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Speaker Builder®

THE LOUDSPEAKER JOURNAL

DOING DR. BAILEY'S T-LINE SIMPLY

Cockroft

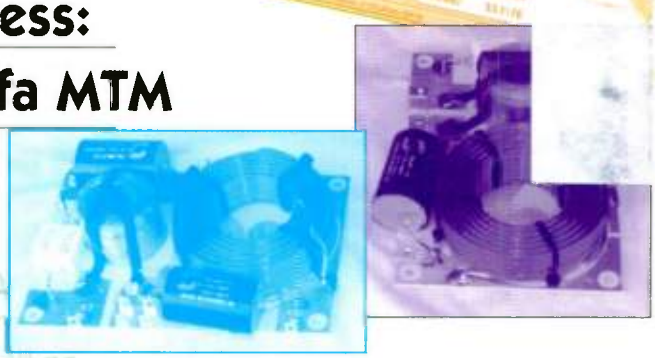
HOW TO SOLVE THE PLACEMENT MYSTERY

Raczynski

TEST DRIVE:

Parts Express: Dual 5" Vifa MTM

Dick Carlson



LAB TEST:

Of Vifa's Dual 5" MTM

Joe D'Appolito

REBUILDING

THE AR-3a: Final Reassembly

Tom Yeago

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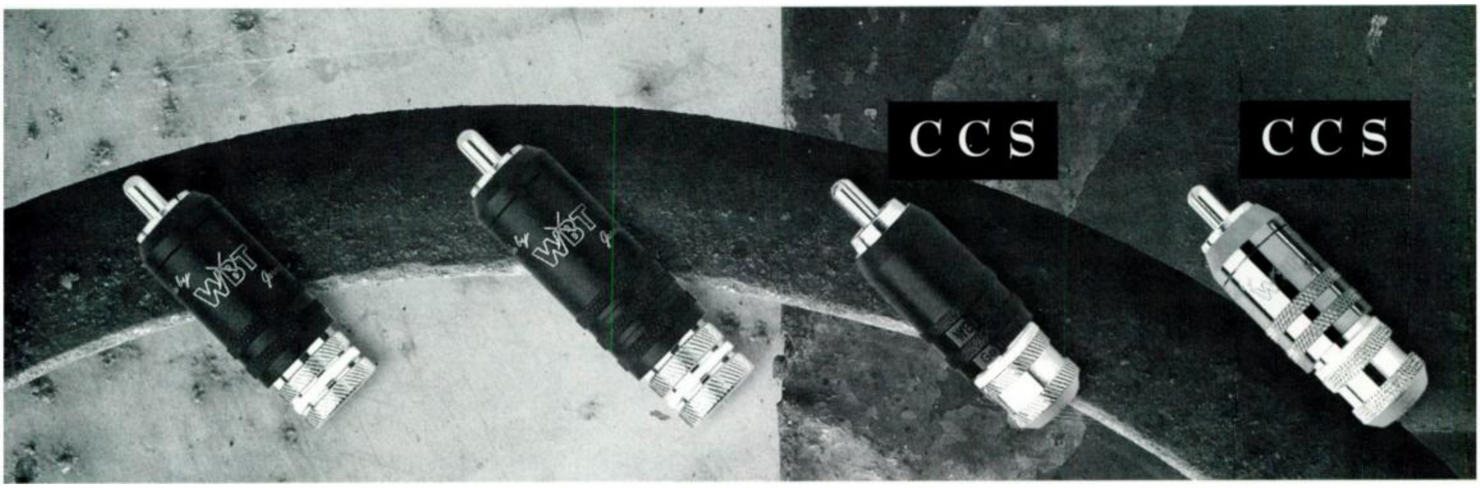
DRIVER TEST: Denmark's Peerless 10" Woofer

