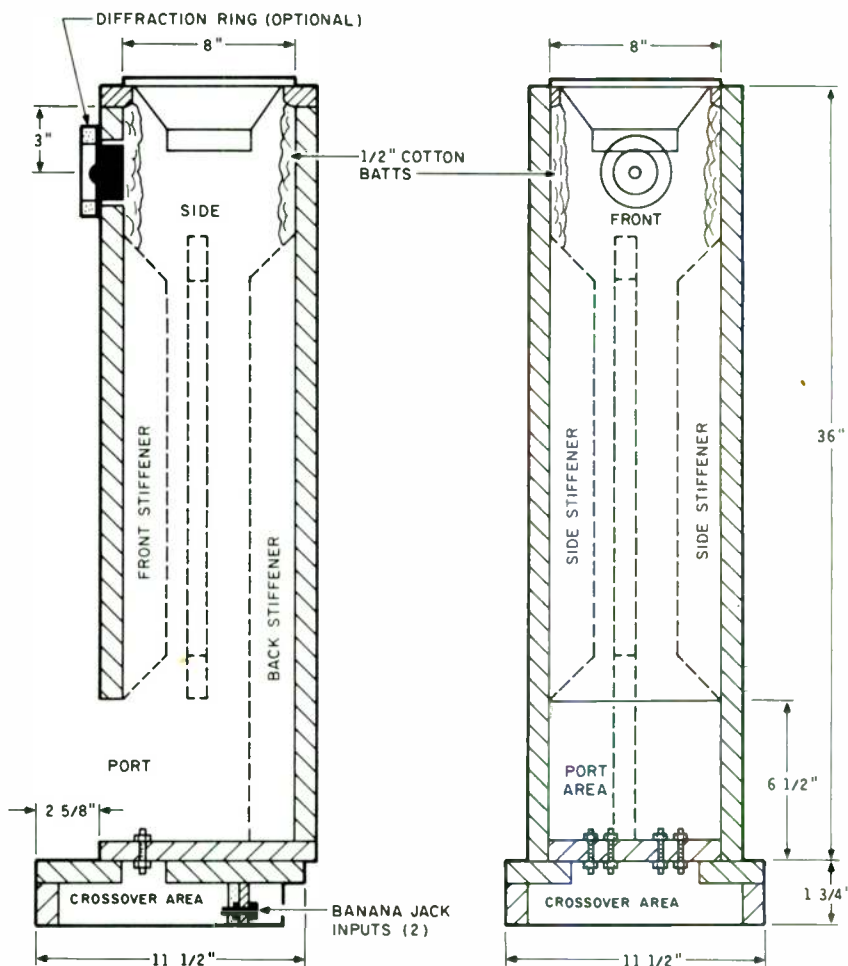


FIGURE 1: Front and side views of the Shortline.

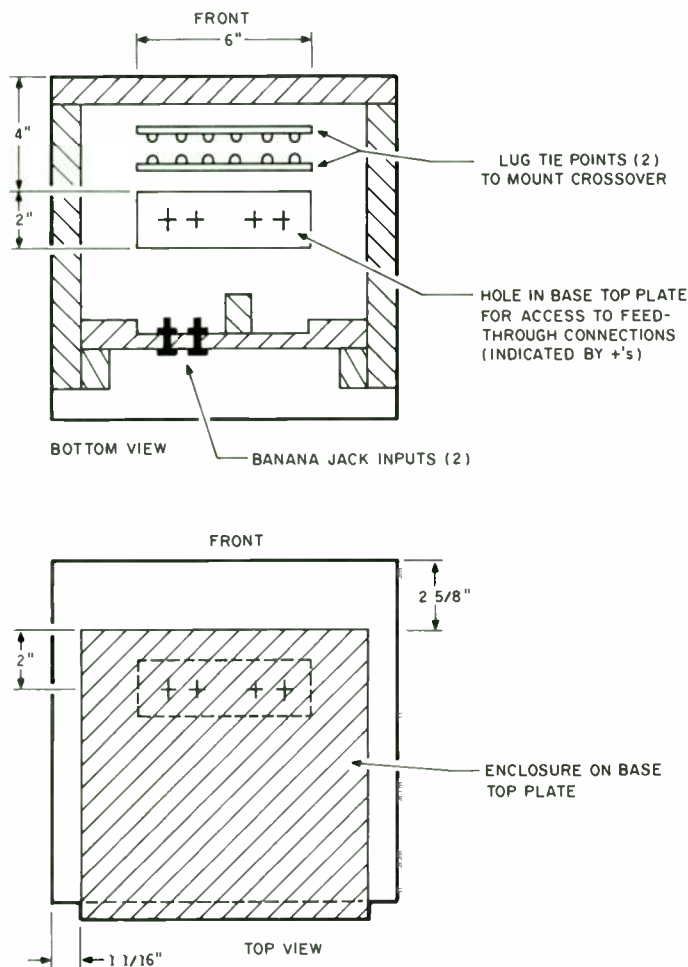


FIGURE 2: Base details of the Shortline.

is best to try to fit them together ahead of time to make sure everything is okay. You may cut holes for the speakers now, but I recommend cutting them when the enclosure is partially finished. This gives you something to grab while cutting. For added strength, all joints should be preglued on both surfaces before assembling. Simply brush on a coat of glue with a paste or acid brush and allow it to dry. In a pinch you can smear the glue on with your finger tip. When the glue has dried, proceed with assembly.

I do not use nails or screws in my assemblies, but feel free to do so if you wish. I rely on square joints and pregluing, and I use weights and fixtures to keep things in alignment. I then go back two or three times, brushing additional glue on all the joints. I make a glue film about 1/4 inch wide on each side of the joint.

Assembly begins with gluing the enclosure top to one of the sides. This is followed by adding the front, the rear,

and the bottom. If you are nailing things together, it might be better to fasten the stiffeners to the panels before gluing them in place. Otherwise, you can add them now, after the assembly has dried. Their placement is not critical, but they should go near the center of the panels, not right at the center. This helps to randomize enclosure vibrations.

Now is the best time to cut the holes for the speakers and to glue the remaining stiffener to the other side panel. Then go back and re-glue all the joints made so far.

Drill four holes in the bottom panel for the feed-throughs, which can be 10-32 brass machine screws or lengths of the same size threaded rod. Use whatever is handy for you or suits your style. Prepare the speaker leads (Fig. 3). For the tweeter, use 16-gauge zip cord. For the woofer, use double 16-gauge zip cord. That is, use a piece of zip cord with both leads twisted together at the ends for each leg of the woofer hookup. The best

way to do this is to strip both leads at each end. Then wrap one lead tightly around the other, leaving about 1/2 inch of a single side remaining at each end. Solder the twisted wires and tin the single stubs. This arrangement allows for easier connection to small speaker lugs. The speaker leads should be long enough to extend several inches beyond the top panel of the enclosure. Tape all four of the wires together at this time and bring them out of the woofer hole so they will not get in the way (Photo 2).

Line the upper part of the enclosure (above the stiffeners) with about 1/2 inch of surgical cotton, stapled or glued (Fig. 1). At this time, only three of the sides are attached, but I used one long piece of cotton and folded the loose, final end over the fiberfill just before I glued on the remaining side.

Stuffing the Shortline requires one 16-ounce bag of fiberfill pillow stuffing, available where sewing materials are sold. I used a brand called Thermo Stuff, distributed by American Fiber Industries of Los Angeles (no local address given), but in the past I have used other brands with equal success.

Spread some newspapers on the floor and dump the stuffing onto them. Begin to pull the material apart with your fingers, tearing apart all the lumps and teasing it to a loose mass that is relatively even in texture. When it is fluffy and unpacked, it is ready to install.

Lay the enclosure horizontally (on its side) on a bench or a table, lay in the stuffing, using a light touch. Try to place it in as evenly as possible. Make sure there are no large gaps under the stiffeners. Fill the whole line, right over the cotton. Later, when installing the woofer, press down the filling a little to make room for it.

Using the point of a pencil, make two holes in the cotton batting behind the tweeter hole and bring the tweeter leads out through them. All four leads should be marked for the correct polarity and for the speaker to which they connect. Note that in this design, the tweeter polarity is reversed (the negative terminal of the tweeter goes to the positive wire).

When the Shortline is stuffed to your satisfaction, fold over the cotton flap (or add a separate piece), then lightly press the stuffing down away from all areas that will be glued. Place a generous 1/4-inch bead of white glue on all the upper edges of the enclosure and set the final side in place (These areas should have been preglued.) It will be messy, but get things in place and weighted (or

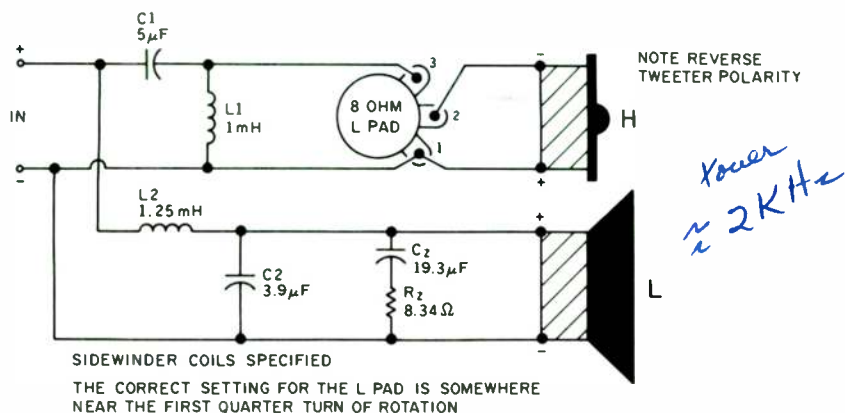


FIGURE 3: Shortline wiring details.

nailed) before cleaning off the excess glue with a damp tissue. Let the structure dry for several hours, preferably overnight.

While the enclosure is drying, you can assemble the base. Preglue all the parts. When the enclosure is dry, set it in position on the bass and scribe a pencil line around it (Fig. 2). Put a generous amount of white glue inside the pencil line and set the enclosure on the base. Line it up and remove any excess glue. Wait a couple of hours, then apply a second coat of glue over the joint line. Let the Shortline stand overnight. If you are impatient, you can start on its twin.

The following morning, or whenever it is convenient, stand the Shortline on its head and install the crossover parts (Photo 2). I used a couple of 4-lug tie points to make the job easier.

Turn the Shortline upright and poke the speaker leads down into the box. Place the woofer in position and mark the location of the mounting screw holes. Drill pilot holes about  $\frac{3}{32}$  inch for the #6 by  $\frac{3}{4}$ -inch panhead sheet metal screws. It is best to drill a hole in a piece of scrap wood first and test a screw. It should not be too tight but should feel as though it is gripping the wood. Repeat the same procedure for the tweeter.

Now connect the proper wires to the tweeter. In this case, that means reversing the tweeter leads—i.e., the negative lead goes to the positive terminal of the tweeter. The system sounds better when this is done. After connecting the wires, run a small bead of Duxseal (about  $\frac{1}{8}$ -inch diameter) around the back of the speaker flange at a place where it will contact the wood surrounding the hole in the enclosure but will still be inside the pilot mounting holes. You may also

use Mortite caulking. Press the bead lightly so it will stay in place when the speaker is turned over for mounting. Tuck the extra length of wire back into the hole where it will be out of the way. Make sure the stuffing is pushed in so it will not interfere with the Duxseal. Place the speaker over the hole and line it up with the pilot holes. Press the

speaker in place with a slight twisting or rocking motion to ensure a satisfactory seal. Keep your fingers curled around the blade of the screwdriver to prevent it from slipping off the screw heads and damaging the speaker.

After the tweeter is mounted, use the same procedure to mount the woofer. (Do not reverse the leads.)

**FINISHING TOUCHES.** It is desirable to mount a diffraction ring on the front of the tweeter (Fig. 1). These are available commercially, but I haven't seen them advertised recently. The sources might still offer the rings or have some old stock lying around. (Audio Concepts, 1631 Caledonia St., La Crosse, WI 54602, (800) 346-9183, sells a  $\frac{1}{8}$ " felt tweeter ring.—Ed.)

Actually with the current tweeter in the Shortline the necessity of a diffraction ring isn't as pressing as it was when I used the Radio Shack 40-1376, which has an extremely wide radiation pattern. In that case it was required to control both diffraction and room reflection (at least in my room). Later when I installed the Audax HD100D8 tweeter I used a ring as a matter of course. More recently,

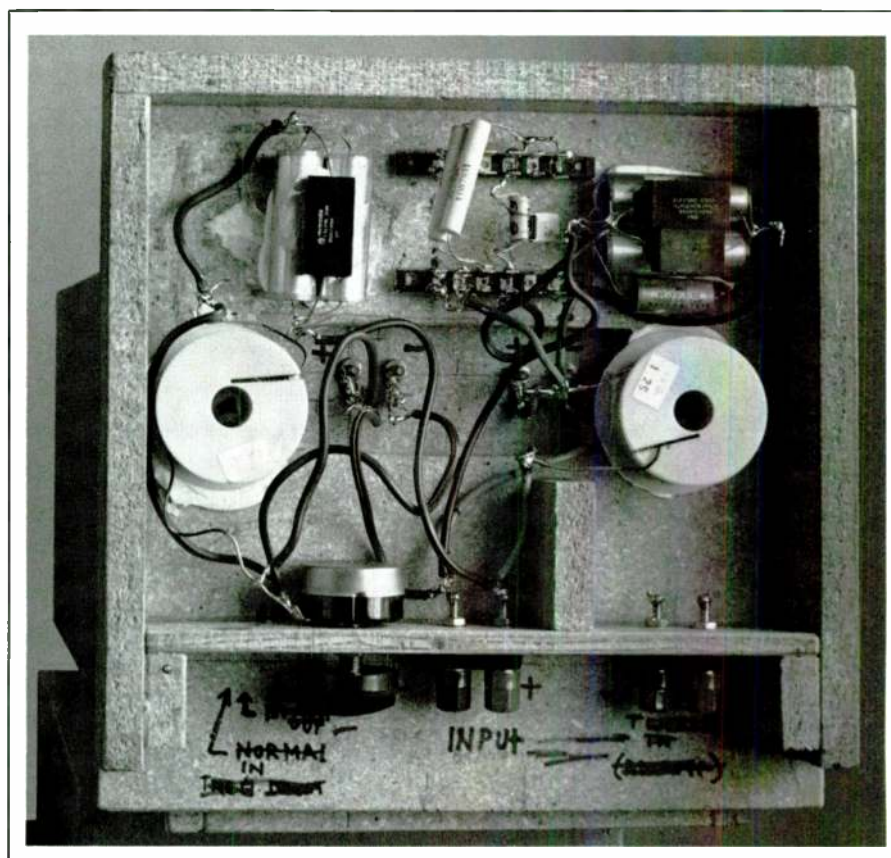


PHOTO 2: Base construction and wiring details. The additional inputs aren't required. They remain from previous bi-amp testing. Making the base deep enough, so that one of the coils could be mounted on a side wall, may reduce inductive problems.

## PARTS LIST

The enclosure and base are  $\frac{5}{8}$ " particle board. I used (4) 4-foot shelf boards.

- 2 9 $\frac{1}{4}$ " x 36" sides
- 1 8" x 34 $\frac{3}{4}$ " back
- 1 8" x 28 $\frac{1}{4}$ " front
- 2 9 $\frac{1}{4}$ " x 9 $\frac{1}{4}$ " top, bottom
- 3 1 $\frac{3}{4}$ " x 21 $\frac{1}{2}$ " front and side stiffeners
- 1 1 $\frac{3}{4}$ " x 28" back stiffener
- 1 11 $\frac{1}{2}$ " x 11 $\frac{1}{2}$ " base top
- 1 11 $\frac{1}{2}$ " x 1 $\frac{3}{4}$ " base front
- 2 10" x 1 $\frac{3}{4}$ " base sides
- 1 10 $\frac{1}{4}$ " x 1 $\frac{3}{4}$ " base back
- 3 1 $\frac{3}{4}$ " x 1" base cleats
- 4 feedthroughs. May be 10-32 x 1" brass machine screws, or 1 $\frac{1}{4}$ " lengths of brass threaded rod, with nuts, lugs and washers.
- 2 input connectors. I used banana jacks.
- 1 16 oz. package polyester pillow stuffing
- 1 package surgical cotton, or non-sterile household cotton
- 1 Radio Shack 40-1021 8" polypropylene woofer, don't substitute
- 1 Audax HD100D8, or Peerless K010DT8 1" dome tweeter (don't substitute unless you are prepared to rework the crossover.)
- 2 4-lug tie points
- 8 #6 x  $\frac{3}{4}$ " sheet metal screws for speaker mounting
- 1 diffraction ring (optional)
- 1 8 $\Omega$  L-pad Radio Shack 40-980 or equivalent.
- 1 1.0mH air-core coil Sidewinder brand, (no substitute)
- 1 1.25mH air-core coil Sidewinder brand (no substitute)
- 1 5 $\mu$ F Mylar capacitor (C1)
- 1 3.9 $\mu$ F Mylar capacitor (C2)
- 1 19.3 $\mu$ F Mylar capacitor (Cz) (this may be fabricated from a 15 $\mu$ F, a 3.3 $\mu$ F and a 1 $\mu$ F capacitor in parallel.)
- 1 8.34 $\Omega$  resistor 10W or better (use a 10 $\Omega$  and a 50 $\Omega$  resistor in parallel. Madisound lists a 15W 8 $\Omega$  resistor which might work well.)

### Miscellaneous

16-gauge hook-up wire (zip cord), Mortite, or Duxseal caulking material for mounting speakers, white glue and finishing materials of your choice.

All capacitors 50V or better

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while working with another system which had the same relationship of tweeter, woofer and baffle, I discovered that the sound was quite good without the ring. Try it first without the ring, and judge for yourself. A Peerless K010DT8 may also be used without crossover modification.

There you have the Shortline. I did not say anything about finishing it, as I think most people have their own methods. For the best sound, do not put any heavy grille cloth over the speakers, especially the tweeter. An open-weave, such as the saran material some nurseries sell for shading plants might work well, but it is not particularly attractive. I have used lame, from a fabric store, but it is hard to find, except around Christmas. Most audiophiles will probably prefer to leave the speakers uncovered, or at least have a removeable grille for serious listening.

The box could be laminated with Formica®, or a similar plastic, or veneered. This should be done, of course, before mounting the speakers. It's easiest to paint the Shortline, as I have done. An additional refinement is to bevel, or round off the sharp edges and corners, to reduce the effects of diffraction. Don't round off the rear edges of the enclosure where it meets the wall.

For your first listening experience with the Shortline, pick something you know is well recorded and has a deep bass line. If there is no bass in the program there will be no bass to hear, as there is no false bass in the Shortline. Music that is not well recorded will not sound good, but excellent recordings will pleasantly surprise you.

Incidentally, the Shortline went through 16 variations of its crossover before I was satisfied. The present crossover is a second-order APC filter, which I think is a superior configuration. In the parts list I have specified Sidewinder coils for use in the crossover. I suggest they not be substituted, as other coils may not have the same DC resistance. In most cases you will find the correct setting of the L-pad to be within the first quarter of its rotation (from off). It is helpful to use white noise, or inter-station hiss from an FM receiver as an aid in adjusting the pad. I find most people tend to go overboard on the treble, which reduces the naturalness of the sound. ▶

### REFERENCES

1. Allison, Roy, "The Influence of Room Boundaries on Loudspeaker Power Output," *JAES*, Vol. 22, No. 5, June 1974.
2. Bailey, AR, "A Non-Resonance Loudspeaker Design," *Wireless World*, October 1965.

# AN ELECTRONIC TURNS COUNTER

BY FERNANDO GARCIA VIESCA

**W**inding their own coils is a task that many speaker builders tackle. Bruce Edgar (*SB* 1/87) describes a homebrew, yet efficient coil winder project. Though he used a mechanical counter in his project, an all-electronic counter may be used, such as the one described here. No fancy or esoteric circuit topologies are used; instead the circuit was designed with three features in mind: simplicity, versatility and low cost. Battery operation is possible due to the low power drain.

**THE CIRCUIT.** The first decision in such a circuit is to select a suitable transducer. I experimented with Hall effect sensors, but since my winder is motor driven, I experienced some magnetic noise problems. Therefore I settled for a slotted photo-interrupter.

The master board is shown in *Fig. 1*, where the light emitted by the light emitting diode (LED) shines on the photo transistor in the interrupter, (A1), yielding a logical low at its collector. Whenever the shutter interrupts the light beam, a rising-edge pulse triggers monostable multi-vibrator A2, which outputs a constant-width pulse. It serves to filter out possible multiple pulses at the interrupter's output. Pulse width is controlled by the R3/C1 time constant. The constant may be changed to suit your particular winding speed by altering any one of those components. Be sure however, to observe the following limits:

$$R3 > 5000\Omega$$

The constant-width pulse appearing at the monostable's output is fed to gating logic made by A3a, A3b and A3c. Whenever the Up/Down switch is closed, a pulse train appears at A3, pin 3, the opposite action yielding the pulse train at

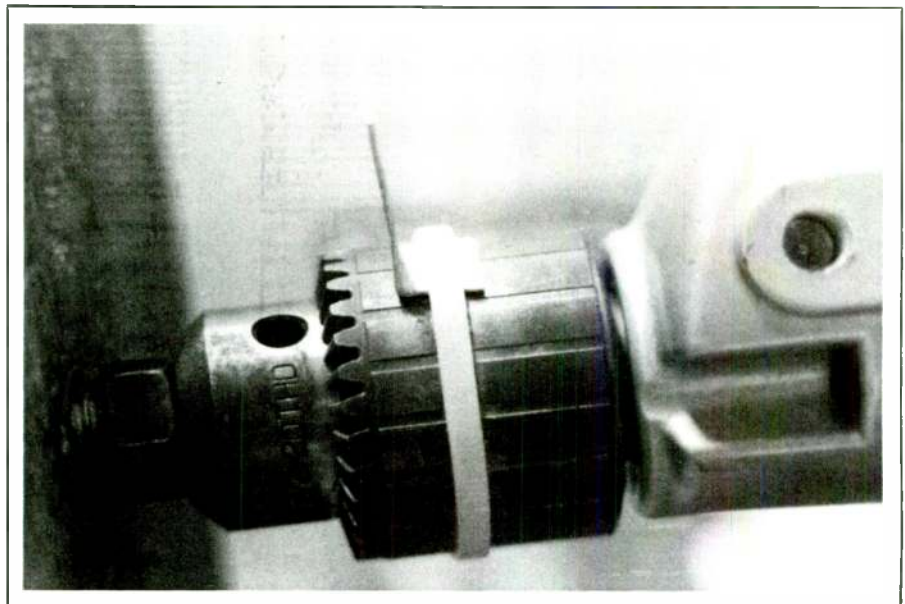
A3 pin 4. An optional motor reversing network, made by Q1, R6, D1 and K1, interchanges the field terminal of a series-wound universal motor, as shown in *Fig. 2*. This reverses the motor's rotation. You will find this motor in hand drills, sewing machines and other tools. Its high torque and easily controlled speed makes it an ideal candidate in a small winder. If you plan to add the motor reversing function, a little surgery in the motor's innards should be done. But if you use straight muscle power, those components may be deleted.

R4 and C2 make a power-on-reset network. This signal is inverted by A3d to be fed to the following counting stages. A manual reset is also provided by normally-open switch S2. The 12V power supply, a straightforward regulated design, is also included in this board. You'll have to furnish an external 12V

@ 500mA transformer, or nine series-connected D cells.

The V+, ground, clear, up-count and down-count signals from the main board are fed to the display board as shown in *Fig. 3*. Rather than offering you a fixed number of digits, I chose to have a self-contained counting and displaying board that can be daisy-chained with several identical boards to make a multi-digit counter.

The selected up-count or down-count signals are fed to their respective input pins in A5, a decade up/down counter. Its BCD coded outputs, Qa thru Qd are fed to A6, a seven-segment decoder with moderate current capability suited for 0.3" displays. A5 also provides carry (up) and borrow (down) signals. These are coupled to the next counting/decoding stage. By repeating this stage a number of times, we may have a several-digit



**PHOTO 1:** Aluminum sheet mounted on the chuck serves as shutter for the photo interrupter.

counter. For most practical work, four digits are enough.

**BUILDING IT.** We must build the shutter first; fortunately, this doesn't have to be fancy. Cut a strip of sheet aluminum from a beer can and paint it matte black. *Photo 1* shows the finished shutter mounted on the drill chuck. Proceed with building the electronic boards. Board layout is shown in *Fig. 4*, but other methods (i.e. wirewrap) can be used. Follow the usual handling procedures for CMOS circuits. Though the circuit is very simple, check everything twice before applying power. The supply transformer is externally mounted and may be of the wall plug variety. If you use batteries, delete D1 through D4, C4 and A4.

A note of caution if you plan to use a

### PARTS LIST

NOTE: Parts marked (md) are for motor driven winders, see text. Parts marked (#) should be deleted for battery operation.

#### MAIN BOARD

##### SEMICONDUCTORS

- D1-D4: 1N4001 50V, 1A, diode (#)
- D5: 1N4001 50V, 1A, diode (md)
- Q1: 2N2222 gen. pur. NPN trans. (md)
- A1: H13A1 Photo interrupter
- A2: CD4538 Dual Monostable
- A3: CD4011 Quad NAND gate
- A4: LM7812T 12V pos. reg. (#)

##### CAPACITORS

- C1: 0.22 $\mu$ F/50V disc
- C2: 0.1 $\mu$ F/50V disc
- C3: 0.22 $\mu$ F/50V disc
- C4: 470 $\mu$ F/25V alum. electrolytic (#)

##### RESISTORS

- R1: 560, 1/2W
- R2: 56k
- R3: 120k
- R4: 120k
- R5: 47k (md)
- R6: 1.5k (md)

All resistors are 1/4W unless specified otherwise.

##### MISCELLANEOUS

- K1: 12V DC coil 2P2T relay (md)
- S1: SPST rocker switch
- S2: N.O. Pushbutton

#### DISPLAY BOARD

##### SEMICONDUCTORS

- A5: CD40192 BCD Up/Down Counter
- A6: CD4543 Seven segment decoder-driver
- A7: MAN10A Seven segment, Common anode, 0.27" red display

##### CAPACITORS

- C5: 0.1 $\mu$ F/50V disc

##### RESISTORS

- R7-R13: 2.2k, 1/4W

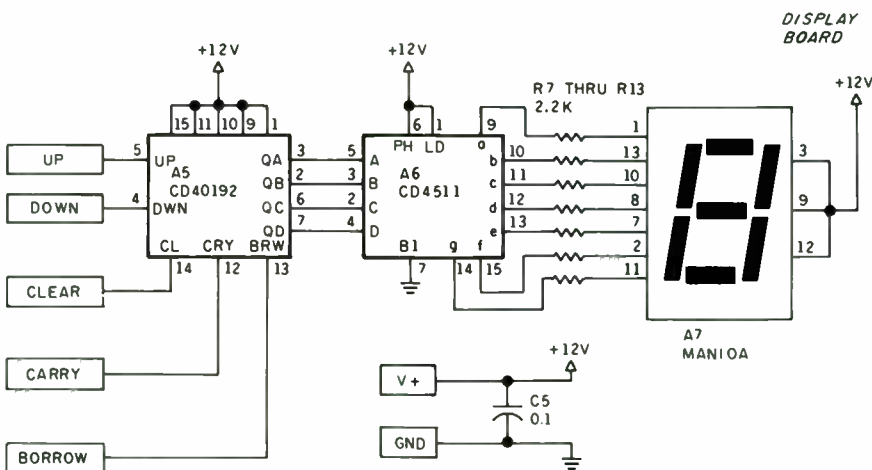
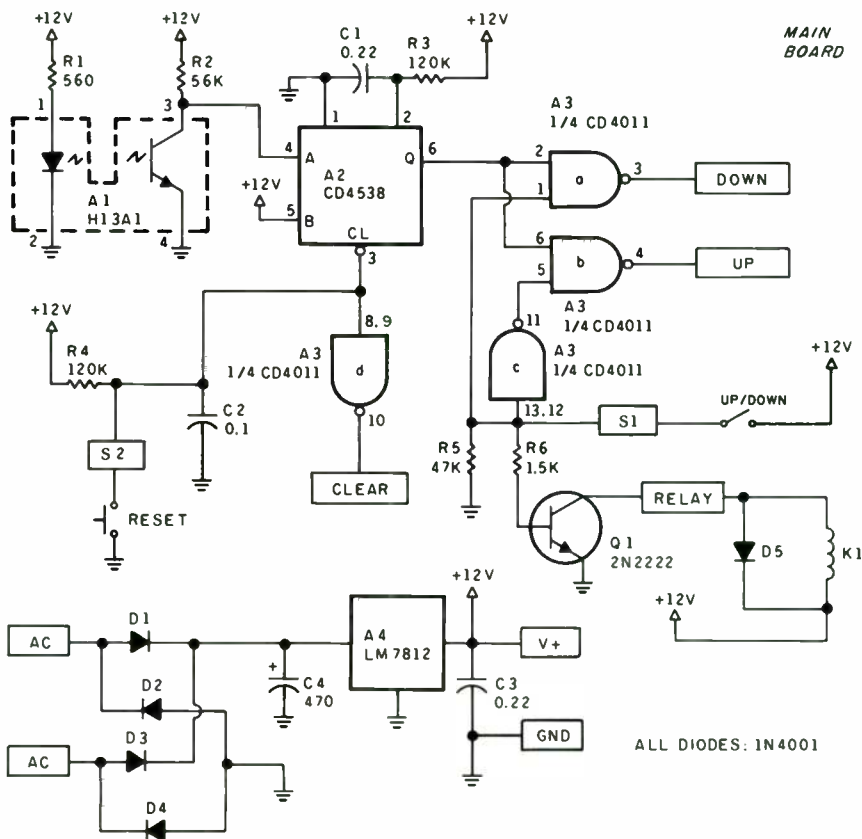


FIGURE 1: Main board and display board schematic.

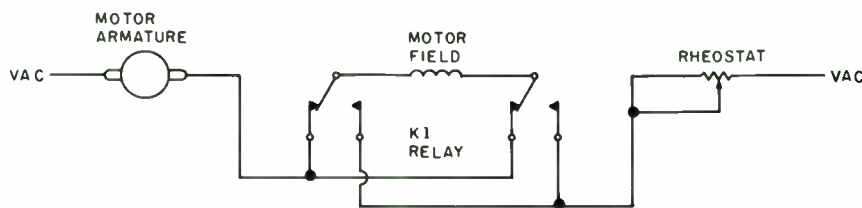


FIGURE 2: A universal motor's rotation may be inverted by exchanging the field wiring by means of relay K-1.

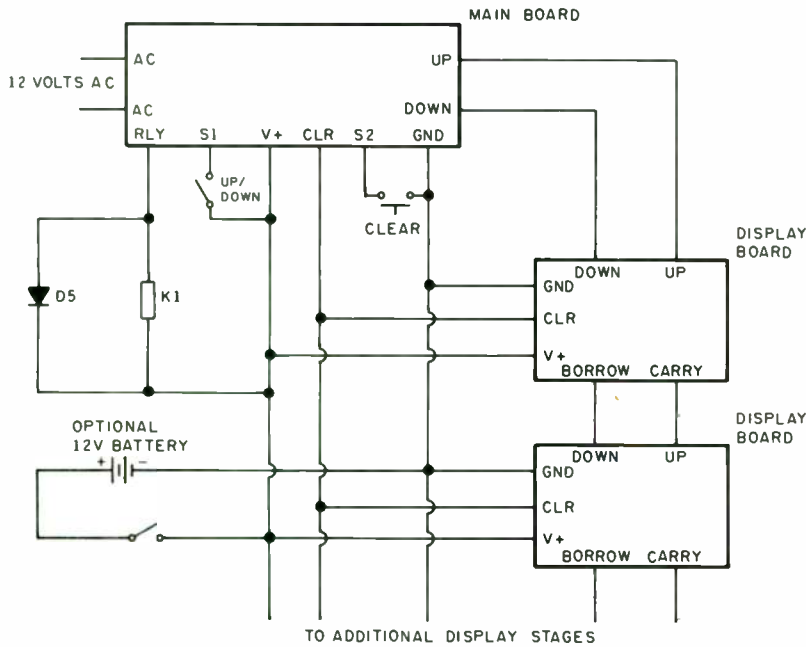


motor driven winder: As noted in Fig. 2, I used a rheostat foot pedal to control the motor's speed. Some may want to replace it with a solid state control using thyristors. The catch here is the excessive amount of electrical noise that may be fed to the counter via the power supply, with probable erratic behavior. If you plan to use such a circuit, design it with a filter.<sup>1</sup>

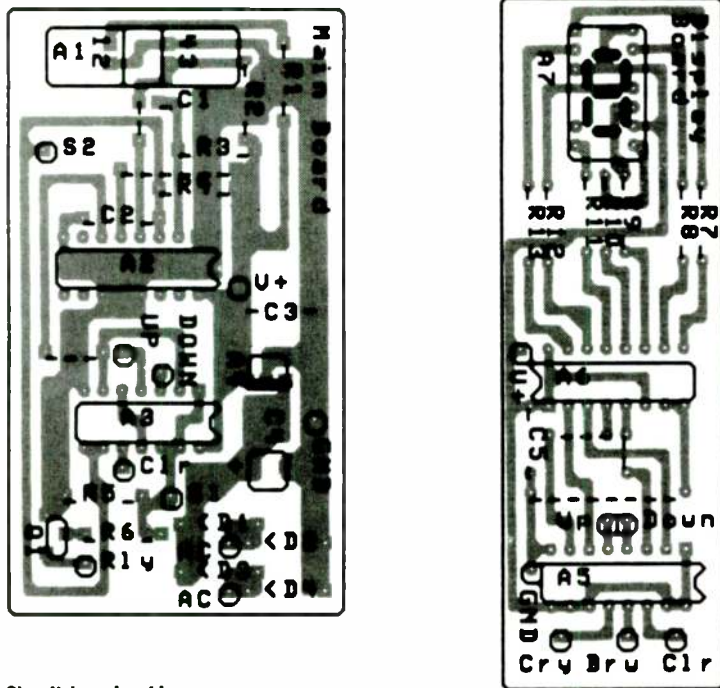
Anyway, it is wise to twist the motor supply lines together, and to use short and shielded wiring from the main board to the counter boards.

**REFERENCES**

1. *SCR Manual*, 5th Edition. General Electric Co., Syracuse, NY, 1972, pages 489-494.



**FIGURE 3: By daisy-chaining and cascading several display boards, a multi-digit counter may be built.**



**FIGURE 4: Circuit board guide.**

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# INCREDIBLE BASS PERFORMANCE FROM A TWO-WAY DESIGN

BY S. WAYNE COX and ROBERT G. PALMER

Initially, we conceived this loudspeaker design as a simple exercise to test the validity of Thiele bass reflex theory. Thiele calculated a series of alignments which can be used to reliably predict bass performance in loudspeakers, and which have of late become *de rigeur* in loudspeaker design.<sup>1</sup> We prefer bass reflex systems over closed-box designs, believing them to be inherently lower in bass distortion (and possibly lower in Doppler distortion, as a result) due to increased efficiency and better woofer damping. They also have an extended bass response when compared to closed box systems of similar size.<sup>2</sup>

The result of our labors is a finished loudspeaker system that has thus far exceeded all our expectations. After extensive testing and fine-tuning of the crossover network, which took nine months, this loudspeaker's full range sound now matches its excellent bass performance. We have produced an exceptional loudspeaker for under \$300/pair (materials only) as finished in an open-grained wood finish arborite or formica (Photo 1).

**THE DESIGN.** We used a 3" ID plastic pipe port in a fourth-order Butterworth alignment based on Thiele theory, in mirror-imaged loudspeaker pairs. The cabinet is constructed of ¾" high-density, white particle board, with heavy internal bracing (1½ by 1½") to control cabinet flexure and spurious resonances (Fig. 1). Removeable lycra spandex grilles feature bevelled inner frame edges to prevent unwanted edge diffraction. Grille boards are also used to achieve

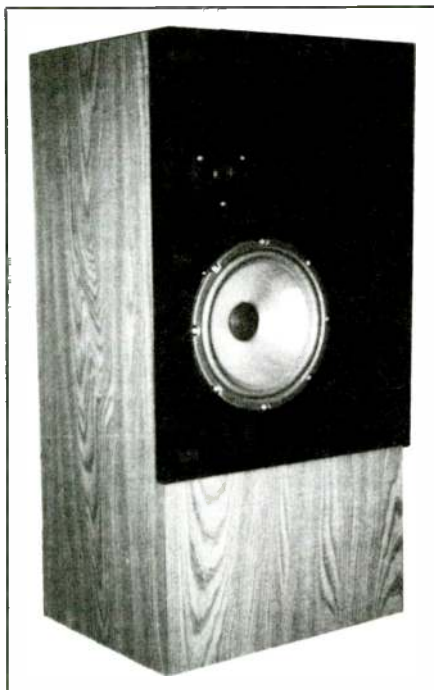


PHOTO 1: Finished two-way speakers.

flush driver mounting with grilles installed. (We prefer no grilles, since any material placed in front of a driver affects sound propagation.) The grilles are attached with velcro, although subsequent test models feature nylon grille pins and sockets.

Each completed system is quite large—18 by 13¾ by 35½" and weighs 75 lbs. We also built an alternate, taller configuration which is more economical of materials but has virtually identical performance (Fig. 2).

The drivers are Radio Shack's 10" polypropylene woofer (rated at 75W RMS into 8Ω, #40-8053, \$32) and the 1" Philips AD0163 T8 treated linen dome tweeter (rated at 20W RMS into 8Ω, \$20). The woofer parameters we used in cab-

inet design are those given in the specification sheet:  $f_s=27\text{Hz}$ ;  $Q_{ts}=0.38$ ;  $V_{as}=4.7$  cu. ft. (see Appendix 1 for calculations).

Small<sup>3</sup> notes that a 30% over volume added to calculated Thiele box volume ( $V_b$ ) achieves predicted bass performance. Because we used heavy internal stuffing (2" white, long-fiber Hollofil® polyester over back, sides top, bottom and front-to-back braces), we think this compensates for the over volume requirement.<sup>4</sup>

Optimal port length was 5.07" but we used 5¾" in case fine tuning dictated a change. We can easily shorten the port later if necessary, but it is cumbersome to lengthen it. (The 5¾" length proved ideal.)

The woofer used in this design has a nominal DC impedance of only 3.6Ω, rather than the 8Ω given in the specification sheet. Therefore, to wring the absolute best from this loudspeaker, we tried crossover components in several crossover configurations before we were satisfied.

We chose the Philips AD0163 T8 tweeter for its wide dispersion and flat frequency response, as well as its relatively low  $f_s$ . Efficiency also closely matched the woofer. We measured tweeter  $f_s$  (Fig. 3) and found it to be approximately 1,350Hz, in close agreement with Philips' value of 1,300Hz.<sup>7</sup> Our woofer test for  $f_s$  produced a figure of 26-28Hz, closely matching Radio Shack's data. We needed a tweeter with an  $f_s$  this low since we wanted an acoustic cutoff frequency of 2kHz. In the final crossover this consideration is paramount, as the acoustic cutoff frequency is approximately 1.5kHz.

**THE CROSSOVER.** Problems with rolloff slopes and phase can occur<sup>5</sup> in the critical crossover region unless we take

## ABOUT THE AUTHORS

Mr. Cox has a B.S. in Biology and is employed by the British Columbia government. Robert Palmer is a certified carpenter. The authors are presently working on several two- and three-way designs, using a variety of woofers and tweeters.



## Model 24CX-2

STEREO 2-WAY ELECTRONIC CROSSOVER



### Electronic Crossovers 24CX-2 Stereo 2-Way 24CX-4 Stereo 3-Way

- 24CX-2 is used for BI-AMP and the 24CX-4 is used for TRI-AMP systems or surround sound bi-amp.
- 4th order State Variable Linkwitz-Riley Filter design. All outputs in phase at crossover point.
- 24dB per octave crossover slopes for greater driver protection than with 12db and 18db per octave types.
- Flat summed electrical response throughout the crossover region.
- Zero lobing error (polar pattern tilt) throughout the crossover region.
- Automatic 3-way operation on Models 24CX-2 and 24CX-4 or independent two or four channel 2-way operation.
- Integral security cover.
- Polypropylene capacitors are used in the signal path, active filter section, and even the power supply.
- The input/output connections used are high reliability 2mil GOLD phono plug connectors.

24CX-2/4 electronic crossovers represent the latest in state-of-the-art design and manufacturing technology. Innovative electrical and mechanical design concepts and implementation have resulted in a product of superior performance expected of units selling up to several times the 24CX-2/4 price.

A 4th order Linkwitz-Riley type of crossover does **not** guarantee flat summed response. Flat summed response of the low and high frequency outputs of the 4th order Linkwitz-Riley crossover is made possible by using precision 1% metal oxide film resistors, selected capacitors, and the industry's only precision matched and selected 1% four-gang Frequency Range potentiometer. No matter where the control is set, you will get flat summed response, not just the end positions where some products are specified. High Slew-Rate, Low Noise, Bi FET operational amplifiers guarantee the finest in sound quality and overall electrical performance.



#### SPECIFICATIONS

- Crossover Filter Type**  
4th Order Variable Linkwitz-Riley design, 24 db/octave slopes.
- Frequency Range**  
x1 60 Hz to 700 Hz  
x10 600 Hz to 7.0 kHz
- Slew Rate**  
 $R_L = 2$  kohms 9 v/usec.  
 $C_L = 0.01$  uFd + /-2.5 v/usec.
- Total Harmonic Distortion**  
 $R_L$  2 k ohms  
**Low Freq Output** .005% THD  
20-9 kHz @ +8 dBu (1.95 volts)  
**High Freq Output** .01% THD  
80 - 20 KHz @ +8 dBu (1.95 volts)  
**Maximum Output Level**  $R_L$  2 kohms  
+21 dBu (6.2 volts)  
@ .05% THD 20 - 20 kHz
- Maximum Output Current**  
25mA peak @ 25°C
- Maximum Voltage Gain** +6 dB  
Hum and Noise (20 Hz - 20 KHz)  
 $A_v = 0$  dB  $f_c = 800$  Hz
- Low Frequency Section**
  - Output Attenuator @ -infinity-104 dBu
  - Output Attenuator @ 0 dB -96 dBu

#### High Frequency Section

- Output Attenuator @ -infinity 104 dBu
- Output Attenuator @ 0 dB 90 dBu

Signal to Noise Ratio 108 dB

Input Impedance :

Noninverting Unbalanced 20 kohms

Output Impedance 300 ohms

#### Controls

Input Level: Continuously variable from +6 dB

gain to 90 dB attenuation

Output Level: Continuously variable from 0 dB

(unity) gain to 96 dB attenuation

Crossover Frequency:

Adjustable from 80 Hz to 900 Hz on the X1 range

800 Hz to 9kHz on the X10 range

Power Source: U.S. & Canadian

Models 120 v AC, 60 Hz

Power Consumption 12 VA

Dimensions (WXHXD) 19 inches x 1.75 inches x 7.5 inches with security cover

Net Weight both models 8 pounds

0dBu = 0.775 v rms

Also available in 1/4" phone or XLR Balanced Line

**Model 24CX-2 \$325.00**

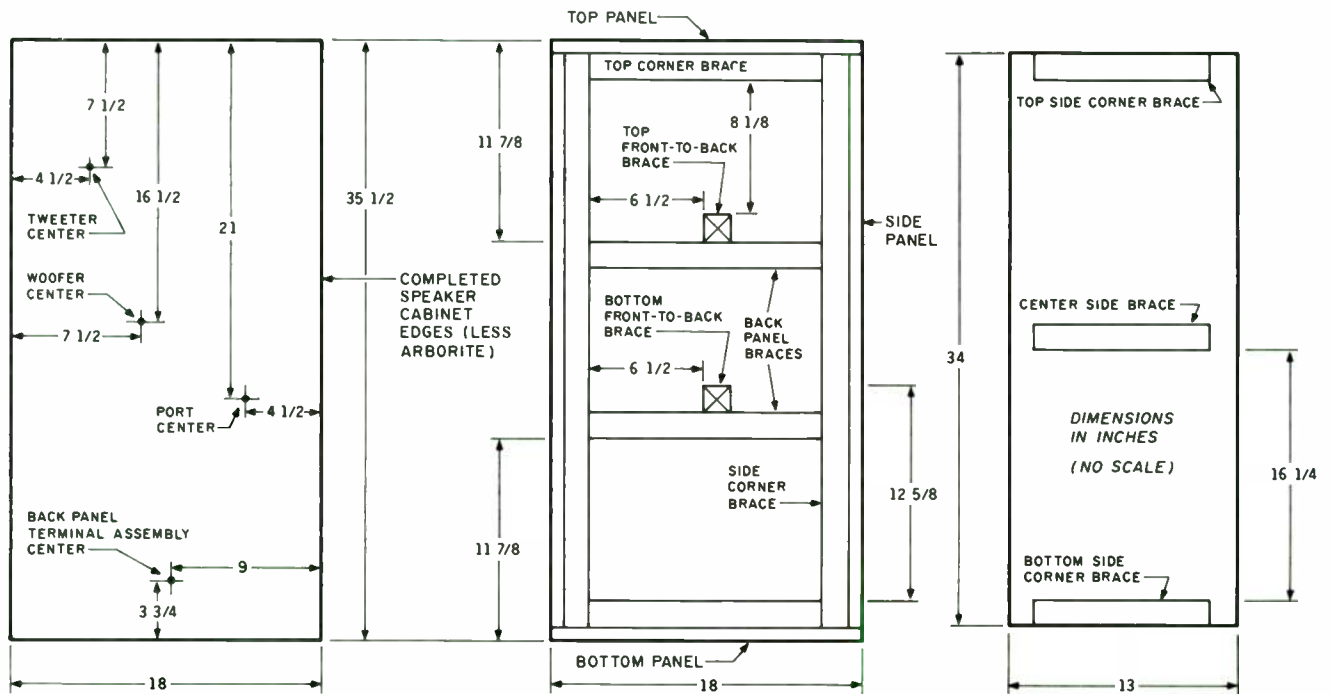
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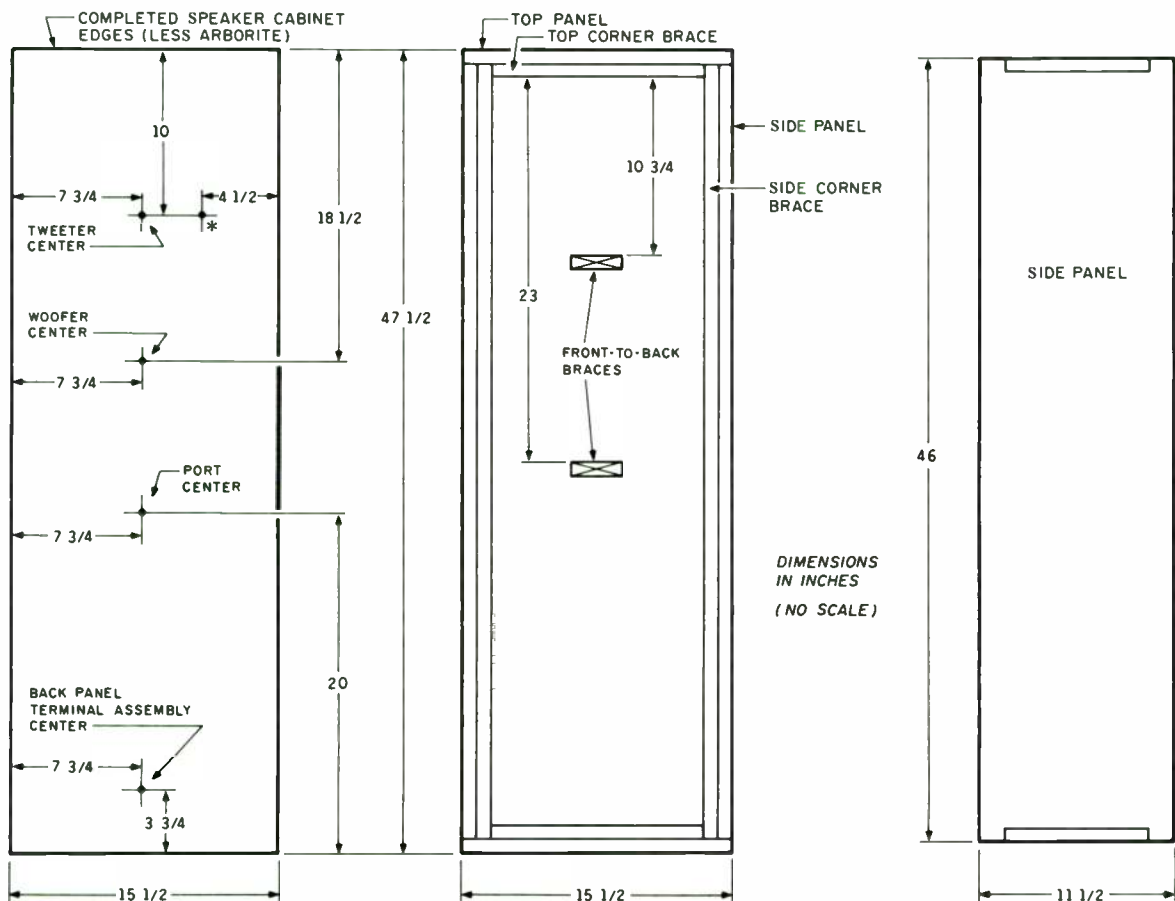


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**FIGURE 1: Construction details and left speaker driver layout. Outside dimensions: 18" x 13<sup>3</sup>/<sub>4</sub>" x 35<sup>1</sup>/<sub>2</sub>". Inside dimensions: 16<sup>1</sup>/<sub>2</sub>" x 11<sup>1</sup>/<sub>2</sub>" x 34". Panel sizes: front baffle/back panel, 16<sup>1</sup>/<sub>2</sub>" x 34"; sides, 13" x 34"; top/bottom, 13" x 18"; lower front, 11" x 18". Braces: side corner (4), 34" x 1<sup>1</sup>/<sub>2</sub>"; front-to-back (2), 11<sup>1</sup>/<sub>2</sub>" x 1<sup>1</sup>/<sub>2</sub>"; top/bottom (4) and back (2), 13<sup>1</sup>/<sub>2</sub>" x 1<sup>1</sup>/<sub>2</sub>"; side (6), 8<sup>1</sup>/<sub>2</sub>" x 1<sup>1</sup>/<sub>2</sub>".**



**FIGURE 2: Tall-box construction. Braces: side corners (4) 46" x 3/4"; front-to-back (2), 10" x 3"; top/bottom (4), 12<sup>1</sup>/<sub>2</sub>" x 3/4"; top/bottom side corners (4), 8<sup>1</sup>/<sub>2</sub>" x 3/4". \*Optional tweeter center.**

precautions. In several crossovers we used Zobel (impedance compensating networks) in the upper low-pass section to flatten the rising impedance of the woofer with increasing frequency, as well as in the lower high-pass section to negate the effect of the resonant peak of the tweeter at 1,350Hz. We did not use a Zobel in the upper high-pass section of the crossover because we believe a rising impedance in the ultrasonic frequencies provides a more stable load to finicky amplifiers driven to high output levels.

In the final crossover configuration (Fig. 4), we placed a shunting capacitor across the 2.2Ω resistor, in series with the tweeter. This allows high frequency transients to pass unimpeded. At first we used a single 50V DC, ±20% nonpolar electrolytic capacitors along with low impedance, hand-wound, air-core coils in all our crossovers. However, sound quality improved marginally using multiple, lower capacitance value 50V DC capacitors, or higher voltage, tighter tolerance (±5%) polypropylene capacitors. Capacitors were matched for left and right channels of a stereo pair using a capacitor matchmaker, from a magazine design.<sup>6</sup> We also matched drivers, but only by  $f_s$ . We did tests for  $Q_{ts}$  and  $V_{as}$  on several woofers, but results varied, so we used Radio Shack values. These proved reliable, as reflected in the results shown in Fig. 5.

While crossover configurations varied significantly during fine tuning, we finally settled on a 6/18dB per octave parallel format with Zobel on the upper low-pass and the lower high-pass sections, as described earlier. This gave an acoustic crossover of 18/18dB per octave, because the 6dB electrical rolloff of the crossover's low-pass section combines with the woofer's natural rolloff of 12dB per octave above 1250Hz to give 18dB per octave. Since the tweeter's flat response with Zobel extends well below the selected crossover frequency, the acoustic rolloff of the high-pass section is effectively that of the crossover itself—18dB per octave. This rate of rolloff gives the most phase-correct sound through the critical crossover region.<sup>11</sup>

We modified the tweeter by carefully removing the faceplate and filling a cavity behind it with plumber's putty. This operation requires considerable patience and dexterity, but the reward is a marked decrease in graininess, particularly in the female vocal range. Our later tests showed this treatment had shifted the resonant peak to a slightly lower frequency as well as increasing its

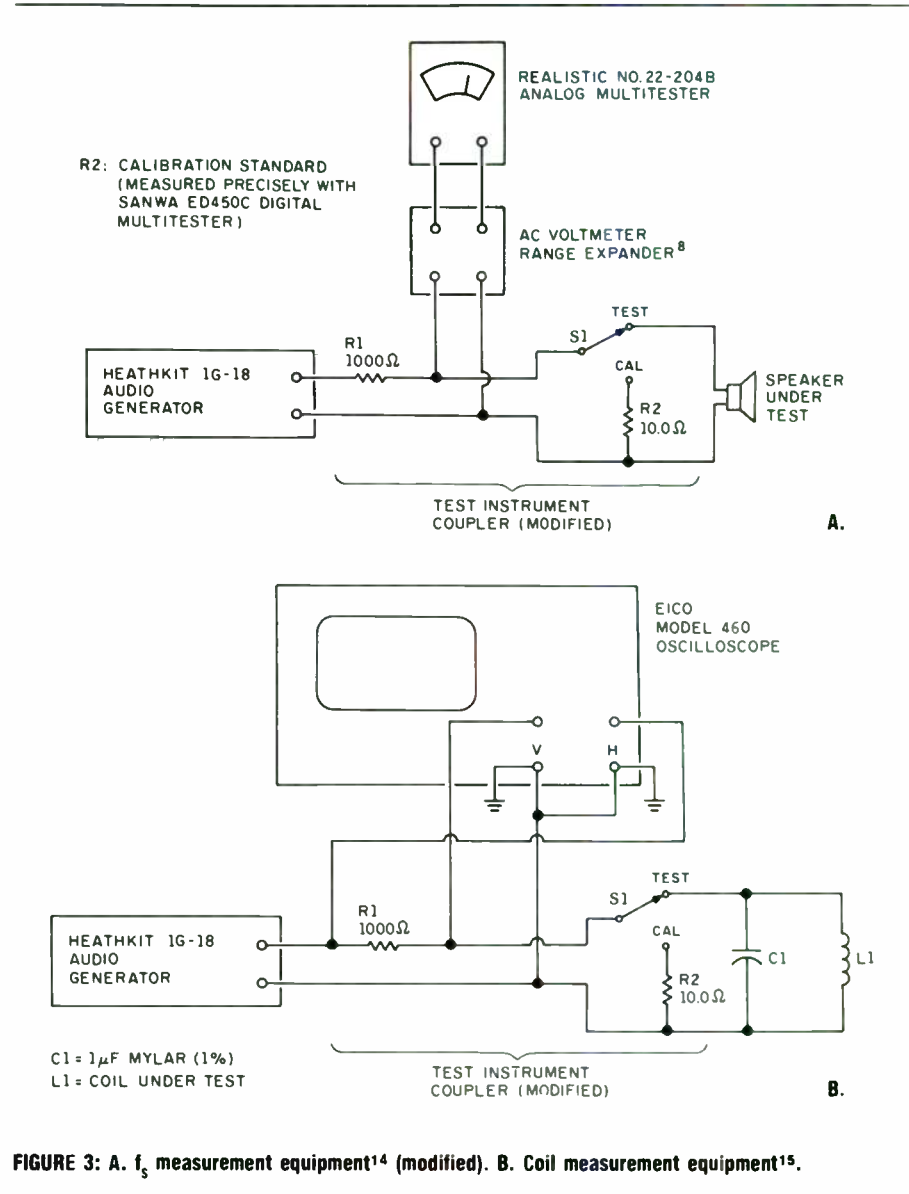


FIGURE 3: A.  $f_s$  measurement equipment<sup>14</sup> (modified). B. Coil measurement equipment<sup>15</sup>.

amplitude somewhat. Even though the Zobel in the final version effectively removed the tweeter's resonant peak, we thought the increased mass of the faceplate would reduce the amplitude of any spurious resonances.

We tried peak suppression circuits in early tests<sup>9</sup> and they did improve sound quality, but also introduced large impedance peaks. We used Zobel instead to achieve flat, and hence, phase correct<sup>10</sup> impedance curves.

The complete system's impedance is very stable (Fig. 6), since the Zobel allow it to simulate pure resistance, with a value of  $6.25 \pm 2.0\Omega$  from just above the second resonant peak to over 10kHz. Above 10kHz the impedance rises gently, as previously alluded to. Crossover phase anomalies are minimal, as reflected in the close matching of the +15° (vertically) and the +30° (horizontally)

curves to the 0° (on-axis) curve. These curves are room response measurements in a "typical," moderately dead listening room—12 by 26 by 8 feet. Figure 5 shows an on-axis frequency response of ±3½dB from 34Hz–20kHz.

Even though much of what we learned did not make it into the final crossover, the obvious conclusion from this work is that the crossover is the single most important factor in determining the sound quality of a loudspeaker. A good crossover, properly matched even to inexpensive drivers, installed in a good cabinet design, can result in better sound than the most expensive drivers, installed in a less-than-optimum cabinet with a poorly matched crossover.

We tried to use tweeter alignment by time in a prototype having a tweeter module placed atop a cabinet with a woofer mounted in the upper front sec-

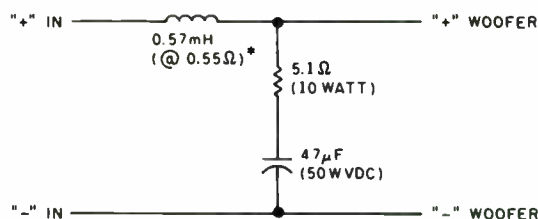
tion of the enclosure. Results were marginally better, but we decided to concentrate on the basics of loudspeaker design rather than dabble in relatively minor considerations such as time. Also, we knew that offsetting the tweeter outboard of the tweeter's center line (as in Fig. 1) would give a degree of alignment. Subsequent versions of this loudspeaker will probably use the separate tweeter module aligned by time considerations.

**TEST EQUIPMENT.** We used two different stereo systems in developing these speakers (Appendix 3). We also used a Technics SH-8000 audio analyzer, which produces 1/3-octave warble tones to evaluate frequency response over the 20Hz-20kHz range. We built several pieces of test equipment using designs by Weems<sup>7</sup> and *Popular Electronics*.<sup>8</sup> A Heathkit Model IG-18 audio generator, an Eico Model 460 oscilloscope, a Realistic Model #22-204B analog multimeter, and a Sanwa Model ED450C digital multimeter rounded out the test equipment. We used a pair of ten year old JBL L166 three-way loudspeakers as a reference. Ultimately, two pairs of very fussy audiophile ears decided whether our efforts were successful as we progressed toward the final result.

**RESULTS.** The sound of these speakers is a considerable improvement over the JBLs. This is due in no small part to the use of mirror-imaging as well as Zobel's and shunting capacitors, none of which are found in the L166s. Ours provide a much more stable sound stage, with precise localization of individual voices and instruments. Imaging, both front-to-back and side-to-side, is excellent.

The imaging of the JBLs, by comparison, is skewed at certain frequencies, particularly in the female voice range, so the sound stage appears to move upward and to the right. This we attribute primarily to the lack of mirror-imaging, because the same recordings auditioned over our two-way design (as presented here) are precisely centered. The JBLs also exhibit an annoying dropout (-10dB or so, relative to the 1kHz level) in the 125-250Hz range, no matter where they are placed in the listening room (even though they measure less than ±2dB above 100Hz, close-field). The JBLs use fixed shelving circuits (on the midrange driver) and variable L-pads, which our listening tests indicate dull transients and restrict dynamics. We simplified this design as much as possible, particularly the crossover, without compromising sound quality.

i) LOW PASS SECTION:



\* No. 20 MAGNET WIRE, AIR CORE (WEEMS<sup>13</sup> DESCRIBES MEASURING COILS-SEE APPENDIX III).

ii) HIGH PASS SECTION:

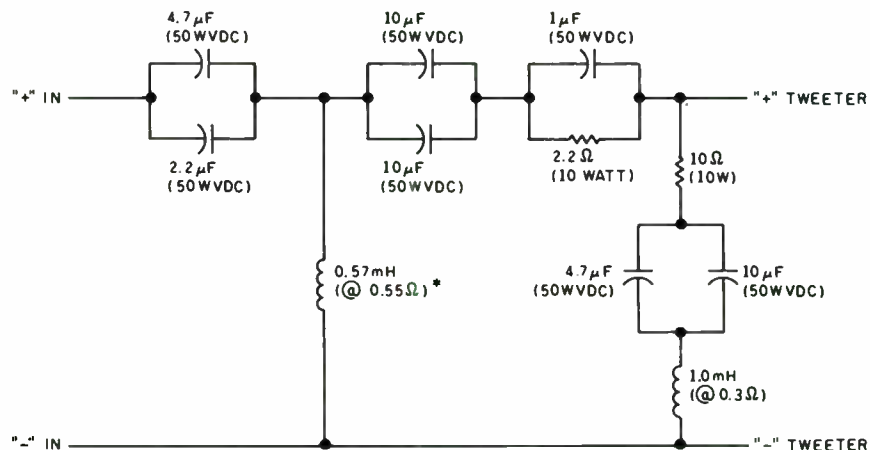
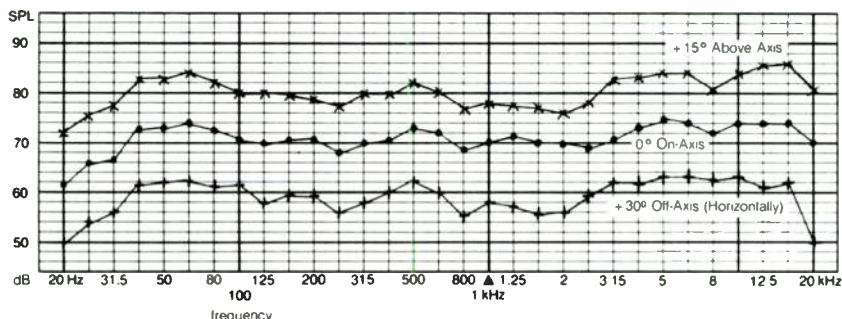


FIGURE 4: Crossover network layout.



Test Conditions:

Left channel  
DC nominal impedance 4.5Ω

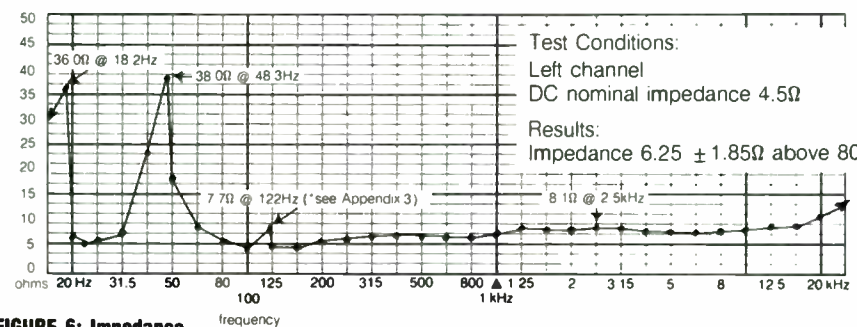
Microphone height (on-center):  
0° (on-axis) - 23"  
+ 15° (above axis) - 29 1/2"  
+ 30° (off-axis) - 23"

Efficiency (into 4π radians or 360° free field - 88.5dB/W/M (based on a pure sine wave warble tone centered at 1,000Hz, using the Technics SH-8000 Audio Analyzer)).

Results:

Frequency response at 0° (on-axis) ± 3.5dB from 34Hz-20kHz.

FIGURE 5: Typical room response.



Test Conditions:

Left channel  
DC nominal impedance 4.5Ω

Results:

Impedance 6.25 ± 1.85Ω above 80Hz

FIGURE 6: Impedance.

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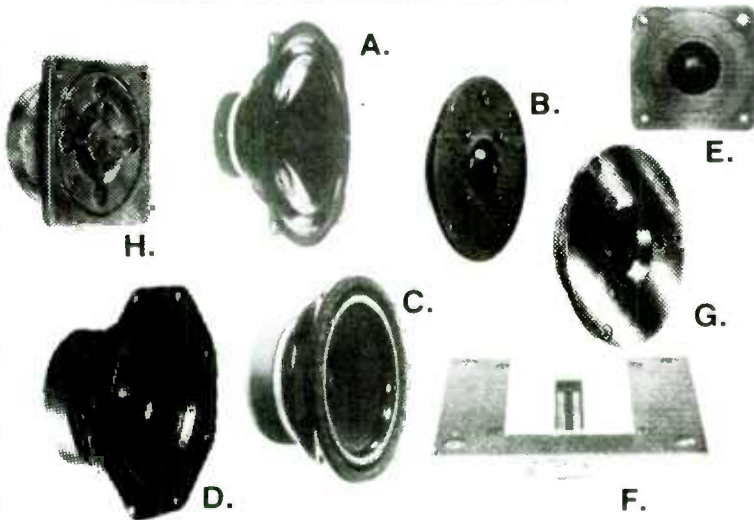
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Dome Tweeter 11410 \$5.00
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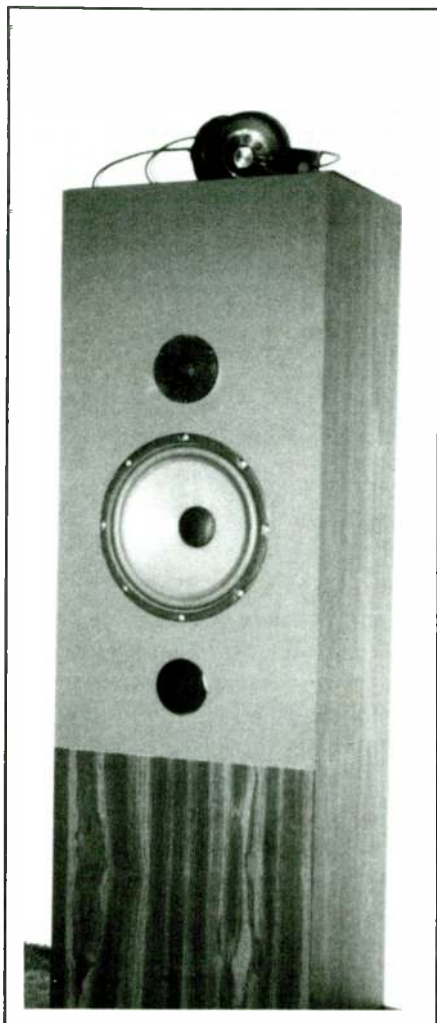
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**LISTENING TESTS.** Actual room response curves (Fig. 5) confirm what we heard in extensive listening tests: these are very good speakers indeed. The Telarc version of the *1812 Overture* is reproduced with incredible authority; the cannon shots shake the listening room at only 20W RMS, because of the extremely low (6Hz) frequencies present on the recording.

On normal-level program material we have driven these speakers with over 100W RMS with no ill effects, (carefully ensuring that woofer excursion never exceeded 1/2"). At this drive level woofer excursion approaches 1/2" even using subsonic filters. These are a must with reflex designs. We use the amplifier's built-in 12dB per octave subsonic filter at all times. In addition, at inputs of less than 10W, we switch in a Cerwin-Vega DB-10 bass turbo charger, which provides either +5 or +10dB of equalization at 30Hz and an 18dB per octave rolloff below 30Hz. This compensates for the ear's inability to perceive low frequency sounds well at low levels, while



**PHOTO 2: Alternative tall-box design.**

**APPENDIX 1:  
THIELE-BASED CALCULATIONS**

1. Desired box volume.

$$V_B = 0.7072 \times V_{as} = 0.7072 \times 4.7 \text{ cu. ft.} = 3.32 \text{ cu. ft.}$$

(or cu. in. = 1728 cu. in. cu. ft.  $\times$  3.32 cu. ft. = 5,736.96 cu. in.)

2. Cutoff frequency.

$$\text{Since } f_3 \div f_s = 1^1, \text{ } f_3 = f_s(1) = 27\text{Hz}(1) = 27\text{Hz}$$

3.  $f_3$  factor.<sup>13</sup>

$$V_B \text{ actual} \div V_{as} = 3.298^* \div 3.32 \text{ cu. ft.} = 0.9934 \text{ (*see calculation 7.)}$$

$$f_3 \text{ factor} = 1.01, \text{ so } f_3(1.01) = 27.27\text{Hz}$$

4. Port length for  $f_3 = 27.27\text{Hz}$ .<sup>13</sup>

a. For  $V_B \text{ actual} = 3.0 \text{ cu. ft.}$ :

$$L_v = -(-\Delta f_B)(2L_v \div f_B) \quad \text{where:}$$

$L_v$  = vent length

$\Delta L_v$  = change in  $L_v$  (in inches)

$\Delta f_B$  = change in  $f_B$  required

If  $L_v = 4.75"$  for a 3" I.D. duct to tune a 3.0 cu. ft. box to 30Hz, then for a tuning frequency of 27Hz:

$$L_v = -(-3\text{Hz})[(2 \times 4.75) \div 27.27\text{Hz}] = +1.045"$$

$$4.75 + 1.045 = 5.795"$$

b. Similarly, for a  $V_B = 3.5 \text{ cu. ft.}$

$$L_v = +0.825"$$

$$\text{as } L_v = -(-3\text{Hz})[(2 \times 3.75) \div 27.27\text{Hz}] = +0.825"$$

$$3.75 + 0.825 = 4.575"$$

c. Average a. and b. for an actual  $V_B$  of 3.298 cu. ft.:

$$(5.795 - 4.575) \div (3.5 \text{ cu. ft.} - 3.0 \text{ cu. ft.}) \div (0.5 - 0.298) = 1.22 \div 2.475$$

$$\text{actual } \Delta L_v = 0.493"$$

d. Since 27Hz tuning in a 3.5 cu. ft. box requires a 4.575" port, going to a smaller  $V_B$  of 3.298 cu. ft. will require a longer port:

$$\text{actual } \Delta L_v \text{ for } 3.298 \text{ cu. ft. } 4.575" + 0.493" = 5.07"$$

5. Inside Volume.

(Less internal displacement of braces, port, woofer, crossover, and speaker terminal plate.)

$$V_B = 16\frac{1}{2}" \times 11\frac{1}{2}" \times 34" = 6,451.50"$$

6. Internal Displacements.

Speaker terminal plate

$$V = 3" \times 10" \times \frac{3}{4}" = 22.52"{}^3$$

Side corner braces

$$V = 4" \times 34" \times 1\frac{1}{2}" \times 1\frac{1}{2}" = 306.00"{}^3$$

Front-to-back braces

$$V = 2" \times 11\frac{1}{2}" \times 1\frac{1}{2}" \times 1\frac{1}{2}" = 51.75"{}^3$$

Top/bottom side corner and side braces

$$V = 6" \times 8\frac{1}{2}" \times 1\frac{1}{2}" \times 1\frac{1}{2}" = 114.75"{}^3$$

Top/bottom (front and back) corner braces

$$V = 4" \times 13\frac{1}{2}" \times 1\frac{1}{2}" \times 1\frac{1}{2}" = 121.50"{}^3$$

Back braces

$$V = 2" \times 13\frac{1}{2}" \times 1\frac{1}{2}" \times 1\frac{1}{2}" = 60.75"{}^3$$

Port

$$V = \pi r^2 \times \text{ht} = 22/7 (1.75)^2 5.75" = 55.34"{}^3$$

(\*r = half of outside diameter of 3.5")

Woofer (estimate)

$$V = 18.59"{}^3$$

Crossover (estimate, including wires)

$$V = 11.54"{}^3$$

$$\text{Subtotal} \quad 762.73"{}^3$$

less negative displacement of woofer surround and woofer cutout space between it and woofer basket (estimate)

$$- 9.78"{}^3$$

$$\text{Total} \quad 752.95"{}^3 \quad - 752.95"{}^3$$

$$\underline{\underline{5,698.55"{}^3}}$$

6. Final  $V_{B \text{ actual}}$ :

$$V_{B \text{ actual}} = 5,698.55"{}^3 \div 1,728"{}^3/\text{ft}{}^3 = 3.298 \text{ ft}{}^3$$



# ACOUSTICAL MAGIC

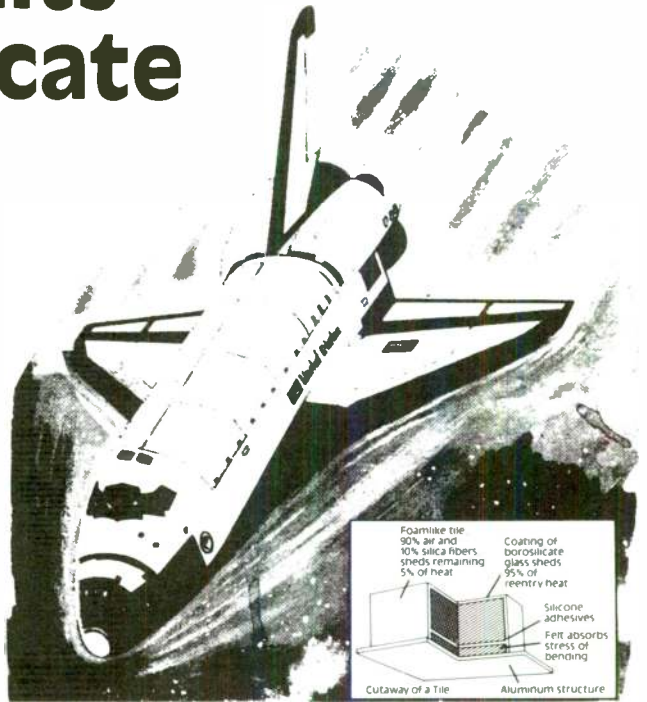
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providing an additional degree of control over woofer movement below resonance of the loudspeaker.<sup>12</sup>

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fuse in-line with the positive speaker input terminal does not open on playing the *1812 Overture*, with the DB-10 on +10, at inputs exceeding 150W peak.

Sound pressure levels are greater than 110dB at nine feet, both channels driven, on the cannon shots.

On home cassette recordings made with single microphones on either side of a Yamaha upright piano, at a height of 42", the speakers provide a very wide, realistic sound stage. Percussives are very fast, and taped male and female voice reproduction is uncannily accurate. Unless you are actually looking at the speakers, it is easy to believe you are hearing a live performance.

Harmonizing of voices is particularly satisfying. The recording of *Once In A Lifetime* by Chicago sounds exceptionally detailed, each layer of the various

*Continued on page 46*

## APPENDIX 2 ASSEMBLY DETAILS

Speaker assembly consists of cutting all the panels and attaching the various braces to them prior to gluing; and then nailing the subassemblies together. It is easiest to attach the side corner, top/bottom side corner, and side braces to the side panels first. Next, the top/bottom (front and back) corner braces are attached (using 2" galvanized nails and plenty of white glue) to the front baffle and to the back panel. Finally, the two back panel braces are attached to the back panel, and the subassemblies are nailed and glued together. (Cabinet clamps are not needed with this method, providing the panels are cut accurately.)

Use a square to ensure the panels are all 90° to each other. Allow several days for drying, then mark the cutout hole centers and use a variable speed jigsaw for cutting. Insert the two front-to-back braces through the woofer cutout and glue and nail solidly.

To reinforce the back panel, install a 3 by 10 by 3/4" terminal plate inside the box in front of the terminal assembly. Glue in the port. Install an 11 by 18" panel outside the box on the lower front baffle to increase rigidity. (It improves the appearance and also provides a ledge for the grille.)

Sand the cabinets prior to finishing. Install 8 T-nuts for each woofer and glue a rubber gasket made from an old inner tube to the back of the woofer basket with contact cement. Cut tap washers (used to repair leaking water faucets) with side cutters so they fit the screw holes in the front gasket of the woofers. This helps to isolate the woofer from the front baffle for minimum

interaction.

Disassemble and putty the tweeter as described in the text. Following reassembly, put it aside with the woofer while you install the crossover in the center of the back panel, which also increases this panel's rigidity. Solder the various wires to the drivers and the terminal assembly, making sure all drivers are in phase and that the wires are long enough to remove drivers without disconnecting them. Line back, sides and top panels and front-to-back brace with 2" of Hollofil® stuffing.

Install the drivers. First, use #10-24 Robertson-head machine screws to hold the woofer in place. Install the tweeter using wood screws and small rubber washers on the faceplate front and 1/4" foam weatherstripping between the tweeter and the baffle. Also use weatherstripping between the terminal assembly and the back panel, and silicon caulking compound to seal the holes in the terminal plate board (inside the box) where the wires lead to the crossover. Install velcro strips or nylon grille pins on the baffle as required. Construct the grille as described in the text.

Prior to system hookup, test each loudspeaker for proper woofer polarity, using a 1 1/2V AA battery and a short piece of speaker wire. Check loudspeaker impedance over the 10Hz-100kHz range (Fig. 3)<sup>14</sup> for consistency and for possible air leaks, which would show up as impedance irregularities. Finally, we checked frequency response at 1/3 octave intervals from 20Hz-20kHz (Figs. 5 and 6).

## APPENDIX 4: Future Modifications

The tweeter might benefit from alignment by time, perhaps using the separate tweeter module described in the text or using an angled baffle panel (either with or without tweeter offset from the woofer's midline). The separate module method is the most appealing because cabinet construction is easier, since it requires only that we relocate the woofer to the upper front baffle area.

The small impedance peak (Fig. 6) at 125Hz is probably due to "ringing" of

the woofer basket, and not to cabinet leaks, since it appears in all examples of the design, both fat and tall boxes. A brace between the woofer magnet assembly and the back panel (with putty between the two) might remove this minor anomaly.

Finally, increasing panel thickness to 1 1/2", especially the front baffle and rear panel, might yield marginal improvements, as might using a router to mount the tweeter and/or woofer flush with the front panel.

## APPENDIX 3

A. System I Stereo Components:  
(used in speaker evaluation)  
Yamaha CR2020 Receiver  
Dual CS721 Direct Drive Turntable  
Shure V15 V MR Cartridge/Stylus  
dbx 3BX Series II Dynamic Range Expander  
Cerwin-Vega DB-10 Bass Turbocharger  
Technics SH-8000 Audio Frequency Analyzer  
Koss Pro 4AAA Headphones  
Realistic Pro Series Cardioid Dynamic Microphone  
Homemade omnidirectional electret microphones (2)  
JBL L166A 3-way Bass Reflex Loudspeakers  
Realistic Minimus 7 Acoustic Suspension Loudspeakers (with modified crossovers)  
Thiele-aligned 2-way Bass Reflex Loudspeakers  
Realistic APM-300 LED Peak- and RMS-Reading Power Meters

B. System II Stereo Components:  
Technics Professional Series:  
Model 1500 Reel-To-Reel (half track)  
Model ST-9030 Tuner  
Model SU-9070 Preamplifier  
Model SH-9010 Equalizer  
Model SH-9020 Analog Peak- and RMS-Reading Power Meters  
Model SH-8000 Audio Frequency Analyzer  
Model SE-9060 Power Amplifier  
Dual CS630Q Direct Drive Turntable  
Shure ML140 HE Cartridge/Stylus  
Sony TC-229 SD Cassette Recorder  
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.20	.14	2.45	.80	.30	4.40	5.00	.49	9.90
.25	.15	2.65	.90	.33	4.70	6.00	.55	10.40
.30	.16	3.00	1.00	.34	5.10	7.00	.62	10.80
.40	.18	3.35	1.25	.38	5.60	8.00	.67	11.20
.50	.22	3.50	1.50	.43	6.30	9.00	.74	11.70
.60	.24	3.80	2.00	.52	6.90	10.00	.79	12.30
			2.50	.59	7.30			
			3.00	.72	7.60			

## SLEDGEHAMMER IRON CORE INDUCTORS

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### IRON CORE INDUCTORS

3.0 Mh	.20 Ω	\$10.75
3.3	.21	10.85
3.7	.23	11.00
4.0	.23	11.20
4.3	.24	11.35
4.7	.26	11.55
5.0	.27	11.70
5.4	.29	11.85
5.7	.30	12.00



### IRON CORE INDUCTORS

6.0 Mh	.31 Ω	\$12.20
6.5	.32	12.40
7.0	.34	12.55
7.5	.35	12.75
8.0	.36	12.95
8.5	.39	13.20
9.0	.40	13.45
10.0	.43	13.85
12.0	.47	14.75

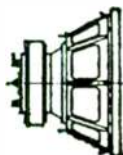
Values between sizes listed are also available. Add 20% to cost of value larger than your requirement.

### Applications For SLEDGEHAMMER & SIDEWINDER Inductors And Polypropylene Capacitors

We suggest that you consider using premium filter components in the signal path of the midrange and the tweeter. Using polypropylene caps in series with the tweeter will result in better high frequency detail at a very low increase in cost. Polypropylene caps in series with dome midranges or cone mid ranges at 500 hz or higher will result in better imaging with only a moderate filter overall cost increase.

With midranges below 500 hz, and with satellite mid bass speakers in subwoofer satellite combinations, the cost of polypropylene capacitors can be significant. We suggest here that you consider a combination of electrolytic and polypropylene capacitors with approximately 50% of each type. Using an nominal 8 ohm satellite system will reduce the capacitance of the first capacitor by 50% over a 4 ohm unit. Even a small percentage of polypropylene capacitance will give some sonic improvement and should be considered.

Stage systems, commercial sound and autosound application will benefit from using SLEDGEHAMMER & SIDEWINDER coils because the resistance loss within the crossover is up to 50% less than similar 18 gauge inductors. This more effectively couples the amplifier to the speaker to realize the full potential of the power amplifier's damping factor and results in better speaker control. In addition, the saturation level of SLEDGEHAMMER & SIDEWINDER coils is much higher than standard types. In home systems, the midrange level can be raised by substituting a low loss inductor for the inductor in series with the midrange loudspeaker. In autosound systems we think you should use Polypropylene capacitors in the tweeter circuit; the improvement is even more pronounced when the tweeter can be mounted on axis with the listening position. In general, the higher the quality of the loudspeakers, the more significant the improvement will be. Single pole (6 DB) circuits show marked improvement, particularly when you add a quality supertweeter to an existing combination. Advanced audiophiles will find many other applications for these capacitors in the phono preamp circuit, in amplifier and CD player signal path and power supply decoupling. For just as in speakers, the signal path can be improved with state of the art electronic parts. Most aftermarket equipment modifications consist of capacitor exchanges as we have just discussed.



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# MODIFYING RADIO SHACK'S MINIMUS-7

BY WILLIAM R. HOFFMAN

One of the most popular entry level, high fidelity speaker systems ever sold for less than \$100/pair is the tiny Minimus-7. Its low price, high tech look, and good sound have made it a favorite for almost a decade. There are probably more of these little systems in homes and offices, as starter systems, and even a few more ambitious but budget conscious main systems, than any other speaker currently in production. Considering its catalog price of \$50 each, and they are regularly on sale for about \$30, these little jewels are just too good for the average listener to pass up.

Is it the perfect speaker? With its limited bass output and electrical power capacity, and a few other problems, it can never lay claim to such a title. The laws of physics bow to no one, not even the giant Tandy organization. Well then, can we do something with this little system to improve it?

**THE BEGINNING POINT.** Listening to a pair placed about 6 inches from a wall in a moderate-sized room, while I sat in a chair, was very revealing. The bass of these diminutive loudspeakers was quite good, but the midrange and highs had some definite peaks, giving the systems a very forward sounding quality. Not bad, but definitely not high fidelity.

The first order of business is to measure the frequency response of the stock system. Then, completely disassemble one of the systems and measure all its parameters. Measure the drivers separately, to assess each one's individual contribution.

Tables 1 and 2 are, respectively, the mechanical and electrical parameters of



PHOTO 1: Minimus-7 with new crossover components.

the woofer and dome tweeter. Figure 1 is a schematic and list of the passive components for the original crossover network. The woofer has no low pass filter at all. Figure 2 is an axial frequency response curve of the complete system taken in a small anechoic chamber, while Figs. 3 and 4 are the frequency responses and impedances of the woofer and tweeter, under the same conditions as Fig. 1, except that the crossover network and the driver were disconnected.

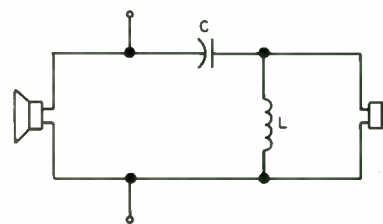


FIGURE 1: Schematic of crossover network as originally manufactured.  $L = 0.38\text{mH}$  at  $60\text{Hz}$ .  $C = 4.7\mu\text{F}$  NP electrolytic.

**TABLE 1**

**WOOFER SPECIFICATIONS**

$Q_{cab}$  and  $F_{cab}$  measured in the cabinet. All others measured in free air.

Diameter	4" nominal
Cone	3" active diameter
Voice Coil	1" diameter
Cone Material	paper
Voice Coil Imp.	8Ω nominal
Voice Coil DCR	6.5Ω
Voice Coil Ind.	1.54μHy @ 60Hz
Magnet	8 ounce
$F_o$	57Hz
$F_{cab}$	101Hz
$Q_{ts}$	0.55, ± 0.05
$Q_{cab}$	1, ± 0.05
Vas	0.13, ± 0.02 ft <sup>3</sup>
Power Rating	approx. 10W
Efficiency	approx. 84dB/W/M*

\*Manufacturer's spec.

**TABLE 2**

**TWEETER SPECIFICATIONS**

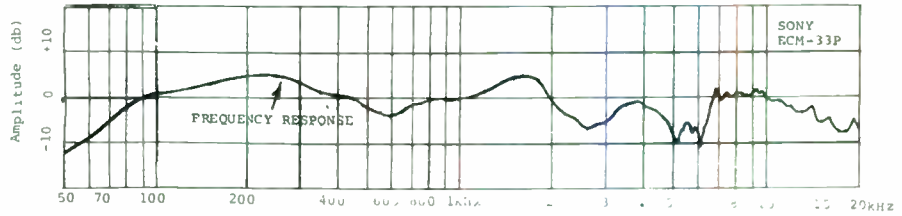
Type	dome, 1" diameter
Voice Coil	1" diameter
Voice Coil Imp.	8Ω nominal
Voice Coil DCR	7.2Ω
Voice Coil Ind.	39μHy @ 60Hz
$F_o$	1.7kHz

\*Manufacturer's spec.

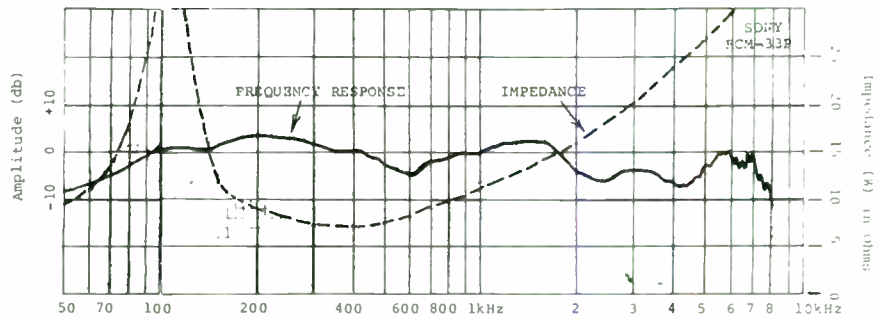
**WHAT IS THE PROBLEM?** Examining these figures tells us why the little systems sound the way they do. The large, rough peaks from 7kHz to 10kHz are mostly due to the breakup modes of the woofer cone, while the dip between 4kHz and 7kHz is due to the woofer and tweeter operating partially out of phase with each other. I confirmed this last anomaly by making further acoustic measurements at various angles off axis. In addition, the rounded peak at about 1.7kHz is due mostly to the tweeter's output peak at its resonant frequency. Even though this is below the nominal 2.5kHz crossover point, it is still evident in the speaker output, along with the peak at about 3.6kHz.

From this, our first order of business is to include a filter on the woofer, which is not an easy task because of its highly reactive impedance curve. Above 1kHz, its impedance is almost purely inductive. This means a simple series inductor will never work as a crossover.

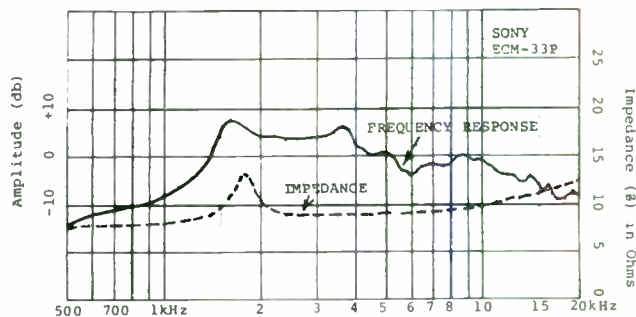
**A NEW CROSSOVER.** As any knowledgeable and practical loudspeaker design engineer knows, all the papers about con-



**FIGURE 2:** Measured frequency response of the speaker system in stock form; made 10" on-axis of the system in a small anechoic chamber with grille removed.



**FIGURE 3:** Measured frequency response and impedance of Minimus-7 woofer in the cabinet, with the crossover network bypassed; made 10" on-axis with grille removed.



**FIGURE 4:** Measured frequency response and impedance of Minimus-7 dome tweeter in the cabinet, with the crossover network bypassed; made 10" on-axis with grille removed.

stant voltage, constant impedance, or other more exotic crossover network designs, are about as practical as a gasoline tank on an electric car. Do not misunderstand, these calculations by many expert mathematicians, and published in *Speaker Builder*, as well as technical journals, represent a mathematical ideal. The only problem is that no loudspeaker currently made has the required amplitude/phase/impedance characteristics to realize these designs.

The Minimus-7 is no exception. Therefore, we properly define our design goals for this speaker just as all other practical engineers do, as follows:

1. The crossover should equalize the drivers' amplitude responses to produce a final curve consistent with the best audible performance for the completed system.
2. The crossover should provide the necessary high pass filtering of the



PHOTO 2: Disassembled woofer.

midrange and (or) high frequency drivers to reduce distortion and protect against excessive out-of-range electrical input and consequent overloading and damage to the drivers.

With this in mind, compare the curves in Figs. 3 and 4 with the new crossover design as shown in Fig. 5. Notice it has both high and low pass sections, effec-

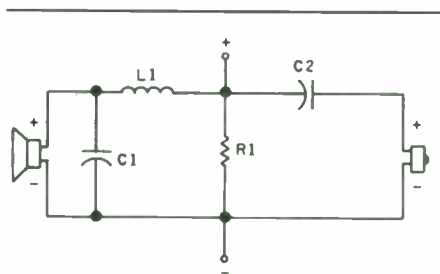


FIGURE 5: Schematic of the redesigned crossover. L1 = 3.5mHy. 10% (1.2Ω DCR); C1 = 3.9μF. 10% 100W/V; C2 = 2μF. 10% 100W/V; R1 = 82Ω/1W carbon.

tively at about 6dB/octave, with the woofer rolling off above about 2kHz, and the tweeter's response below about 4.5kHz. I chose the value of C1 to compensate for the rapidly rising woofer voice-coil impedance. R1 helps equalize the large impedance variations of the crossover and woofer to a value more easily tolerated by most amplifiers.

The result of a fresh frequency response measurement with the new crossover in place is shown in Fig. 6. Notice the much improved response from 2.5kHz upward. All the previous roughness from the modal operation of the woofer cone is now gone, and the response from about 2kHz to 15kHz is now within ±3dB, an excellent figure for such an inexpensive system.

**BUILDING THE CROSSOVER.** All the new crossover parts were assembled on a piece of 3" by 4" perfboard (Fig. 7). Because of the fairly critical importance of the little system's internal volume,

and the impossibility of easily modifying the cast metal cabinet, leave the old crossover components intact, and glue down the capacitor and inductor inside so they cannot rattle or vibrate.

Then, install the new crossover outside, drilling holes for two new insulated input terminals near the rear top edge of the box for connection directly to the tweeter. Solder quality 18-gauge stranded wire between the new terminals and the tweeter.

For the woofer, simply cut the old crossover elements from the original input terminals inside the cabinet, and connect these directly to the woofer with more 18-gauge wire. Once this is done, it is important to check both drivers for correct phase. The red terminal on the tweeter is positive; the woofer has a "+" on the terminal board on the side of the basket. Finally, reinsert the original fiberglass blanket and carefully mount the drivers.

To be sure the cabinet is well sealed, simply press gently on the woofer cone and quickly release it. The cone should take a second or two to come back to its normal position. Also press on the cone and listen closely for any hissing or whooshing noises, sure signs of an air leak. Check the new tweeter input terminals on the back. Seal any leaks with silicon sealer, or some similar product, then tighten the driver mounting screws firmly after placing a small daub of sealer around each one.

### Specifications: Radio Shack 4" Woofer (40-1022)

This little woofer is similar to the one in the Minimus-7 system. From one sample I determined the following specifications.

- $F_o = 55\text{Hz}^*$  (59Hz)
- $Z \text{ at } F_o = 46\Omega$
- $Q_{ts} = 0.35^*$  (0.55 ± 0.05)
- $V_{as} = 0.23 \text{ ft}^3^*$  (0.13 ± 0.02 ft<sup>3</sup>)
- Voice Coil DCR: 6.4Ω
- Voice Coil Inductance: 1.66mHy @ 60Hz
- Voice Coil: 4 layer, aluminum former, 1" diameter nominal
- Voice Coil Length: 7mm
- Gap Length: 5mm
- Efficiency: approx. 84dB/W/M.\*
- The axial frequency response and impedance curves are the same as those of the Minimus-7 woofer (Fig. 2).
- \*Manufacturer's spec.

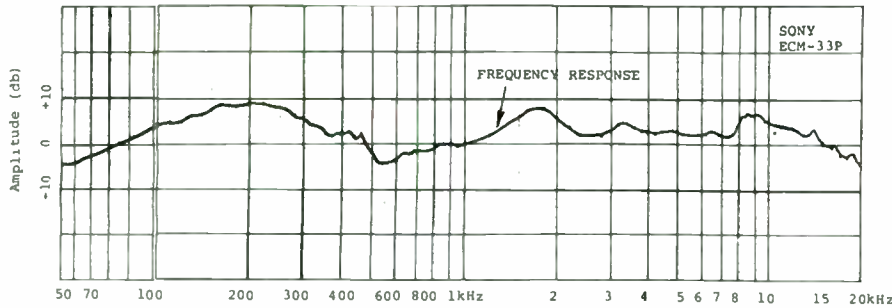


FIGURE 6: Measured frequency response of the complete system with new crossover network; same procedure as Fig. 1.

**RESULTS.** But what about the other large peaks and dips, starting down from approximately 2kHz, so clearly visible in Fig. 6? I measured the speakers with the new crossover, placed face up on a hard floor of a live room, 10 by 15 by 25 feet, from a distance of 12 feet. The results are plotted in Fig. 8. Note the big difference compared to Fig. 6, especially below 2kHz. Except for the expected reflections from the floor causing a large series of cancellations around 600Hz, the response is now much smoother. This means most of the remaining response

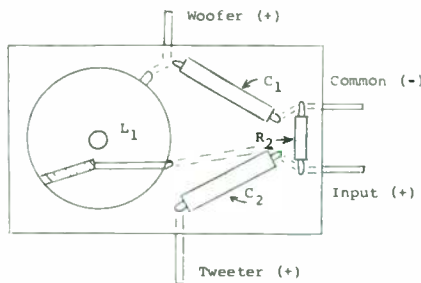


FIGURE 7: New crossover board. Mount components with silicon sealer to prevent vibration or rattles.

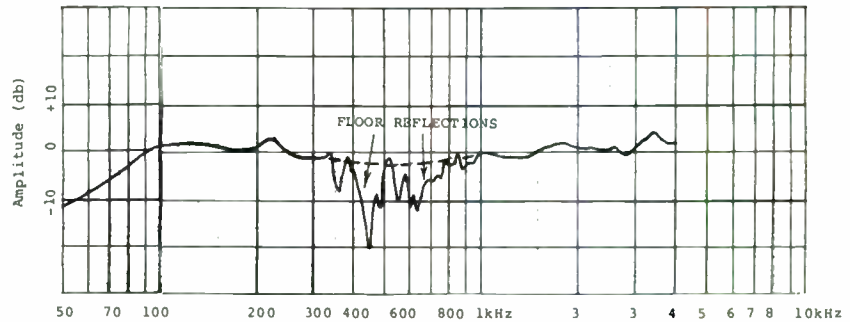


FIGURE 8: Axial frequency response curve with system on floor facing upward. Microphone was 12" above speaker.

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irregularities in Fig. 6 are due to diffraction effects from the front baffle edges of the little speaker.

Therefore, placing the speakers on a bookshelf, with their backs to a wall, will produce a favorable change in audible response; even better when they are positioned with the fronts flush with some books or other large objects. This should eliminate almost all the major reflection and diffraction effects and produce the smooth response shown in Figure 8.

In contrast, if the loudspeakers are placed on stands, well away from any walls or other reflecting surfaces, the system has a very disturbing nasal and box-like sound. Flush wall mounting should result in a very flat frequency response. When the responses of Figs. 6 and 8 are combined (Fig. 9), the result is an excellent  $\pm 4$ dB from about 85Hz to 17kHz; impressive performance for so inexpensive a speaker system.

And finally, how do the little systems sound? I will let other SB readers tell us about that. Good listening. ▶

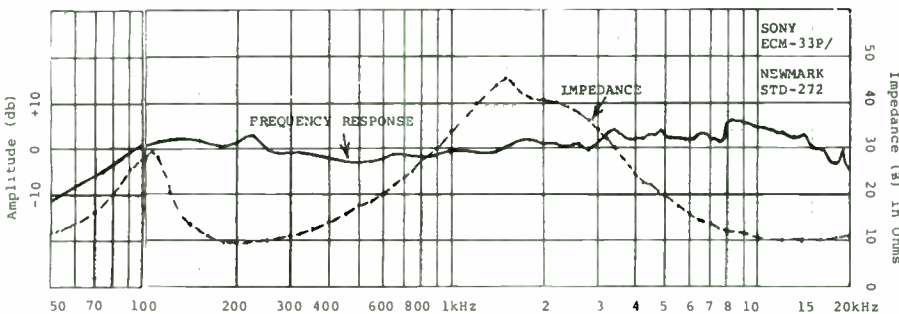


FIGURE 9: Response curve of the Minimus-7 as if taken from a flush mounting position in a large wall. (The impedance curve is for the completed system with the new crossover.)

### SOURCES

Crossover parts:  
 A & S Speakers  
 3170 23rd St  
 San Francisco, CA 94110  
 (415) 641-4573  
 Madisound Speaker Components  
 8068 University Green  
 Box 4283  
 Madison, WI 53711  
 (608) 831-3433

### TEST EQUIPMENT

B&K Precision 80MHz oscilloscope model 1570A  
 Leader AC voltmeter model LMV-182A  
 Sound Technology oscillator and analyzer model 1700B  
 Sony ECM-33P condenser mike (calibrated)  
 Newark STD-272 probe condenser mike (calibrated)  
 Marantz model 250 power amplifier (modified)

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# Kit Report

## DUAL-COIL DRIVER

I'm sure that you've seen dual-coil speakers listed in catalogs and wondered about the purpose of the second coil, but perhaps haven't had the chance to use one in a system yet. I had an opportunity to use a dual-coil speaker when I built the Focal Egg (*SB* 3/86, p. 30). In this speaker system, the second coil is used to tailor the bass response. I wondered what I could do with such a speaker versus a conventional one, so I decided to experiment. I found that a dual-coil speaker presents some problems, but also some interesting possibilities for the amateur speaker builder. Several months have marked the sometimes frustrating, sometimes enjoyable, but always educational journey I share with you now.

### Dual-Coil Impedance Compensation

When I built the Egg, I noticed the crossover did not include impedance compensation for the woofer. One evening, thinking it would take only a couple of hours, I sat down to make some measurements and build an impedance compensation network for the woofer. Well, it's an understatement to say that nothing worked, as the articles in *SB* predicted.

I started by measuring the impedance of the voice coil and calculating the values of a network to compensate for the rise of impedance with frequency, as recommended by Max Knittel (*SB* 1/83). After a little experimenting, I settled on values of  $10\mu\text{F}$  and  $7\Omega$  to use in the network. *Figure 1* shows the impedance with and without the compensation network. So far, so good.

The reason for impedance compensation is to ensure the response of the crossover will be correct when attached to the speaker, so I connected the speaker as shown in *Fig. 2*, and checked its response. For a reference, I substituted a pair of  $6\Omega$  resistors for the speaker. You can imagine my surprise at the results (*Fig. 3*). Something strange was happening here: certainly not what I expected.

Then it became clear. The two voice coils are not independent. They interact

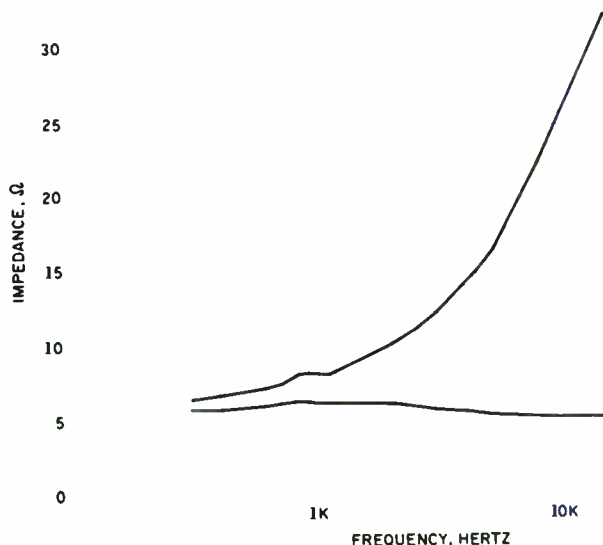


FIGURE 1: impedance of one voice coil with and without compensation.

in a manner similar to a transformer, so that any impedance compensation introduced into one voice coil is "reflected" into the other voice coil. *Figure 4* shows the results when I applied a constant level signal to one voice coil and measured the output from the second voice coil. This implies the speaker can be modeled from the network shown in *Fig. 5*.

I decided to compensate the speaker to provide the correct response with the crossover rather than a flat impedance. I connected the voice coils in parallel and recalculated values for the compensation network. The results indicated a  $44\mu\text{F}$  capacitor and  $3\Omega$  resistor (which I raised to  $4\Omega$ ). Remember, this is the total capacitance and resistance to be shared by the two voice coils. I split this equally between them with a  $22\mu\text{F}$  capacitor and  $8\Omega$  resistor network on each, which provided the response shown in *Fig. 6*. I was halfway home; the upper curve was within a few tenths of a decibel from the

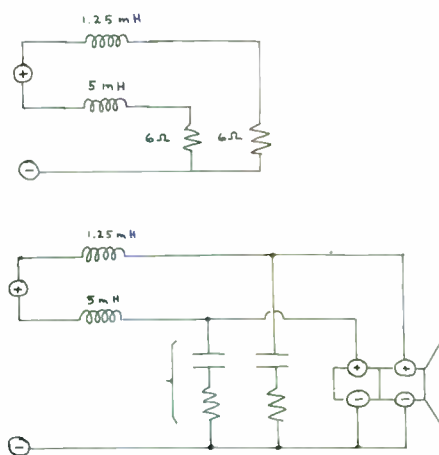
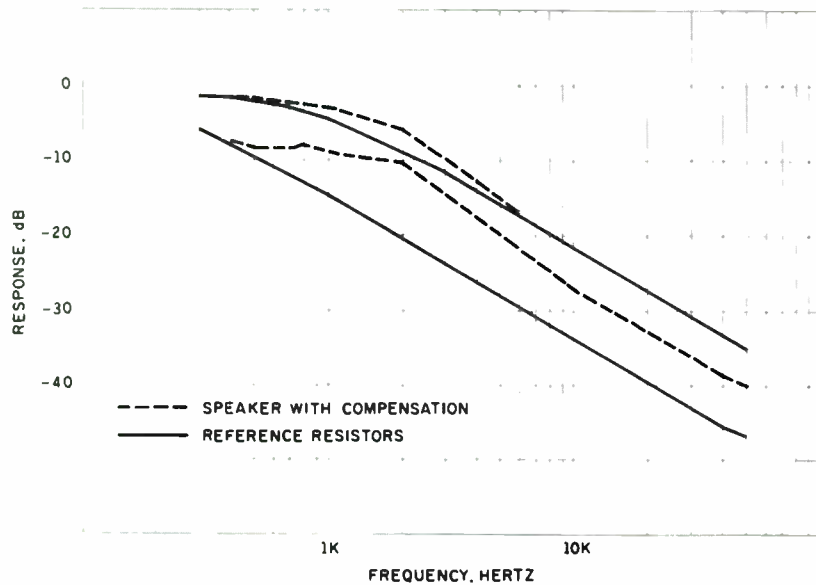
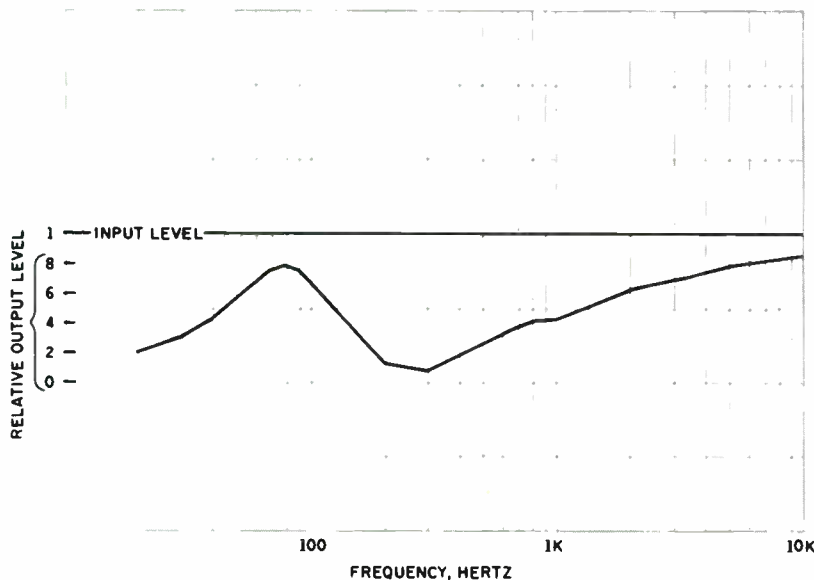


FIGURE 2: Crossover connected either to reference resistors or to a dual-coil loudspeaker with impedance compensation.



**FIGURE 3: Response of speaker connected to crossover with compensation. Compensation is  $7\Omega$  in series with  $10\mu\text{F}$  for each voice coil.**



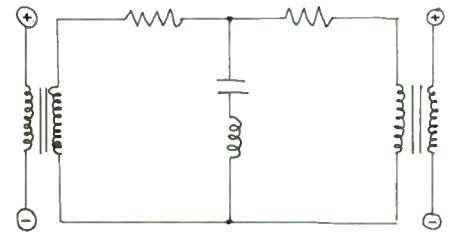
**FIGURE 4: Output of one voice coil with a constant level signal applied to the other voice coil. No crossover or compensation used.**

reference, but the lower curve was still incorrect.

For discussion, I will call the voice coil connected to the  $5\text{mH}$  inductor the "lower voice coil" because it produces the lower curve. The voice coil connected to the  $1.25\text{mH}$  inductor will be referred to as the "upper voice coil." Experimenting with different values across the voice coils, I found the resistor generally determines the resultant impedance at the high frequencies, and the capacitor determines how low in frequency the resistor will have an effect.

The desired response on the lower voice coil required a resistor of  $2\Omega$  or less. Of course this affected the value of the resistor needed on the upper voice coil. The final value I chose for this resistor was  $10\Omega$ . Using a  $30\mu\text{F}$  capacitor in series with the  $2\Omega$  resistor, and a  $22\mu\text{F}$  capacitor in series with the  $10\Omega$  resistor tested within a few tenths of a decibel from the reference for both voice coils, from  $300\text{Hz}$  to over  $50\text{kHz}$ .

I have some doubt whether it is necessary to equalize both voice coils as described. Look at the response of the lower



**FIGURE 5: Model of a dual-coil loudspeaker.**

voice coil in Fig. 6 again. It deviates from the reference not because the impedance of the voice coil is incorrect; rather, it is because the lower voice coil is acting as a source rather than a sink of the signal. In other words, the speaker is a generator instead of a motor.

How can this be? For frequencies above about  $400\text{Hz}$ , the impedance of the  $5\text{mH}$  inductor is greater than the sum of the impedance of the  $1.25\text{mH}$  inductor plus the internal impedance between the voice coils of the speaker. These impedances are independent of the voice coil impedances. Placing an appropriate valued resistor across the lower voice coil will drop the signal level at that point to the level I would expect to see at the junction of a  $5\text{mH}$  inductor and  $6\Omega$  resistor connected in series. But, so what—this voltage is not driving the speaker, and therefore not contributing to its acoustic output. Note that below  $400\text{Hz}$  the impedance of the  $5\text{mH}$  inductor is low enough that the lower voice coil is driven, contributing to the acoustic output of the speaker.

It appears the response of the lower voice coil doesn't matter at all, so don't bother to compensate for it. However, the lower voice coil cannot be totally ignored; it does affect the level of the signal on the upper voice coil. Connecting the voice coils in parallel for measuring the impedance, and then splitting the compensation as I did earlier is probably adequate. As long as the response of the upper voice coil is okay, don't worry about the response of the lower voice coil.

After all this, how does the speaker sound? If you remember, I was impressed with the vented Egg using the F280-FA crossover. I described its sound as "detailed and transparent as well as analytical and revealing, with a slightly dry characteristic" (SB 3/86, p. 32).

After adding the impedance compensation, the speaker sounded slightly sweeter, smoother, and mellower. The dry characteristic was gone. The effect was a subtle, but noticeable, improvement that I consider well worth the effort.

### Dual-Coil Crossover

In the process of experimenting with the dual-coil speaker, I measured the impedance of both voice coils connected in

parallel with one voice coil reversed. The interesting result is the impedance is constant across the whole audio range, from  $2.9\Omega$  at 20Hz to  $3.2\Omega$  at 20kHz. There is no peak at resonance, and the impedance does not increase with frequency. With the voice coils connected in this manner, there is no acoustical output from the speaker at any frequency.

I wondered whether I could somehow use this property to my advantage. What would happen if I provided a frequency selective signal to the reversed voice coil? A capacitor in series would pass high frequencies to the reversed voice coil, which would buck the signal on the other voice coil. Interesting—a low-pass filter using only a capacitor. The impedance curve in Fig. 7 shows the characteristic of constant impedance is retained at the higher frequencies, which means that no compensation is needed. Unfortunately, since the reversed voice coil has little effect at low frequencies, constant impedance is not retained. It does act as a low-pass crossover however. I only listened for a few minutes, but it seemed to work.

Replacing an inductor with a capacitor is an interesting experiment, but what excites me is the possibility of replacing a capacitor with an inductor in a high-pass crossover. Think of it—no capacitor at all to distort the signal. Figure 8 shows a tweeter with such an inductive high-pass crossover. Unfortunately, dual-coil tweeters do not exist. Perhaps a tweeter that doesn't need a capacitive filter will interest a speaker manufacturer enough to produce a few prototypes.

In addition to reactive components forming a crossover, resistors in series or parallel with the reversed voice coil will provide padding.

There are advantages to this type of crossover. It is simple to design and doesn't need compensation, but the biggest benefit is the main voice coil is driven directly by the amplifier with no intervening components to affect damping. I'm concerned by the low impedance, and the opposition of the voice coils means the signal is dissipated as heat in the driver mechanism. I don't know whether this is could melt my drivers but I won't chance extended listening until I'm sure it won't. Perhaps for this crossover to be viable, the speaker would need high impedance voice coils treated with ferrofluid.

### Related Considerations

I'm sure there is a lot more to the dual-coil speaker than I have discovered in my short adventure. I hope this stimulates you to experiment and perhaps share your findings.

Although the data presented here were taken from a Focal 7N402-DBE driver mounted in a sealed Egg and using a F280-FA crossover, the concepts should apply to any system using a dual-coil driver.

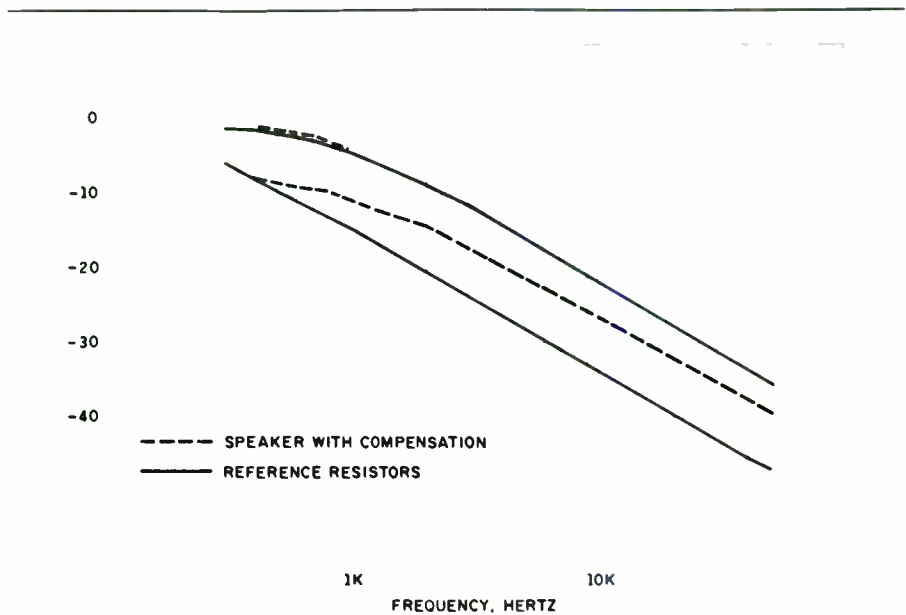


FIGURE 6: Response of speaker connected to crossover with compensation. Compensation is  $8\Omega$  in series with  $22\mu\text{F}$  for each voice coil.

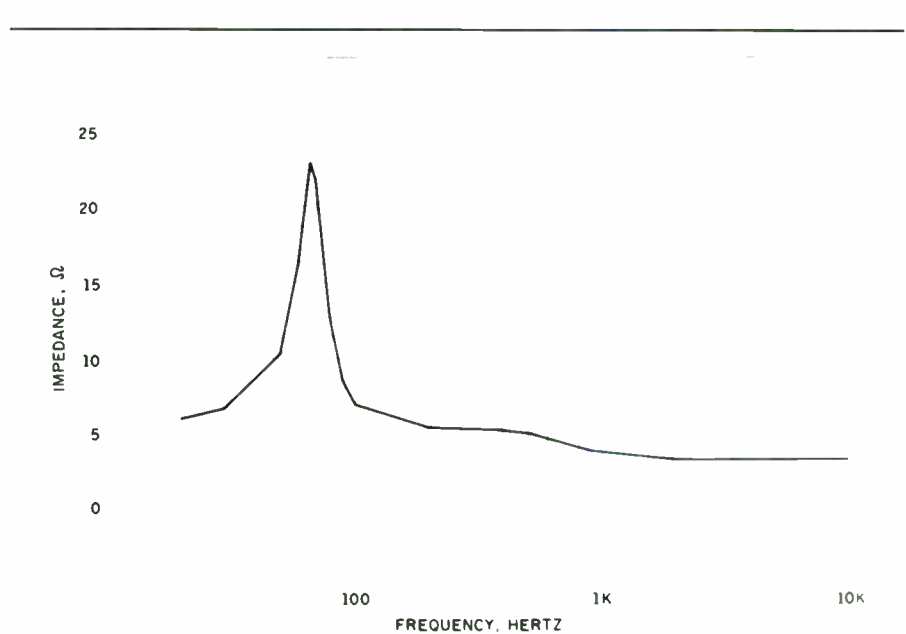


FIGURE 7: Impedance of one voice coil with other voice coil reversed and connected in series with a  $32\mu\text{F}$  capacitor.

These applications could even go beyond dual-coil speakers. For instance, two or more drivers share an enclosure in some speaker systems. Unless the speakers are identical and driven by the same signal, look for some of the same effects discussed here, perhaps somewhat diminished. An imaginative person could achieve some interesting results, using these ideas.

David W. Davenport  
Raleigh, NC 27615

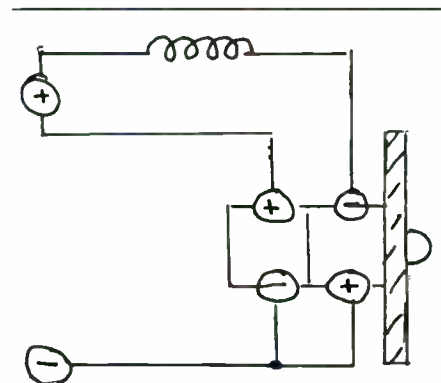


FIGURE 8: High-pass crossover using an inductor.

# Kit Report

## The VMPS Small Subwoofer

Manufacturer: VMPS, 3412 Eric Court, El Sobrante, CA 94803, (415) 222-4276.  
List Price: \$299.

Late in 1985, I purchased a pair of Siefert Maxim III speakers factory-direct on a thirty-day trial. I had been looking for good-sounding speakers smaller than my Polk 10s. The *Stereophile* review of Siefert's speakers was so complimentary I couldn't resist trying them. I waited nearly two months for them, because the company had moved and the review had produced a demand which exceeded their production capabilities. The review said these 9 x 11 x 13" speakers had a -3dB point of 43Hz and would play loud cleanly. The promise of such low bass from speakers this size intrigued me. Siefert's literature claims a -3dB point of 46Hz, which I believe is more accurate. I used a *Stereo Review* test record with warble tones and a Realistic sound pressure level meter to measure speaker response and distortion. These indicated a rapid roll-off below 50-60Hz, depending on their proximity to the rear wall. Unless I placed them within one foot of the rear wall, I heard no low bass.

### The Audition

But my subject is the subwoofers I added to augment the Siefert's lower register reproduction. Since Itone Audio, the purveyor of the VMPS speakers, is conveniently located near my home, I carted the Siefert's over there to listen to what the smaller VMPS subwoofers would do. The IA demo room is carpeted and covered in Sondex-type panels at the end where the speakers are located. In this darkened room I concentrated on the sound instead of the visually unattractive speakers. What a clever sales approach.

The signals were carried through a garden hose-size Monster cable (reported to cost \$9 a foot) from a rack at the opposite end of the room. I listened to various classical, orchestral, and jazz piano selections on a Sony CDP-650ESD compact disc player, connected directly to a Classe



**PHOTO 1: The VMPS smaller subwoofer, front view. The passive driver vents through the panel, at bottom.**

Audio power amp. First I listened to the Siefert's alone. Then I heard them at slightly higher than "live" levels. Since my ears are quite sensitive to sound pressure level, I generally listen to less than live concert levels. But I make exceptions when the music and the hardware combination reproduce sound without distortion and when a performance is true to the composition. When the subwoofers were added to the system, I heard another octave of low bass and the lower middle range. The bass was also much cleaner.

This all happened with the passive crossover which rolled off the subwoofers above 100Hz about 12dB/octave (see *Fig. 1*). It gave me the option of rolling off the low end of the main, or satellite, with or

without speakers. With the Siefert's placed on top of the subwoofers the sound stage presentation was seamless—no localization of frequencies. In other words, I couldn't sense where the Siefert's left off and the subwoofers came in. Perhaps this was partly due to the frequencies' large overlap produced by both sets of speakers. As with all choices in audio, two schools of thought on overlap exist. One says a lot is good; and the other, of course, advocates as little overlap as possible.

### One or Two?

If you have done much reading about audio reproduction, you know of the ongoing argument over whether or not stereo separation worth reproduction exists below 100Hz. One faction says it is worth the effort, while the other says localization and ambience clues occur mainly at frequencies higher than 100Hz (some say 200Hz). I believe there is merit to both sides of the argument, but qualifications are needed.

I can hear recordings with stereo separation below 100Hz, but most of the effects from stereo separation are in the range of 100Hz-3kHz. So I can enjoy stereo using just one subwoofer, but two are better. Perhaps the greatest advantage to be gained from two subwoofers is not the stereo information below 100Hz, but the seamless blending of the sound from the satellites and the subwoofers.

Seamless blending is most readily accomplished when the satellites are placed close to the subwoofers. Various configurations of KEF and B&W speakers have had the tweeter and midrange drivers mounted in separate enclosures on the tops of the bass sections. Emulating this configuration for satellites and subwoofers worked very well for me. To argue that the subwoofers replace stands otherwise needed for the satellites may help you sell your spouse on the new addition to the decor.

Don't be afraid to experiment with relative placements between the satellites and subwoofers. The VMPS installation in-

structions suggest you place the subwoofers as much as 10" in front of the satellites to align them properly. The setup enables you to easily vary the satellite front-to-back placement in the horizontal plane.

The audio information from the subwoofers is non-directional, so you don't have to place them exactly facing the listening position in order to have good sound. Directionality increases as the frequency rises in relationship to the diameter of the drivers. The best stereo imaging results when the satellites are pointed toward the listening position. Placing the satellites on top of the subwoofers allows more flexibility in subwoofer placement. From this raised position they can fire over the top of the furniture while the subwoofers, although somewhat blocked by furniture, are not diminished by it.

### Bass Reproduction

Bass reproduction from the subwoofers, as from any speakers, will be affected by their proximity to room surfaces. To get convincing bass frequency reproduction, place the subwoofers well out into the room so the only nearby room surface is the floor. Move the subwoofers closer to the rear wall of the room to reinforce the bass registers. These subwoofers each have a 12" polypropylene cone active driver and a 12" passive radiator which fires into a cavity at the bottom of the cabinet. This cavity is only open to the front of the cabinet via a slot in the front baffle. The smaller VMPS subwoofers are designed to be placed on the floor either vertically or horizontally. Mortite putty ropes, applied to the passive radiator cones at the factory, fine tune their damping. The instructions say you can vary the damping by adding or subtracting putty to increase tautness or low-frequency extension.

### Building the Kits

You can buy all VMPS subwoofer drivers and passive crossovers either factory assembled or as kits. The optional John Curl designed, (\$449), electronic crossover is not available in kit form. I opted for the kit version. Besides saving money, I get a lot of satisfaction from building them.

You can buy the VMPS subwoofer kits with finished cabinets and passive radiators already installed. Presumably these are put in before the bottoms of the cabinets are closed up. You must assemble and install the passive crossovers. The polyester knit fabric comes mounted on the grille frame which snaps into place with sturdy plastic clips.

The crossover consists of a dished plastic terminal board with binding posts and spring clips installed, a potentiometer for adjustment of the satellite levels, an inductor, nonpolar electrolytic capacitors with polypropylene bypass, and Monster cable for the internal wiring. It is the original, not Powerline 2 or 3. The literature says

the inductor has all air core, but mine were iron core—perhaps a design change. This crossover is described as being "quasi-second order, 100Hz low-pass fixed, high-pass variable, mono crossover (one required per speaker, non-summing)."

You will find the crossover assembly is relatively straightforward. My main challenge was to connect the large gauge Monster cable to relatively small terminals. I had to solder these connections with a high-output iron in order to get a good connection with such a large heatsink. It took me about three and one half hours to assemble the kit. Mounting the components in the speaker cabinets and verifying proper speaker/terminal polarity took another half hour. I saved time by using a power

screwdriver to install the eight screws per driver and the four for each crossover.

The kit includes thin weatherstrip material to apply to the back of the drivers' mounting flanges and the crossovers for an airtight seal on the cabinets. Fiberglass batting is included to stuff the insides of the cabinets before you mount the drivers. The kit's instructions leave something to be desired in the way of logic and clarity, but this seems to be the norm for most companies. You can figure out what to do and when to do it; but the directions could be made easier.

### The Sound

Were the effort and the expense worthwhile? I believe they were. The sub-

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woofers sound a little different in my listening room than they did in the demo room, but this is more often true than not. You can never really evaluate the sound of a component and be sure of all of its sound characteristics anywhere other than in its intended location. My listening room is smaller than the demo room, and has a corner fireplace as the focal point for speaker placement. The room is basically rectangular with a wall extending on the long dimension side, so I have very little trouble with standing waves and echoes. The subwoofers add a realistic and pleasing low end to the music. This greatly increases the realism of jazz and orchestral music over what it was with just the Sieferters.

VMPS chooses to ignore many of the more recent tweaks and design features for which so much is claimed by so many. The cabinets are made of walnut or oak-veneer 3/4" thick particle board with no internal cross-bracing or stiffeners. There is no automobile undercoat or other damping compound smeared over the inside surfaces. The woofer baskets are made of stamped steel, not diecast, and have high-strength, lightweight metal alloys. Do these omissions affect the sound? Probably. Do they degrade the sound? I think not. After all, B&W found that once they had made their newest speaker cabinets so rigid, they needed new drivers. Anyway, the subwoofers sound good for now, and have plenty of room for tweaking in

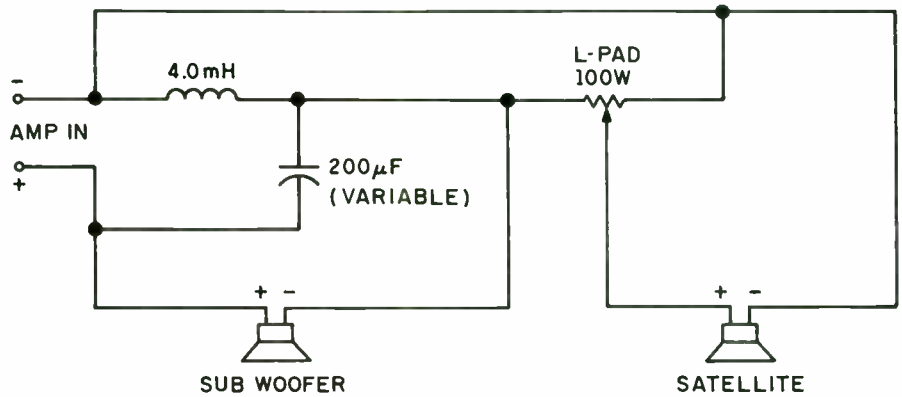


FIGURE 1: The VMPS passive crossover schematic.

the future for me to experiment with changes in the sound.

Would I change anything? Yes, and I plan to. The spring-loaded clips serving as the terminals for the main leads from the amplifier will barely accept banana plugs. I called VMPS to find out whether I could purchase another set of five-way binding posts like those on the satellite speakers. They said they would put them in the mail to me, or I could stop by and pick them up. I'm sure they use two different types of terminals to avoid confusion in assembly and hookup.

If you need a subwoofer or two, you probably won't find any as good as these at the price. The smaller subwoofer is \$229. Each comes in a factory assembled kit form for \$299. The passive crossover is \$30 per kit, and \$40 assembled. ▶

James T. Frane  
Orinda, CA 94563

Photograph by the author

## INCREDIBLE BASS

continued from page 34

voices having its own distinctly defined space within the soundfield. Bass is never heavy, as with many designs having a built-in hump at 60-80Hz and lacking true low bass response. Rather, bass is clean and precise, by virtue of the extended low frequency ability of these speakers. ▶

Completed matched sets of the final crossover version are available in limited quantities. Contact: Robert G. Palmer, 141 S. Alder St., Campbell River, B.C., Canada V9W 5J1, (604) 287-3723 or Wayne Cox, 107-322 Birch St., Campbell River, B.C. Canada V9W 2S6, (604) 287-4887.

## REFERENCES

1. Weems, David B., *How to Design, Build and Test Complete Speaker Systems*, TAB Books, 2nd ed., 1979, p. 158—.
2. *ibid*, p. 130—.
3. *ibid*, p. 161.
4. *ibid*, p. 118—.
5. Knittel, Max R., "Impedance Compensating Crossover," *SB*, 1/83, p. 11—.
6. "Capacitor Match-Maker," *99 IC Projects*, C&E Hobby Handbooks, Summer 1985, p. 47.

7. Weems, David B., *How to Design, Build and Test Complete Speaker Systems*, TAB Books, 2nd ed., 1979, p. 65.

8. Hollabough, John F., "Measure Low Millivolts With a Multi-Tester," *Popular Electronics Handbook*, Ziff-Davis Pub. Co., 1977, p. 11—.

9. Weems, David B., *How to Design, Build and Test Complete Speaker Systems*, TAB Books, 2nd ed., 1979, p. 253—.

10. Knittel, Max R., "Impedance Compensating Crossover," *Speaker Builder*, 1/83, p. 11—.

11. Bullock, Robert M., "Passive Crossover Networks," *SB*, 1/85, p. 13—.

12. Weems, David B., *How to Design, Build and Test Complete Speaker Systems*, TAB Books, 2nd ed., 1979, p. 130—.

13. Weems, David B., *Building Speaker Enclosures*, TAB Books, 1st ed., 1981, p. 76—.

14. Weems, David B., *How to Design, Build and Test Complete Speaker Systems*, TAB Books, 2nd ed., 1979, p. 65—.

15. *ibid*, p. 95.



## EDITORIAL

continued from page 8

Thus the Sony purchase may well bring a new level of excellence to CBS Records, help remove the cloud of doubt hanging over a new recording technique that can give music lovers a new and excellent recording medium, as well as remove the threat of butchered recorded music on a variety of future compact disc offerings. Some speculated that the Copycode proposal might well threaten the acceptance and marketing success of DAT altogether. I think such a result may have been far more costly than just the loss of a potentially fine audio recording system. DATs apparently also have enormous potential as data recording devices and are actually fast enough on search to serve as possible competitors to fixed data disk home computers and present forms of tape backup systems for them.

I hope all of you are facing the new year with a renewed sense of fresh and challenging opportunities—of good luck and beneficent dragons.—E.T.D.



# SB Mailbox

## CORRECTION: POWER RESPONSE

Joseph D'Appolito's reply to Mr. Fagen's letter ("Lower Response and Equalization," SB 4/87, p. 59) contains an error in the second paragraph, which should read:

*Power response is a measure of the maximum acoustic output a speaker will produce at its maximum allowable input power. At higher frequencies maximum input power is limited by voice coil heating. At lower frequencies it is limited by maximum voice coil throw. Power response is often referred to as "large signal" response and represents the input power level above which driver operation becomes nonlinear. Power response is displayed on a plot of dB SPL versus frequency. The maximum allowable input power that produces that sound pressure level may also be plotted.*

In addition, in Mr. D'Appolito's description of the Swan IV (SB 4/87, p. 39), inter-driver time delay has been reduced to less than 5µsecs (not 5mSecs, as stated).

## CORRECTION: OCTALINE

I am writing about John Cockroft's Octaline article (SB 3/87). I believe the wiring diagram (Fig. 3, p. 14) is incorrect. The right side of the 6.6µF capacitor and the 5Ω resistor seem to go nowhere.

Stephen Horn  
Plymouth, MA 02360

Mr. Cockroft replies:

*Thank you for pointing out the error in the wiring diagram. To be correct, the leads you mention should have a loop tying them together like the one tying the two resistors together. I can only assume someone in the art department was out to lunch (perhaps it was the free lunch I read so much about a couple of years ago in SB).*

*Since the Octaline article was written, I have altered the crossover slightly. The 6.6µF capacitor has been replaced by a 4µF capaci-*

*tor and the 5Ω resistor has been increased to 6.7Ω—I used a 10Ω and a 20Ω resistor in parallel.*

*In addition, the caption for Photo 2 states "½" felt," but the photo shows ¼" felt; also that I found cotton more effective than felt. I meant cotton was effective but easier to obtain.*

*Page 10 refers to naming the Octaline "because I have arbitrarily chosen a length about ½ of a line based on Bailey's thinking." I have no idea what Dr. Bailey was thinking. What I intended was that I named the speaker because I picked about ½ the length of a line designed by using the prevailing theory. I don't know of any instance where Dr. Bailey espoused the quarter wave theory.*

## SETBACK AND PHASE SHIFT

This comment is a result of recent articles by Max Knittel ("Step Response of Loudspeakers," SB 4/86) and Ralph Gonzalez ("An Introduction to Frequency Response and LMP," SB 1 and 2/87) and my experimental work with two loudspeaker systems.

Mr. Knittel's article discussed the setting of speaker placement to attain the best response to a step input, for a true reproduction of transients. He suggested the method of using the step waveform and a microphone/oscilloscope for instrumentation. I have adapted his method with the idea that proper placement of the mike will give data to determine the proper setback, with suitable calculations, if your cabinet is fixed at the time of the tests (Fig. 1). This test established the distance from the apparent sound sources rather than some estimated position. I implemented a short program on my computer to solve the math.

My tests on two speaker systems indicate the tweeter must be set back 3", for example, when physical geometry of the speakers would suggest only about 1.5". I believe the measurement includes time delays due to the leads and lags of the crossover and compensation, if used, as well as the physical displacement of the speakers.

Mr. Gonzalez's article discussed the time phasing of speakers (Part I), giving considerable emphasis to the phase shift at crossover and did not clarify, in my mind at least, the relationship of the cross-

over components and this time phasing. Using his computer software I obtained smooth frequency response with smaller displacements than I established in my tests. I was not able to see the phase relationships that would help me.

I am convinced Mr. Knittel's and my approach is correct, to account for the real time phasing needed; even though crossover lags and leads, the only other factor I see, vary with frequency. I have attempted to check the phasing as a function of frequency but do not see a difference over the range of frequencies I can test. The sound reproduction of properly phased speakers is far superior to the unphased system, my final convincer.

I purchased Mr. Gonzalez's software and find it interesting to use, though I could not run a result to the printer with "Ctrl-PrtSc" when using the compiled program; it did not print the graph. Everything worked fine on the BASIC interpreter program.

Arthur E. Brown  
Davison, MI 48423

Mr. Knittel replies:

*First, your basic method seems useful and has the advantage over the step response in using relatively common and inexpensive equipment (square wave generator and oscilloscope). I tried a similar method several years ago with varying results and finally settled on the two-microphone method (Fig. 13, SB, 4/86, p. 12).*

*The problem with any phase or alignment by time method is that when listening, your ears should be along the same axis for which the speaker was aligned. In your experimental setup, it appears you should listen on the woofer axis to maintain the correct interdriver phase relationships. In the step response test, I try to locate the test microphone at the height and distance of my listening position, producing very personalized speakers.*

*Delays in the arrival times of the outputs of the woofer and tweeter in a two-way system can be caused by at least four variables:*

- 1. Physical differences in the sizes and shapes of the drivers.*
- 2. Different time delays between the inputs and outputs of the individual drivers.*
- 3. A phase difference between the outputs of the high- and low-pass sections of the crossover.*
- 4. Relative distances between the drivers and measurement location.*



In a two-way speaker system, a first-order, 6dB/octave crossover produces a phase difference of 90° between the outputs of the high- and low-pass filters. This phase difference is constant for all frequencies. All other considerations equal, this would be the most desirable type of crossover. Higher order crossovers produce varying degrees of difference between the outputs of the high- and low-pass filters that are dependent on frequency, particularly even-order filters.

Since the first-order crossover introduces a phase difference of 90° between the woofer and tweeter, we might start by trying to compensate for a quarter wavelength path difference at the crossover frequency. For example, if the crossover frequency is 3.5kHz, then:

*add to eq 2000?*

$$\begin{aligned} \frac{1}{4} \text{ wavelength} &= \frac{1}{4} (c \div f) \\ &= \frac{1}{4} (13068" \div \text{sec}) \\ &= 0.93" \end{aligned}$$

Therefore, we might want to move the tweeter back about 1" to compensate for the crossover induced time delay.

Adding 1" to the 1.5" geometrical difference between the drivers gets fairly close to your measured tweeter setback of 3". The additional 0.5" may come from phase shifts in the drivers themselves. I have found that impedance compensation (Zobels) to the drivers makes their phase responses more constant with frequency.

Ralph Gonzalez replies:

I'm sorry if my article wasn't clear on the relationship between driver phase angles and the net loudspeaker response, and welcome the opportunity to discuss this with you, since you have done considerable work.

Driver phase angle, crossover phase angle, and interdriver depth displacement are all significant factors in determining the phase angle between drivers in a multi-way speaker. As I discussed in my article (Part I), the limited bandwidth of a practical driver causes phase shifts near its upper and lower frequency limits. If you have entered a correct LMP model for your drivers (according to the procedures in my article), as well as entered the correct crossover components and carefully measured the physical depth displacement between the diaphragms of the drivers, the frequency response graph produced by LMP should be comparable to the actual loudspeaker, carefully measured in an anechoic chamber.

Incidentally, to see the phase response of a single driver, enter its model into LMP, using crossover #0. To see the phase angle of the individual driver/crossover sections of your completed loudspeaker, temporarily reduce the "sensitivity" of the remaining driver(s) by about 60dB. Then you can judge the phase relationships among the drivers.

If there is a disparity between your measurements of frequency response and the graph produced by LMP, it is possible the models you entered for your drivers need adjustment.

This is a critical and potentially troublesome area when using LMP. For example, your woofer's high frequency rolloff may be closer to fourth-order than second-order, as explained in Part II. Also, during your measurements if your microphone is off-axis from one or both drivers, make sure to use that driver's off-axis curves to determine its LMP model.

Perhaps you could clarify your test procedure. You should use the physical difference in the distances from the microphone to the woofer and tweeter diaphragms (not w2-w1) for LMP's depth displacement.

Let me give a little background information before discussing Max Knittel's article. A rare but interesting loudspeaker is the minimum phase type, which some claim to be audibly superior in soundstaging and tonality. With such a system, obtaining flat on-axis frequency response will result in a net phase angle near zero over much of its range. Compare the phase responses in Fig. 1b and 2d (Part II) in my article. This would appear to be a desirable characteristic, since it is necessary if you want to preserve the shape of the music waveform. Square waves, steps and impulses are reproduced accurately. On the other hand, I have not yet seen conclusive evidence that the benefits are audible.

Only an ideal first-order crossover can produce a minimum phase speaker. (There are other unconventional approaches, but without compromises.) Unfortunately, it is very difficult to achieve an ideal crossover, since the phase angle of many raw drivers at the crossover frequency is itself already greater than the phase angle required of the driver/crossover combination.

The reason most speakers cannot produce a convincing step response is that they are of the non-minimum phase type, where a flat frequency response is obtained in conjunction with a non-linear phase response.

Mr. Knittel's article provides a powerful tool for evaluating loudspeakers and individual drivers. However it is not quite correct to say a tweeter whose diaphragm is physically aligned with the woofer may still "speak" earlier than the woofer, since a true time delay does not exist between the drivers. The phase shift between the drivers' limited bandwidth and/or its crossover is not the same as the phase shift caused by a simple time delay, and therefore cannot be accurately compensated by adding a deliberate interdriver time delay (SB 1/87, p. 22).

As you obtained the best step response by setting your tweeter back 1½" more than required to align its diaphragm with your woofer's (of course, this conclusion applies only to your driver/crossover combination), it is not clear to me whether adding interdriver time delay to a conventional speaker will necessarily result in a speaker more nearly minimum phase, since a time delay is itself non-minimum phase. Note, for example, the much poorer initial rise in the step response of the corrected three-way system in Knittel's Fig. 11c, compared with his midrange driver in Fig. 8a. On the other hand, changes in interdriver depth displacement usually have

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significant, audible effects on the frequency response near the crossover frequency and may be adjusted for optimum results using LMP and/or measurements and listening tests.

An entirely different consideration from that of minimum phase response is the amount of interdriver phase shift at the crossover frequency. Mr. Knittel describes how to adjust the interdriver depth displacement to reduce this phase shift to zero at the crossover frequency. The result will often not have the driver's diaphragms aligned at equal distances from the microphone, since the driver and crossover phase shifts may cause an additional interdriver depth displacement to be required for an interdriver phase shift of zero at the crossover frequency. Eliminating interdriver phase shift at the crossover frequency is often desirable since it results in symmetric vertical lobing at the crossover frequency. However, as indicated in off-axis response in my article (Part II), a mild dip in the reverberant response may occur.

More relevant to the issue is the fact that having the drivers in phase with each other is neither necessary nor sufficient to produce a minimum phase loudspeaker. For example, with an ideal (i.e., assuming perfect drivers) first-order, two-way crossover, the on-axis frequency response is flat, and the phase angle of the combined drivers (relative to the input signal) remains zero through the crossover region. While the system is thus truly minimum phase, the low-pass section alone has a phase angle of  $-45^\circ$  at the crossover frequency, while the high-pass section is at  $+45^\circ$ , resulting in a  $90^\circ$  interdriver phase angle. This results in asymmetric lobing at the crossover frequency, but a flat frequency response.

On the other hand, with an ideal fourth-order crossover, the drivers are always in phase with each other ( $0^\circ$  interdriver phase angle), yet the phase angle of these drivers relative to the input goes from near  $0^\circ$  at low frequencies, to  $-180^\circ$  at the crossover frequency, to  $-360^\circ$  at high frequency—clearly non-minimum phase.

As you can see, this is a complicated and non-intuitive area. You might want to read about Laplace transforms and frequency response analysis in a good engineering text, such as Ogata's [see References—Part I]. I frequently see incorrect conclusions about "phase" by professional audio reviewers and attempts by many manufacturers to exploit the public by misleading use of terms such as linear-phase, phase-coherent, phase-correct, and so on. None of these terms necessarily imply true minimum phase response.

I hope I have managed to clarify this issue, and wish you luck with your speaker designing.

Arthur E. Brown writes:

I appreciate the comments from Messrs. Gonzalez and Knittel and I have continued my experimental work to learn more

about my system and to expand on the test I performed.

In my original basic test set-up (Fig. 1), Mr. Gonzalez suggested I should use the actual distances to the speakers as setback for the tweeter rather than the  $w_2-w_1$  distance. I assumed that the  $w_2-w_1$  distance represents the offset that is "seen" from the listener's position. I have shown the mike in-line with the woofer to allow a simple presentation of the calculations. I actually have a general program in my computer to handle any mike position. I get essentially the same  $w_2-w_1$  results regardless of the mike position. I have even run the test with the mike directly in front of a speaker at a selected distance to the speaker mounting panel, other speakers off-line, and confirm the  $w_2-w_1$  measurement. I trigger my scope from the square wave from the amplifier that drives the speaker to eliminate the possible amplifier phase shifts.

The speaker systems I am testing are two-way. The first system has a 5" low frequency cone driver and a dome tweeter, with a third-order 2250Hz passive crossover. The other system has a 10" low frequency cone driver crossing over to a dome tweeter at 1.7kHz with a second-order crossover.

Mr. Gonzalez suggested I could identify my time lags by looking at the LMP model. Using the first system I was able to see much of the system behavior, but could not account for the behavior as it happened. Mr. Knittel pointed out the driver might be a significant factor. I ran tests of the individual drivers with the mike at a fixed distance, with and without the crossover. With the data I was able to relate the effects I had seen.

To understand my data, please consider the following. A filter—a spring-mass or an electrical network, responds to a step signal in a particular manner. Its initial response is directly dependent upon the filter high frequency characteristic response. The latter part of response then behaves based on the total bandwidth of the system. Generally these responses are independent of the step (square wave) frequency if the base frequency is in or below the bandwidth of the filter and the period of the step signal is sufficiently long to allow the total transient to happen. The results of driving a repetitive step into the drivers is discussed next.

The dome driver responded very quickly and was under damped. With the high-pass crossover circuit connected there was no change in the initial response, no additional phase lag or lead. There was a slight change in the damped part of the response. The 5" cone driver also showed a rapid response to the step, again under damped. When I inserted the low-pass crossover I saw a significantly slower response and additional phase lag to the response. I interpret the distance difference between just the two drivers' data

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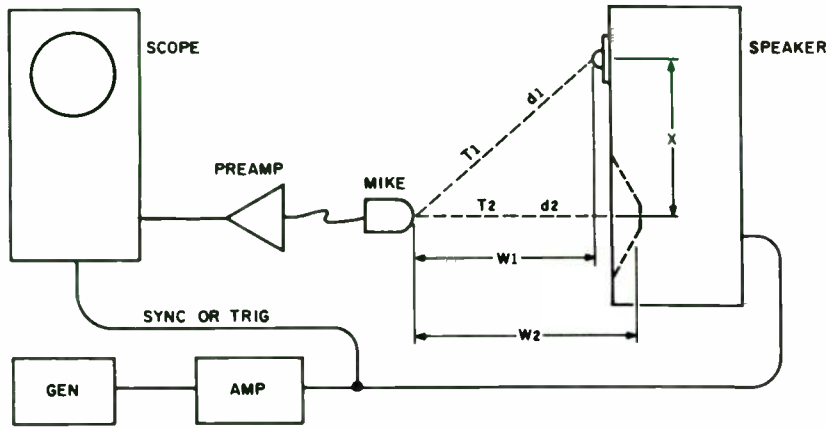
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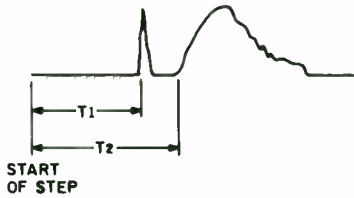
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$$\text{FROM SOURCE TO MIKE}$$

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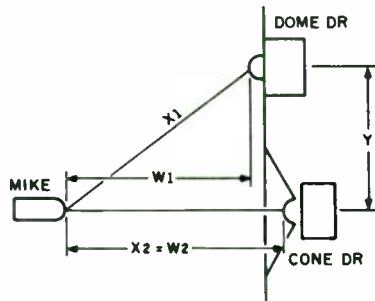
$$w2 = d2$$

$$w2 - w1 = \text{DISP NEEDED}$$

FIGURE 1: Test setup.

as the distance between the apparent sound sources of the two drivers; the distance differences between the 5" driver with and without the low-pass filter as the phase effect of the filter.

This phase effect did not change with frequency of the step wave as long as the drive requirements were met (above). It was interesting that I could choose the dome response to fall where I wanted, relative to the 5" driver plus filter response. My choice led me to move my dome tweeter back about 1" for driver geometry and 2" for filter phase effect. This data did not correlate with the LMP model data. It repeated very well with changes in test parameters (Fig. 2) such as mike position



$$X1 (X2) = 13500 \text{ f/s} \times T \text{sec}$$

$$w1 = \sqrt{X1^2 - Y^2}$$

$$w2 - w1 = \text{OFFSET NEEDED}$$

FIGURE 2: Revised test setup.

changes. The response curves of the drivers are shown in Fig. 3.

This procedure does not take into account the drivers' signals phase as many discussions do at crossover. I am not sure whether in-phase operation of drivers at crossover is possible, with all I have seen in this experiment.

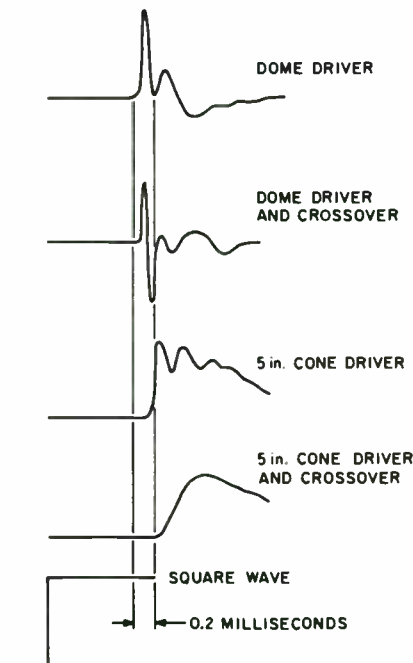


FIGURE 3: Response to step signal.

Presently, I am in the planning stage of constructing Craig Cushing's compact transmission line subwoofer (SB 1/87). Before I commit myself to any definite plans, I was wondering whether he had thought of any modifications since. For instance, is the best driver still the Peerless TA30F? If not, what would Mr. Cushing recommend and how would this driver affect the dimensions of the speaker enclosure?

I would appreciate any tips for a beginner speaker builder.

Lawrence Perez  
Salt Lake City, UT 84102

Craig Cushing replies:

I might suggest one basic modification regarding construction of my subwoofer, which is cosmetic in nature. Lower the horizontal baffles and angle baffles by approximately 5/16" to allow a piece of glass to be recessed flush with the top of the cabinet. Naturally this requires veneering of the top edges of the cabinet too. Otherwise my system remains as originally described.

Several readers have suggested the Eclipse W1238R woofer, available from Meniscus. \* I plan to try one of these woofers soon, and my guess is it will work well. Gary Galo, Contributing Editor for SB, has tested the 10"

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companion to the 12" Eclipse model and has found it to be an excellent driver. KEF drivers have been used to good advantage in numerous TL designs, and the B300B, SP1071, a 12" Bextrene-cone driver, is highly recommended by the manufacturer. Its specifications look good, but its one drawback is cost, about \$165, considerably more than either the PLI or the Eclipse drivers.

For the beginning speaker builder, reading the available literature on speaker system design and construction is my best advice. Some books which will be helpful include Martin Colloms' High Performance Loudspeakers, 3rd edition (comprehensive, but pretty technical); The Loudspeaker Design Cookbook (highly recommended); and David Weems' Building Speaker Enclosures (the projects are only based on Radio Shack drivers, but there is other useful information).\*\* It goes without saying Speaker Builder should be on your shelf.

Secondly, work carefully when you are actually building. Don't do anything without reading instructions at least twice. Thirdly, don't be afraid to make mistakes, because you will, no matter how careful you are. I continue to make errors in judgement and execution—and I expect to. But I learn something each time, and I forgive myself for those errors.

Take your time when building the subwoofer. It's a project that could rightly be called "high intermediate" in difficulty. Careful planning and leisurely construction will help you immensely.

\*Meniscus: 3275 Gladiola SW, Wyoming, MI 49509.

\*\*The first two books are available from Old Colony Sound Lab; the latter from your local Radio Shack.

## A CATENOID CORNER

Some years ago I acquired a homemade Lee-Catenoid corner horn speaker. My son has it now and it needs repair.

Do you have any knowledge of the speaker or access to any literature concerning its construction? Since this horn is smaller than most I think it might be worthwhile to rebuild it, using modern speaker design improvements.

Frank N. Nichter  
DeLand, FL 32724

Bruce Edgar replies:

The Lee-Catenoid horn enjoyed a brief popularity in the mid 50s. It used the hyperbolic horn formulation for a  $\text{Cosh}^2 \text{MX}$  (hyperbolic cosine) area expansion rule:

$$T = 0$$

A side view of the horn is shown in Fig. 1 from an article by Augspurger (Radio Electronics, V. 26, May 1955, p. 83). The term catenoid comes from the catenary curve

which is generated by a uniform chain, hanging under its own weight between two points. If one point is higher than the other, the curve is described by the hyperbolic cosine function.

The catenoid horn expands slower at the throat but then flares rapidly at the mouth. This can translate into a smaller horn volume than an equivalent exponential horn. The drawback to the catenoid horn is the throat resistance is not uniform and becomes very large at the flare cutoff frequency. I would expect a very boomy sound as a result. In contrast, the throat resistance above the cutoff frequency for an exponential horn is fairly uniform and goes to zero at the cutoff frequency. Although I have not heard a catenoid horn, I have experimented with hyperbolic

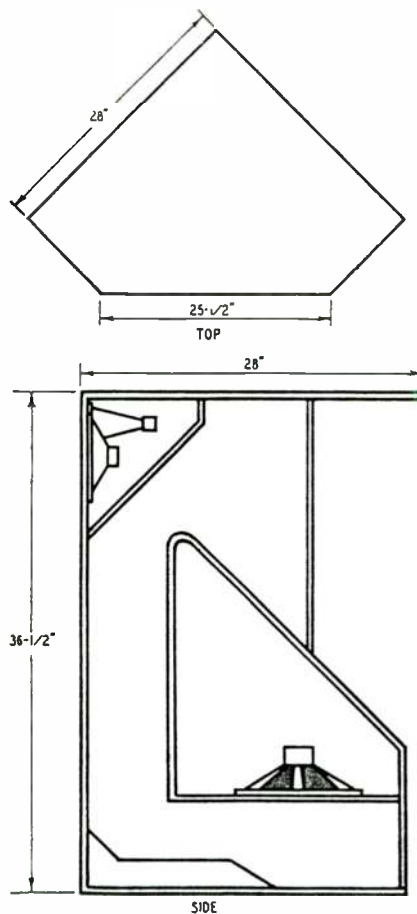


FIGURE 1: Internal layout of Catenoid.

horns with  $T$  values less than 0.5 and they always had boomy bass.

The Lee-Catenoid design used a 12" driver with 1:1 coupling at the throat. The bass horn crossed over at 300Hz to a direct radiator midrange with a horn tweeter turning on at 6.5kHz. The direct radiator midrange implies the bass horn had very little bandwidth and did not have the usual horn efficiency.

Due to the generosity of a SB reader, I have a set of plans for the horn that appears to be from an underground source. (Interested readers can write to me through the Editor for a copy of the plans. Provide a 9 by 12 self-addressed envelope and US postage for 2 oz.)

Scaling the throat and mouth areas and the

total path length from the drawings and plugging into the  $\text{Cosh}^2 \text{MX}$  expansion formula, I found it is approximately a 50Hz horn.

Most any 12" driver will produce boomy bass in a catenoid horn with varying efficiencies. I would try available 12" drivers to see what sounds acceptable. I would use a catenoid horn only as a subwoofer, which may be its best application.

## "NEW" IDEAS

I would like to comment on Mr. Sommerwerck's article on SCES 87 (SB 3/87). He mentions Thiele is using a copper ring on the voice coil of their woofers.

If I remember correctly, my pair of Philips (Norelco at the time) 12" dual cone speakers about 23 years ago had a copper ring inside the coil or the gap, I don't remember; something similar to smooth out impedance.

Also, I would like to congratulate Mr. Sutheim on his article about Richard Heyser—what a pity such a brilliant man had to leave us so soon.

Rafael Lopez  
Miami, FL 33125

Mr. Sommerwerck replies:

It is no surprise this showed up in Philips' speakers of 25 years back. An invention often reappears every 20 years or so, as a "new" idea.

## REINVENT THE WHEEL

Mr. Sommerwerck's special report on the 1987 CES was well done and enjoyable. I disagree with his review of Acoustat's Spectra ESL, however. The "new" ESL with electrical subdivision of six separate panels in a frequency dependent fashion for improved high frequency dispersion is hardly a "breakthrough design." Rather, The Hafler Corporation has reinvented the wheel, albeit a better wheel.

Subdivision of electrostatic panels into R-C networks by feeding sections of wire grid stators through fixed valve resistors is not new. This design idea is elegantly described by Charles Malme ("A Wide-Range Electrostatic Loudspeaker," JAES, Jan. 1959) and A. Janszen, R. L. Pritchard and F. V. Hunt (Electrostatic Loudspeakers," Office of Naval Research: NR-014-903, 1950). These articles describe a method of electrically curving a planar electrostatic loudspeaker for improved high frequency dispersion. Although difficult to find, the articles contain much information for builders of ESLs and are well worth reading.

I currently use this technique on my own ESLs and home-built "sheathed conductor" stators, based on Janszen's description.

As an old sage once said, "There is nothing new under the sun, just new reflections of old ideas."

David Lang  
Milwaukee, WI 53213

## PASSIVE CROSSOVER NETWORKS

I have just read Mr. Bullock's article, "Passive Crossover Networks," *Part I* and *II* (SB 1 and 2/85). I plan to use his formulas for the new first-order crossovers on a three-way design, using APC networks.

I am a little confused on what values to use for determining  $R_L$ ,  $R_M$ , and  $R_H$ . Mr. Bullock states in *Part I* the load resistances should be the DC resistance of the particular driver being used. I have always thought the load resistance should be the actual impedance value of the driver at the crossover frequency. I plan to equalize my drivers to enable a smooth impedance curve. Please explain which is the better way to go.

The same question applies to the source and inductor loss formulas. In *Part I*, Mr. Bullock uses  $R_E$  for determining source and inductor losses. In *Part II*, he uses  $R_M$  for the formula:

$$LG = 20 \log (R_M + R_S) \div R_M$$

I assume that the same formula can be used for  $R_L$  and  $R_H$ . However, which is preferred, using  $R_E$  or using the impedance value of the driver at the crossover frequency?

I would also like Mr. Bullock to explain why the bandpass output level is too high to match the other sections.

As a final question regarding *Part II*, he states limitations on using his formulas on first-order, three-way crossovers. Is there a better way? Are the following formulas on page 30 correct:

$$A = (R + 1) \div R \text{ and } H = (R - 1) \div R?$$

Thomas J. Saraceno  
Denver, CO 80221

Mr. Bullock replies:

The design load resistance for each crossover section should reasonably reflect the actual load over some interval about the crossover frequency. Preferably, this interval should be at least an octave on either side of the crossover frequency. Quite often some equalization is required to obtain a flat impedance over such a range. The standard equalization I have described in the article has  $R_E$  as its target value. This is what I had in mind when I made the statement that confused you. If you believe some other value more accurately reflects the design load, then by all means use it.

The same answer applies to your question



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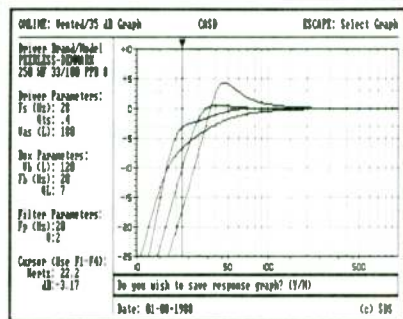
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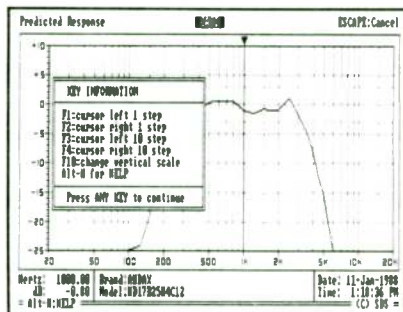
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Fast Reply NEC14

about the inductor loss formula: use the design load value that best reflects the actual value.

There are actually two reasons the bandpass gain needs to be adjusted for proper matching to the other crossover sections. The first is that the bandpass gain is one of the variables used in the derivation of these crossover alignments. This is necessary to get a system of equations with as many variables as equations.

The other reason has to do with the choice of circuit topology for the bandpass section. Each possible choice has its own characteristic midband gain, which is not necessarily the correct one for the crossover alignment. This is demonstrated in the latest of my crossover series (Part V, SB 4/87), where I suggest an alternative bandpass topology to improve the crossover network impedance curve. This alternative topology requires a different value of  $R_A$  than the topology described in Part II, i.e. its midband gain is not the same.

I always use a crossover network of order greater than one. This is my better way.

As you suspect, the formulas are incorrect. In addition to the two you named (Formulas 9 and 10), Formula 16 should also be corrected. In each case  $(R + 1) \div R$  and  $(R - 1) \div R$ , should be:

$$R + (1 \div R) \text{ and } R - (1 \div R)$$

Note: See SB 3/85, p. 45, for the original correction notice.—Ed.

## SW35 IS NOT ISOBARIK

Reading the review of the Focal SW35 kit (SB 1/87), I was somewhat surprised at the configuration of the drive. I did not expect each of the woofers to be driven by different channels. It is my impression that an Isobarik system works best when the woofers are moving in uniform (as closely as possible considering the loading).

With each woofer driven by a different channel, this certainly would not seem to be as uniform as if the two channels were summed and both channels driven by the mono signal.

David Grant Willemain  
Towson, MD 21204

Mr. Davenport replies:

Remember, the SW35 is a subwoofer; it is expected to reproduce only the bass frequencies below 100Hz or so. In a normal stereo recording of live music, the deep bass is approximately the same in both channels. For all practical purposes both drivers are in fact receiving the same signal. You could sum the bass from both channels of an electronic crossover and drive the composite speaker

with this mono signal. Theoretically this would be more accurate and require only a mono amplifier. However, don't discount the dual channel method recommended by Focal; it works fine for the SW35.

Let me clarify one point: The driver configuration used in the SW35 is a composite, not an Isobarik. In a composite, both drivers are tightly coupled and work together as a single driver. In an Isobarik, the drivers are separate. The main speaker faces the outside, while the second speaker provides an acoustic environment for the main speaker.

Note: While the microgroove recording method does not produce a clearly separated stereo image below 100Hz, many compact disc recordings do.—Ed.

## VEEXING HORN PROBLEMS

I am finishing yet another project using information from *Speaker Builder*, a magazine I have learned so much from. I might add all my knowledge has come from TAA and SB and the plans, upgrades and building projects are written cohesively and concretely for the relative novice to follow.

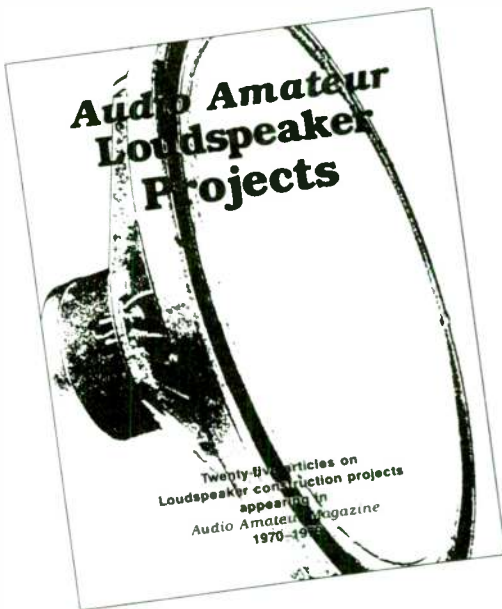
This latest project was building Bruce Edgar's midrange horn (SB 1/86) and 70Hz bass horn (SB 2/83). I had built two D'Appolito enclosures and was impressed with the balanced color of instruments. For the bass I tried several enclosures. From Augspurger's comment about 8" drivers, I chose Dynaudio's 21W54. I tried Cockcroft's Isobarik, Cushing's transmission line (SB 1/85) but settled for the double chamber enclosure revamped by Dick Marsh (SB 3/80), using two 21W54s in each. For house-shaking waves I modified a big bass box designed for the 24" Hartley (TAA 2/78) by David Ruether. I kept the length of the line the same, but quartered the area to fit a 12" Eminence woofer.

I was intrigued with the tractrix curve and horns, so I started with the 70Hz version. The sound is detailed and clean. I continued with the midrange horn, using the Siare 16VR drivers, which I think are beautiful machines. I attempted to make the curve as smooth as possible, using narrow strips of 1/2-1" wide particle board. For spacers I used rubber grommets, compressed a bit. I was amazed, inspired and delighted with the results, and they are very efficient.

Next, I decided on the EV-35 horn tweeter with 104dB SPL. I hear things I hadn't before and the sound is all around me. Imaging is remarkable with depth and overhead sweeping motions. I use a Hafler 220, POOGEd, for the horns and a Dynaco ST150 for the double chamber and the big bass box. The amps have been POOGEd

# Audio Amateur Loudspeaker Projects

Twenty-five articles on  
Loudspeaker  
construction projects  
appearing in  
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for 4P24 OFHC wire, 1% resistors and polypropylene caps where called for.

I would like to regulate the power supply for the bass line. For filters I want to use as little as possible. I built the 30Hz rumble filter and two Jung filters at 90Hz (one high- and one low-pass) at 18dB. Ideally I'd quad amp, but for now bi-amping will do. I am familiar with different crossovers, But I am confused about what value to use for  $R_L$ ,  $R_M$  and  $R_H$ . Of course I am following Mr. Bullock's fine series of articles on filters (SB 1/85-1/86). Do I use the nominal values (8Ω), DC value for the voice coils or resistance values at crossover points (400Hz and 4kHz)? Mr. Bullock does not recommend a 6dB crossover because of its shallow slope, but I think the drivers can handle it. If not, since the spread  $S = 10$ , is an 18dB APC positive polarity favored because of its shallow -1dB dip?

I find Max Knittel's Table 1 very useful and I would evaluate the need for an impedance network if only I had more than a good digital VOM. For the horns, is it necessary? Lastly, to align the voice coils on the same plane—the 70Hz horn has a 50" pathway in front of the driver (and folded). This is hard to align with the Siare and EV, which as separate units are easily moved, relative to each other. Can this problem only be cured with an active delay network a la Linkwitz? I would appreciate comments and expertise in this matter. I am grateful to SB and TAA for fueling my obsession.

Robert Roggeveen  
Port Orchard, WA 98366

Contributing Editor Bruce Edgar replies:

The question of aligning by time bass and mid-horns is a vexing one. After much thought and experimentation, I have concluded that below 300Hz the human ear is relatively insensitive to time delay differences, so that a several millisecond difference between a bass horn and a midrange horn will be imperceptible to listeners.

However, with a midrange horn and a tweeter horn it is important to align the drivers. As a starting point, you could align the voice coils, but the crossover and your seating position will affect the alignment. I have had some success using female vocal recordings (Debbie Harry's voice is particularly useful) for determining the best relative position. If the voice quality sounds rough and edgy, move the tweeter back and forth until you find the voice quality has a smooth, fluid character.

Contributing Editor Bullock replies:

I think you could use either the voice coil DC resistance or the nominal driver impedance and not get into too much trouble, unless one of your crossover points is close to a driver resonance or where the inductance has a significant effect. In this case, or even in general,

run an impedance curve on each driver for an octave or two on either side of the crossover point it affects, and use the average impedance value on this interval.

I usually don't recommend first-order networks because the interaction between the driver response and the crossover response is generally more severe than for higher-order networks. This is not necessarily so, but in the absence of actual measurements, the higher-order network is safer. If you decide to use a third-order APC, I believe the negative polarity is best, because of system impedance considerations. But with a spread of ten, this impedance should not drop to dangerously low levels even with the positive polarity network. The ripple you refer to must be the power response ripple, which occurs with either polarity.

## MODEL-ONE: CROSSOVER

In the article by Kenneth Robinson ("A Model-One Speaker," SB 1/87) the drivers are listed by model number, but not the crossover (2.5kHz, 6/12 slope). Could you please supply the model number?

Arthur A. Twitchell  
Alexandria, VA 22304

Mr. Robinson replies:

The crossover used was assembled by Madisound to complement the drivers. Figure 1

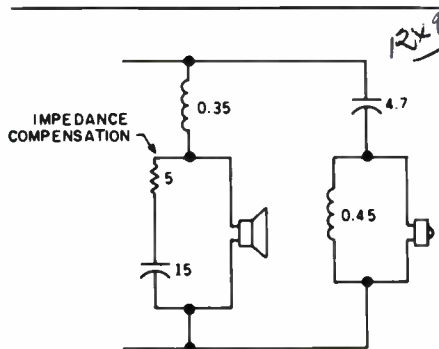


FIGURE 1: Crossover for the Model-One.

is a schematic of the crossover, which I hope will be of help. Perhaps Madisound could supply them upon request. Thank you for your interest in my article.

## ULTIMATE BASS

Is there anyone out there who can help me with the physical dimensions to build a true 16Hz horn?

I will build it out of concrete, with a 4-5"

reinforced wall thickness and be about 20 feet long. I will load it with a three-foot sealed box cube, using a quality 15" driver. Castings will be integrated to facilitate bracket connections for dolly-type transport.

Scott P. Johnson  
Menomonie, WI 54751

## 3/2 DESIGN: MATCHED DRIVERS

I'm very much interested in building Joseph D'Appolito's three-driver, two-way configuration (SB 4/84), using the Dynaudio 17W75 6½" woofer and the D-28AF flat-flange tweeter. I would like to know whether this combination of drivers is suitable, particularly the D-28AF. Although it has a more nearly flat, extended response than the horn version, it is at the cost of sensitivity, which could affect interdriver sensitivity so important to the design.

Mr. D'Appolito presented a method of finding  $V_{as}$  using mechanical conversion by adding mass to the driver diaphragm in free air (SB 4/82). How can this method be applied to twin woofers in a composite driver configuration? Also, I work with English units of measurement. Could Mr. D'Appolito supply the constants in English units for these equations? Is there a material he would recommend for providing the mass at the woofer cone that will stick? Modeling clay just doesn't do the job.

Regarding amplifier power distribution in a satellite/subwoofer system: I use two Hafler amps, one rated at 60W per side and another at 115W per side. If the subwoofer is crossed over at 125Hz, which part of the system requires the most amplifier power?

David Del Zotto  
Seattle, WA 98155

Mr. D'Appolito replies:

At first, the Dynaudio 17W75/D-28AF combination looked promising for my 3/2 geometry. However, extensive testing proved disappointing. The success of my design depends heavily on the two mid-bass drivers sharing power almost equally.

This in turn means these drivers must be reasonably well-matched in  $Q$ ,  $F_{SA}$  and sensitivity (10% or better). Pairs of 17W75s selected at random do not share power very well because of their high driver-to-driver variability in these parameters. I typically experienced driver mismatches of 3-4dB. Since matched drivers are not supplied by Dynaudio, I cannot guarantee the reproducibility of my design with the 17W75 and do not recommend it. On the other hand, I have found stock KEF B-110s and Focal



5N402DBs selected at random will generally match within 1dB. For \$2 more Focal provide matched pairs.

The formulas you are interested in with English units:

$$C_{ms} = \frac{0.893}{M} \left[ \frac{(f_{SA} + f_{SAM}) (f_{SA} - f_{SAM})}{f_{SA}^2 f_{SAM}^2} \right]$$

where  $C_{ms}$  equals driver compliance and  $M$  equals added weight in ounces.

$$V_{AS} = 0.0579 S^2_D C_{ms}$$

where  $V_{AS}$  equals volume in cubic feet and  $S_D$  equals cone area in square inches.

To obtain the compliance ( $C_{ms}$ ) of a compound woofer, first measure the compliance of each driver separately and then combine them to obtain the total compliance using the formula below. Use the total compliance together with the area of a single driver in the formula for  $V_{AS}$ .

$$C_{mst} = (C_{ms1} \times C_{ms2}) \div (C_{ms1} + C_{ms2})$$

Fresh mortite caulking compound will stick well to most plastic-based cones.

Almost all program material has maximum power concentrated in the 200-500Hz region. Furthermore, clipping in the satellite amplifier will be much more objectionable than in the subwoofer channel, so I use the higher power amp with the satellites. Of course, you can try it both ways and decide which you prefer.

## HOOKED ON BI-AMP THEORY

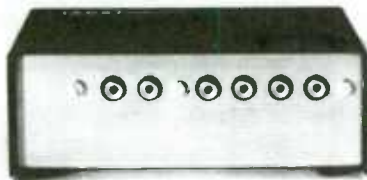
I caught the speaker bug six years ago when I installed a new crossover and midrange in my two-way Infinitys (an Emit and 10" woofer). After helping a friend select new speakers, I wanted to upgrade my own. Unable to shell out the \$1,000 price for what I wanted, I decided to design my own (based on commercial designs).

I then read most of the Thiele/Small articles from the University of Pennsylvania library (I am a grad student in bioengineering), David Weems' book on speaker design (half-price at Radio Shack) and all the speaker catalogs with driver specs I could find. What a mountain of information!

I designed several systems on paper and even one three-way system from old drivers my brother never used. I realized the difficulty in selecting components based on specs alone, without first hearing them. As a compromise I purchased the drivers and crossover in a kit from McGee Radio, a satellite/subwoofer system, and built the cabinets myself.

I then became hooked on the bi-amp theory, so I designed and constructed, including the circuit board, an active crossover (100Hz, third-order Butterworth, low frequency variable EQ, bypass switches, variable gain). My subwoofer

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still had the second-order, passive crossover at 200Hz for a combined rolloff of 40dB/octave above 200Hz. The satellites used only a first-order rolloff at about 70Hz, for a combined fourth-order below 100Hz; pretty wild, but it works. Everything is bypassable, for example, the caps giving the satellites their first-order rolloff, so I can experiment.

I rely on *SB* to shed some light on design alternatives, different construction materials and techniques and new drivers. I most enjoy reading an article about a completed project, one I can duplicate, with a good theoretical introduction. I would also enjoy articles, for example, on the theory behind choosing crossovers—Bessel or Butterworth, active or passive—and their relative merits; and reviews of component drivers as well as kits and construction ideas.

Sandy Weininger  
Philadelphia, PA 19130

## TIE-WRAP FOR SNUG COILS

I read Bruce Edgar's article on coil winders with interest since I've been winding them by hand for about 15 years. One idea I had to prevent the coil from turning into a slinky is to simply put a "tie-wrap" (available from Radio Shack) along the axis of the form. When sufficient turns are attained, simply snug up the tie-wrap and the coil will remain firm.

Another trick I have used is to periodically check the inductance when winding by scraping the insulation, checking, and then reinsulating with electrical tape. Alternately, overwind the coil, check the inductance and subtract turns until the exact inductance needed is arrived at.

If readers are interested, I have a program for the HP-41 and IBM PC which computes turns for air-wound inductors. This is much easier to use than the nomograph because one can adjust for the diameter of the wire. The precision is surprisingly accurate in comparison with trial and error results.

Lastly, the now defunct *Popular Electronics* published a construction article about 10 years ago on a simple and effective reactance measurement instrument. I could never get it to work because my time for tinkering was limited, rather than any defect in the design. I think this kind of measurement tool would be helpful. My Heath impedance bridge is one of the most useful instruments in my shop.

John C. Walton  
Short Hills, NJ 07078

Bruce Edgar replies:

*The idea of using tie-wraps is a good one. To implement it on my coil forms, cut equally spaced radial slots as shown on Fig. 1.*

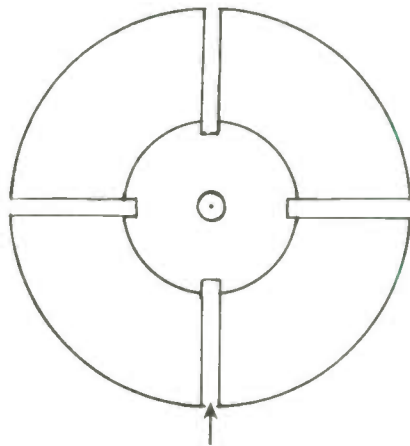


FIGURE 1: Cut slots approximately 1/8" wide.

*I calibrated my forms using your second method—overwinding my coil, taking 10 turns off at a time, and making inductance bridge measurements. The method of checking the inductance as the coil is wound is susceptible to error because the wire left on the wire roll will add some stray inductance. However, I have not done the experiment to determine the magnitude of the error.*

*I urge Mr. Walton to publish his programs for calculating inductance and I strongly second his suggestion that readers invest in an impedance bridge to check their crossover inductors, capacitors and resistors. Although I have not tested it, Fordham carries a B&K Precision LCR meter (model 875) with a digital readout, for under \$150.*

## TL DESIGNS

Using Craig Cushing's design (*SB* 1/87), I built a pair of the smaller TLs for 8" drivers. I reasoned that two drivers would work also, and modified the design to accept Eclipse W0838RLE 8" drivers from Meniscus, that have 2" vented voice coils and 38 oz. magnets with undercut pole pieces.  $Q_s$  was 0.27–0.29 and  $F_s$  was 25–29Hz.

I also added corner plugs to the cabinets. The terminus was split and drivers are mounted on adjacent sides of the woofer chamber, with satellites mounted on top. Oddly enough, I used HIF13H2C12s and an HD13D34HT TW74. Crossovers are 18dB active at 200Hz and 18dB passive at 2.5kHz with a 6dB to the TW74 at 15kHz.

The satellite woofers are B4 aligned with ports to the rear at the top and bottom of the box.

The preamp is an APT Holman and the bass amp is a Kenwood Audio Purist KA 1000 (100W at 8Ω with a feedback to the drivers). The amp from 200Hz is an original B&K ST-140 (70W at 8Ω). Source is from a Dual 1228TT and a Van Alstine modified Magnavox 2041 CD player.

I used Dupont Hollofil® stuffing instead of wool with about 10% more by weight than specified (for wool) with excellent results. I filled the woofer chamber with polyester 1" thick batting.

Would you describe your design for the TL satellites? I think my drivers would be close enough to use your design, or maybe Focal 5N40Ps. I believe in high sensitivity and big magnets.

Though the Eclipse drivers are well-made, there is not enough magnet on most of them, except the W1038R with a  $Q_s$  of 0.29. Gold Sound sells a 40 oz. 10" polywoofer with dual vented voice coil and a 60 oz. 12" poly that might be useful. The new 40 oz. magnet SEAS drivers might also be used.

Are two- rather than four-layer voice coils to be used as they are generally longer in length?

Connol Reid  
Phoenix, AZ 85006

Craig Cushing replies:

*I'm gratified to know you had good luck with my design, and your changes appear to be appropriate in every instance.*

*Either of my designs (*SB* 1/85 and 1/87), with slight modification, can successfully use two 8" woofers if they are of sufficiently low free-air resonance and well-damped, as your Eclipse woofers appear to be. In a recent variant of my 1/85 design, I lowered the woofer chamber shelf and the terminus about 7" each, and installed a pair of Precision Loudspeaker TA205Rs. This combination has plenty of bass extension, excellent power handling, and fine transient response.*

*I haven't experimented with the Hollofil® as stuffing, but on your recommendation I plan to try it soon. Regular polyester fluff just doesn't sound as good as wool in a line, even when the amount is optimized for the smoothest impedance curve; however, it costs a lot less and if the Hollofil® can do the job for fewer dollars, I'll certainly be pleased, as my wool budget is used up for the next five years.*

*Figure 1 will give you an idea of my satellite system. The speakers are big, but they have good bass extension, even without a sub-woofer. The F3 point is approximately 50Hz, and useful response goes to almost 40Hz without over-extending the small mid-bass drivers, at reasonable listening levels. All material is ¾" cabinet grade particle board. The vertical internal baffle is angled to help reduce standing waves. The chamber behind the drivers is lined with 1" thick fiberglass: one sidewall, underside of the top, top of the woofer shelf and angle baffle.*

*The tweeter is flush mounted, and the mid-woofers are "floated" according to Mr. D'Appolito's instructions (*SB* 4/84). Stuffing is presently wool at a rate of 8 oz. per cubic foot of internal volume; this gives the flattest impedance curve with the Audax drivers I use, although other drivers of similar size might require more or less stuffing to approximate the impedance curve.*

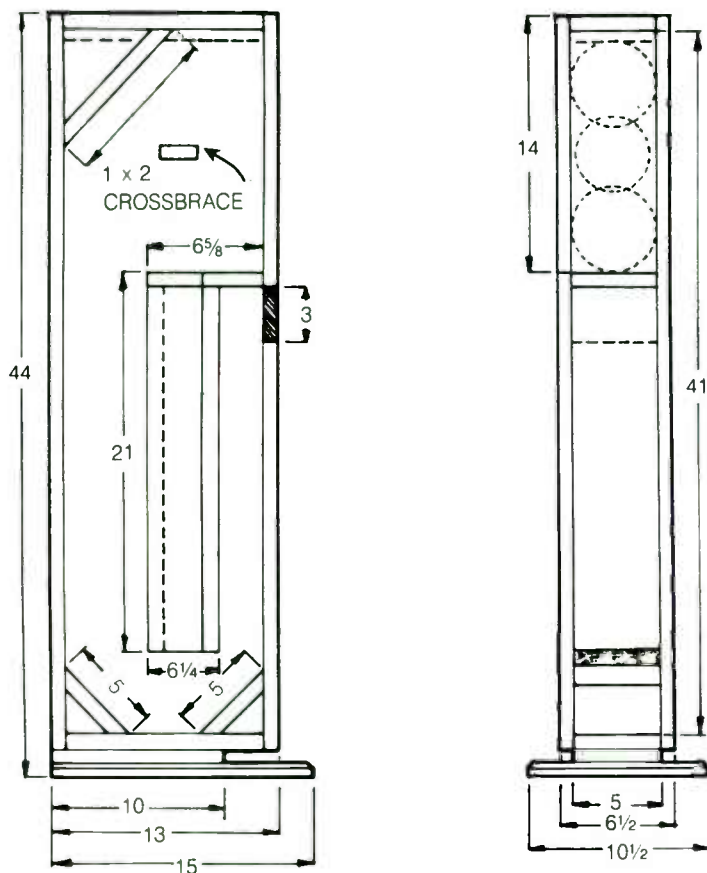


FIGURE 1: Cabinet design for satellite system.

I made my cabinet tops removable to facilitate stuffing changes; battens and closed-cell insulating foam make this possible. The Audax HIF13H2C12s you are using as midwoofers should work in my design and the specifications for the Focals look good. The one drawback to the Audax might be the paper cones, which some contend do not sound as good as synthetic materials.

Interestingly, I recently added to my satellites the same super-tweeters you use—the Audax TW74s. I mounted mine high on the rear of either cabinet facing away from the listener. Crossovers are similar: 6dB/octave at 15kHz, using polypropylene capacitors. This arrangement is from the top-of-the-line Snell system and they provide added ambience and spaciousness to the sound. Output of the TW74s is within 1dB of the others, and their sound is unobtrusive and seamless at the extreme high frequencies. Actually, I think they extend the highs nicely in a range where the Dynaudio mid-tweeters I use naturally roll off at the top end. This modification can be accomplished for under \$15. Although the TW74s are now inlitted into the cabinet backs, I originally mounted them with velcro temporarily, just to see how they sounded, wired in parallel with the Dynaudios using external wiring to the terminals on the back

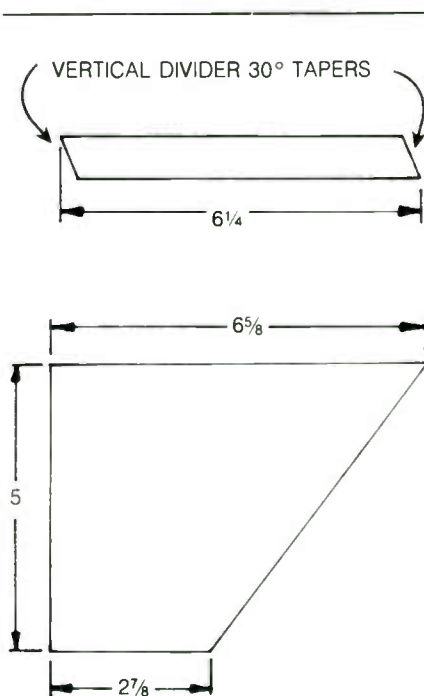


FIGURE 2: Woofer chamber shelf.

of each cabinet. You might want to try the same before permanent mounting.

Both the Gold Sound and SEAS woofer drivers' specifications indicate they should work well in a transmission line configuration. Eclipse and Madisound have some 12" drivers which probably would do the job nicely too. My experience with PLI drivers for TLs continues to be highly positive. I'm convinced they are not only bargains, but excellent in an absolute sense.

I'm afraid my knowledge of voice coil windings is virtually nil. Perhaps Speaker Builder's Contributing Editors could enlighten us.

## FRIED'S RIGHT

In the Mailbox section, SB 4/87, Contributing Editor Gary Galo describes his frustrating relationship with Fried Products and the reluctance of its president, Irving M. Fried, to provide technical information.

Mr. Fried is attempting to sell loudspeakers and kits to hard-core audiophiles and music lovers. Since his transmission line and pressure relief designs follow no published equations I know of, I would bet he spent a lot of money on in-house research and development. Many readers of this magazine are potential Fried customers, but if enough details were available we could simply mimic his designs if we liked them. And if we could do it, so could his competitors and they would easily undersell him because they have no development costs to recoup. I would like to know useful specifics about Fried designs, but that is too much to expect. No manufacturer should be expected to divulge his secrets, for without secrets there is no monetary incentive to develop a superior product.

Duke LeJeune  
New Orleans, LA 70118

Mr. Galo replies:

I agree that manufacturers have a right to protect proprietary principles. If manufacturers wish to protect certain technical information, they should simply state the information is proprietary, and they do not wish to have it revealed. This has not been Mr. Fried's approach. If he has certain trade secrets he wishes to protect, he should say so.

There is a second point. Any manufacturer selling kits has invited the builder and reviewer to investigate the design, particularly if the review is to appear in Speaker Builder. Mr. Fried does not subscribe to SB, however, and when he first expressed interest in having his kits reviewed, apparently was not aware of the types of articles and reviews which normally appear in the magazine. Perhaps he was not originally concerned with the contents of a typical issue, and simply saw a review as a chance to get some free publicity: mere speculation, of course.

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**INTERACTIVE AUDIO DESIGN SOFTWARE** for PC and Macintosh. **SpeakerCAD** draws predicted performance graphs, calculates Thiele/Small parameters, vents. **Filters** calculates first through sixth-order, Bessel or Butterworth electronic crossovers, quotes nearest standard values. \$29 for both. **ATRIUM ELECTRONICS**, 2302 5th St., NE, Salem, OR 97303, (503) 363-5143. T4/88

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**"IN PHASE"** 24dB/octave electronic crossover minimizes irregularity in radiation pattern through crossover region. 0.0008% distortion, 5 year warranty. Single frequency with power supply (specify) \$523. **DB SYSTEMS**, Main St., Rindge, NH 03461. TTF

**RAW DRIVERS:** CTS 2T2 2" 1.98; Foster FDS10 1½" dome, \$5; FDT11 or 13 1" dome, \$5; Herald S392A 3"×7" horn tweeter, \$10; McIntosh (Peerless) 2¼" or 2½" tweeter, \$7.50; 036016 or 017 1½" dome, \$29; 036054 10" woofer, \$45; 12" 036001 woofer, \$105; 12" 036039, \$50; Philips AD0163T8, \$15. See our monthly equipment list at the beginning of *Audio* magazine's classifieds. **AUDIO CLASSICS** Buys-Sells-Trades Precision Audio Equipment. **FREE** catalogue. MasterCard and Visa. 8a.m.-5p.m. EST, Mon-Fri. PO Box 176SB, Walton, NY 13856, (607) 865-7200. T1/88

## FOR SALE

Altec N800F networks, \$50 pair; much modified BGW 250 using ILP plate series bipolar modules, slight hum, \$200; Koss ESP9B electrostatic headphones and energizer, functional, as is, \$75. Charles Mann, RR #2, Site 7, Box 31, Liveley, Ontario Canada P0M 2E0, (705) 692-3842.

Symmetry electronic crossover ACS-1, factory modified to ACS-1A, \$325; Heathkit IG-18 audio generator with separate 100k frequency counter, \$75; Conar 6MHz oscilloscope, \$75; Digital capacitance meter, \$50; (2) Grace F-9E cartridge bodies, need stylus, 10 hours on each, \$10 each. All above O.B.O. Vance Hoyt, 23296 Brookhaven Dr., Moreno Valley, CA 92388, (714) 242-1155.

Dynaco PAT-5 preamp, unmodified, champagne front panel, good condition, asking \$65 (\$95 Canadian); (2) Cerwin-Vega speaker cabinets, model CDN, holes for 12" woofer, midrange, tweeter and port, asking \$30/pair. Call or write Greg Nawrocki, 21 Indiana St., Kitchener, Ontario N2H 2A4 Canada, (519) 745-1579.

New SAE EQ-10 parametric equalizer, 3 bands, \$175. The new model has 2 bands and lists for \$650. David Grant Willemain, 725 Morningside Dr., Towson, MD 21204, (301) 321-9063.

KLH Burwen DNF 1201A, \$150; KLH Burwen TNE 7000A, \$160; Pioneer Timer DT50, \$55. All in good condition. Michael Sikora Jr., PO Box 281, Dorothy, NJ 08317, (609) 476-2903.

RFL 750D Digital Readout Gaussmeter, \$400; H/P 5233L frequency counter, 2MHz, \$75; H/P 241A pushbutton oscillator, 10Hz to 1MHz, \$30;



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Datapulse 110B pulse generator, 50MHz max., \$100. All manuals included. Mark Matthews, 3318 Shield Lane, Garland, TX 75042.

dbx Model 21 tape encoder/decoder, disc decoder, \$50; 12 dbx encoded discs, \$6 each or \$35 for all. \$75 for Model 21 with all 12 discs. Realistic sound level meter, \$25. Dean Price, 1616 Millbrook SE, Grand Rapids, MI 49508, (616) 241-5324 evenings.

DB Systems Model 4 pre-preamp with 2A power supply, \$115; SWTP Tigersaurus 210/A, \$155; Hafler DH200, \$225; Magnavox FD1051 with remote, \$150; IBM brand ink jet cartridges (black and color) and cut sheet paper (250 sheets/pack) for Colorjet 3852, Cannon PJ-1080A, Quad/Quadjet and Tandy/CGP220, \$8 each. Michael Marks, 7490 Brompton Blvd., #369, Houston, TX 77025, (713) 666-3611.

RTR ESR-15 electrostatics. \$400 plus shipping for pair. Included are two extra power supply transformers and two original audio transformers. Both units have been modified, all polypropylene capacitors. Excellent. 1000Hz-30,000Hz, ±3dB. David Landrie, 120 SE Everett Mall Way, #1113, Everett, WA 98208, (206) 353-4036.

Seventeen volumes of *Stereophile*, 1985 to present, *TAS* Vol. 10 #40, all \$37; Linn, Ittok, recent HiPerf moving coil cartridge, \$750; Dyna PAT-4, \$50; CD stabilizer, \$10; JBL 2221 10", near mint, \$125 pair; Sherwood int amp, \$50; CDs—Jennifer Warnes, Raincoat, Digital Domain, Zen Meditation, Heart, Little Queen, \$8.50 each; Robertson 4010, \$350. Steve Hluchan, (203) 397-8777, 7-10 p.m.

Two Strathearn and one Radio Shack ribbon tweeter per side in pair of IRS type baffles, 12" Dynaudio per side in pair of unfinished transmission line (Bradbury) enclosures, Ace Audio 6000 crossover (280Hz, 12dB), \$1000. Michael Kurzawa, (201) 499-7650.

Magnavox 560 CD player, factory sealed, warranty under your name, \$215 includes shipping etc.; Magnavox 460 also available for \$185, same deal; Dynaco ST-400, perfect, \$275; Corcom power line conditioner with transient surge absorbers, never used, \$75. Harold Schaefer, (301) 661-1202.

dbx 21 decoder with 9 records, offer. Need manual or copy for EICO Model 425 oscilloscope. Kent Johnson, 2985 Quitman St., Denver, CO 80212, (303) 455-5610.

Rapid Systems Turnkey FFT spectrum analyzer for IBM. Model R400/401 and R410/492 enhanced digital scope. Ideal for acoustics/speaker development use. Four-channels, SR to 2MHz. New cost \$800, sell for \$495. Richard Marsh, 3301 Fallen Tree Ct., Sacramento, CA 95827, (415) 422-7731 days.

KLH Research stereo receiver model 51, excellent condition, with walnut cabinet and original documents. \$50; pair Altec Lansing model 755-E 8" wide range drivers, as new, 45-15,000Hz, \$55 for both; Dynaco amplifier model SCA-80Q, 80W with Dynaquad 4 channels and original manuals, one channel needs repair, \$45; pair Empire 6000M Mark 6 speaker systems with marble tops and manual, all new drivers, will sell as cabinets, only \$60 for both or \$110 with drivers and crossovers. Shipping paid in US. R. Brantley, 1604 Terrace Dr., Westminster, MD 21157, (301) 875-2571.

Stevens Tru-Sonic mono speaker system, late 1950s, 36"x18"x40"H corner cabinet, nice furniture finish, no data. Offers. Information appreciated. E.D. Loesch, 6220-147th Pl. SE, Bellevue, WA 98006.

## WANTED

Used toroid and coil winding equipment. Please state manufacturer, model numbers, condition, price and terms. E. Wittenbreder, 4402 Quaker Hills Court, Havre de Grace, MD 21078.

Help! I have 15" drivers in huge Carvin horn loaded stage sound reinforcement cabinets with matching mixer, amp. I want to convert it to home stereo. Any ideas, suggestions, please write Lawrence Eubank, #5288, C39656, Box 8101, San Luis Obispo, CA 93409-0001.

Would like (2) midrange horns from Speakerlab SK speaker. Can be with or without driver. Michael Sikora Jr., PO Box 281, Dorothy, NJ 08317, (609) 476-2903.

Any help on upgrading a 1st generation pair of Rogers Studio One speakers to realize their full potential would be very much appreciated. Steve Kandell, 2910 Urban, Santa Monica, CA 90404, (213) 828-1305.

Ionovac or Ionofane loudspeakers. State condition and price. Henry Eng, 173 Heward, Toronto, Ontario M4M 2T6 Canada.

Desire to change Jantzen model I-30 electrostatic tweeter with 4 panels from 16Ω to 8Ω. I need color code on signal transfer primary and critical component values. Write or call with any information you may have concerning this. Alexander Avis, 460 Knoll Dr., Los Altos, CA 94022, (415) 948-6143.

Schematic for Rodgers LS3/5A crossover. KEF T27 and B110 drivers (used). Dean Collins, 90 Finger Ave., Redwood City, CA 94062, (415) 369-7071, days and evenings. Call collect if you've got the goods in hand.

## 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 to Audio Clubs in care of the magazine.**

**CONNECTICUT AUDIO SOCIETY** is an active and growing club with activities covering many facets of audio—including construction, subjective testing, and tours of local manufacturers. New members are always welcome. For a copy of our current newsletter and an invitation to our next meeting, write to PO Box 346, Manchester, CT 06040 or call Mike at (203) 647-8743.

**AUDIOPHILES IN CENTRAL PENNSYLVANIA** (also eastern Pennsylvania and Delaware): Interested in forming a serious audio organization? Contact Steve Gray, 625F Willow St., Highspire, PA 17034 or phone (717) 939-4815.



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### THE BOSTON AUDIO SOCIETY INVITES YOU

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### PACIFIC NORTHWEST AUDIO SOCIETY

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

### THE ATLANTA AUDIO SOCIETY

started in October 1983 and has regular meetings on the third Sunday of each month as well as special programs with leaders in the industry, such as

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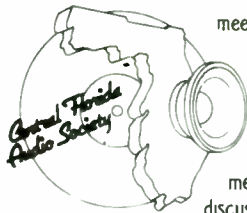
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Mr. William Conrad of Conrad-Johnson and Mr. William Johnson of Audio Research. We are currently looking for additional members in the Southeast. All members receive the minutes of each meeting and program, as well as other relevant announcements and correspondence. For full information and membership packet, write Atlanta Audio Society, PO Box 92130, Atlanta, GA 30314, or call Howard Royal in Newnan, GA, (404) 253-6419.

**HI-FI CLUB OF CAPE TOWN**, South Africa issues monthly newsletter for members and subscribers. Get a different approach to understanding audio, send two IRCs for next newsletter to PO Box 18262, Wynberg 7824 South Africa.

**WASHINGTON AREA AUDIO SOCIETY** (N. VA, MD and DC) is looking for sincere audiophiles who are eager to devote their time and get involved with the direction of the society and the publication of a monthly newsletter. Please contact: Horace J. Vignale, 13514 Bentley Circle, Lake Ridge, VA 22192-4316.

### CENTRAL FLORIDA AUDIO SOCIETY



meets monthly in Orlando. Come and meet others who share your interest in music reproduction as we audition equipment and recordings or discuss audio related topics.

Contact: Bill Boswell (305) 678-3724  
P.O. Box 579, Orlando, FL 32802

**SAN DIEGO AUDIO SOCIETY** forming for hi-fi tinkerers and do-it-yourselfers. If you enjoy collecting, building, rebuilding and repairing classic audio equipment, especially tube-type, call Mike Zuccaro (619) 271-8294 (evenings & weekends). Old timers and engineers welcome.

**NEW JERSEY AUDIO SOCIETY** meets monthly. Emphasis is on construction and modification of electronics and speakers. Dues includes monthly newsletter with high-end news, construction articles, analysis of commercial circuits, etc. Meetings are devoted to listening to records and CDs, comparing and A-Bing equipment. New members welcome. Contact Bill Donnelly, (201) 334-9412 or Bob Young, 116 Cleveland Ave., Colonia, NJ 07067, (201) 381-6269.

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

**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 hows and whys of audio. Each meeting consists of a lively discussion topic and equipment demonstrations. For information on meeting dates and location, contact Craig Tyau, 2293A Liliha St., Honolulu, HI 96817.

**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., East Palo Alto, CA 94303 for newsletter.

**MINNESOTA AUDIO SOCIETY.** Monthly programs, newsletter, special events include tours and annual equipment sales. Write Audio Society of Minnesota, PO Box 32293, Fridley, MN 55432.

**THE INLAND AUDIO SOCIETY IN THE SAN BERNADINO-RIVERSIDE AREAS**, now in its third year of existence, is inviting audiophiles and music lovers in the San Bernardino, Riverside, Orange and Los Angeles counties to join us at our bi-monthly meetings and through our quarterly publication, in the pursuit for that elusive sonic truth. We provide a forum for auditioning equipment, sampling live music for educational purposes, guest presentations, discussing recordings, and the sharing of ideas, tips, theories, opinions, experience, and new product news relating to audio systems. Additionally we cater to the hobbyist who designs, builds and/or modifies electronic components and transducing gear. Write for information concerning membership, dues and subscription. IEAS, PO Box 77, Bryn Mawr, CA 92318, (714) 793-9209.

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**TUBE AUDIO ENTHUSIASTS.** Northern California club meets every other month. For next meeting announcement send a self-addressed, stamped no. 10 envelope to Tim Eding, 2113 Charger Dr., San Jose, CA 95131.

**SAN DIEGO AUDIO SOCIETY** forming for hi-fi tinkerers and "do-it-yourselfers." If you enjoy collecting, building, rebuilding and repairing classic audio equipment, especially tube type, call Mike Buccaro, (619) 271-8294 evenings and weekends. Old timers and engineers welcome.

**THE VANCOUVER AUDIO SOCIETY** publishes a bimonthly newsletter with technical information, humor and items of interest to those who share our disease. We have 40 members and meet monthly. Six newsletters per year. Call (604) 251-7044 or write Dan Fraser, VAS, Box 4265, Vancouver, BC, Canada V6B 3Z7. We would like to be on your mailing list.

**MEMPHIS AREA AUDIO SOCIETY** being formed. Serious audiophiles contact J.J. McBride, 8182 Wind Valley Cove, Memphis, TN 38115. (901) 756-6831.

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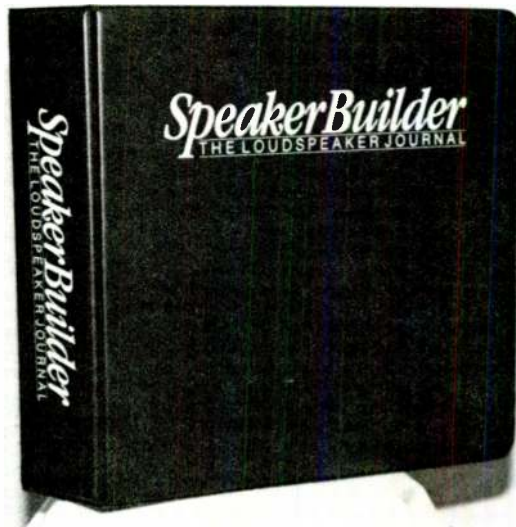
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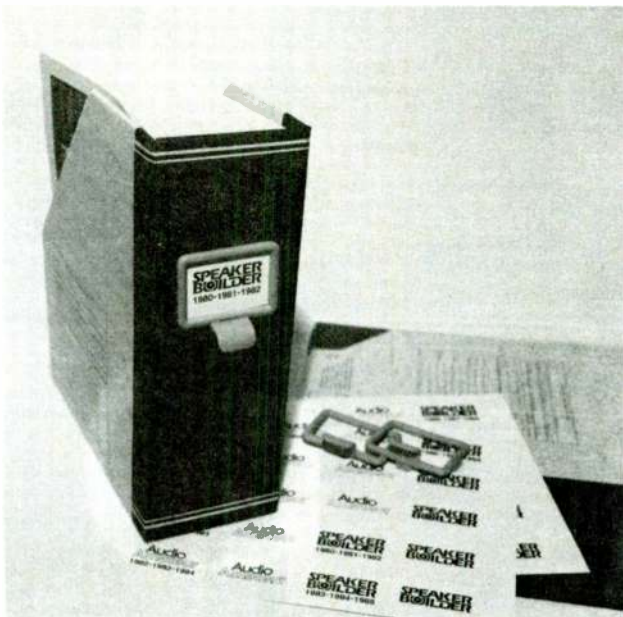


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