THE ART OF CONNECTION



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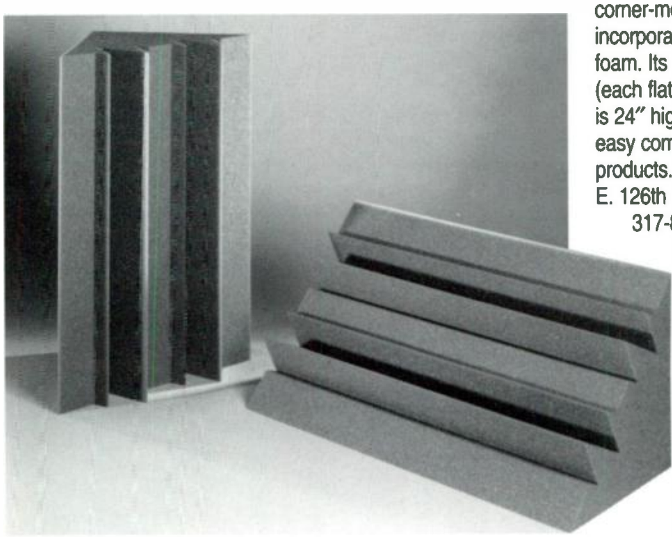

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RCM Akustik of Germany has made its Detonation! subwoofer amplifiers available in North America. For use in high-end systems and home theater, these assembled units feature second-order Linkwitz-Riley (L-R) active crossovers; continuously variable low-pass filters; low- and high-level satellite filters; 12dB/octave subsonic filters; thermal and power overload protection; and automatic on/off/standby switching. All are protected behind a flat black, brushed-aluminum panel accented by high-quality controls and connectors. Other models also available include the 70W DT105, 125W DT107, and 150W DT109. Jack Burnett Associates, LLC, PO Box 26, Dept. VC01, W. Peterborough, NH 03468, 603-924-2383, FAX 603-924-3392, E-mail FDTF77B@prodigy.com.

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JOHN STUART MILL

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About This Issue

As we begin our 19th year of publishing, ***Speaker Builder*** remains the premier magazine for DIYers. In the coming year, we plan lots more building projects and modification plans to help you construct and improve your speaker gear. And, to assist you in choosing which new products to purchase for your endeavors, we're committed to bringing you more in-depth reviews of products.

Regular contributor ***John Cockroft*** starts off the new year with yet another of his patented speaker designs. His trademark has become the use of inexpensive components to produce exceptional sound quality. This one is a transmission line speaker using a 6½″ woofer. Hop aboard the "B-Line" for an interesting ride (p. 8).

Loudspeaker placement is a critical consideration that every speaker builder must face. ***Bohdan Raczynski*** discusses room acoustics in the home environment and uses a modern mathematical tool—the Finite Element Method—to determine loudspeaker placement (p. 16).

Tom Yeago continues his massive overhaul of the AR-3*a* and offers an inside perspective of speaker makeup rarely published. In the fourth of six parts in this series ("Rebuilding the AR-3*a*," p. 24), you'll complete the woofer work and begin to tackle the midranges.

The Vifa dual 5″ woofer kit is the focus of this issue's Test Drive series (p. 38). The kit comes together under the capable hands of veteran builder ***Dick Carlson***, and then pro evaluator ***Joe D'Appolito*** takes over measuring the system. You'll gain a clear idea of what's involved in the challenge and satisfaction of building this kit from Parts Express.

We are pleased to introduce a new series entitled "Trade Secrets" by industry insider ***Mike Klasco*** (p. 50). We look forward to his useful insights on design and manufacturing as he presents a close-up analysis of the components that make up our speaker units.

In this issue's report on drivers, ***Vance Dickason*** measures the performance of the 10″ CSX 257 woofer from Peerless of Denmark (p. 53).

Speaker Builder (US USSN 0199-7920) is published every six weeks (eight times a year), at $32 per year, $58 for two years; Canada add $8 per year; overseas rates $50 one year, $90 two years; by Audio Amateur Corporation, Edward T. Dell, Jr., President, at 305 Union Street, PO Box 494, Peterborough, NH 03458-0494. Periodicals postage paid at Peterborough, NH and an additional mailing office.

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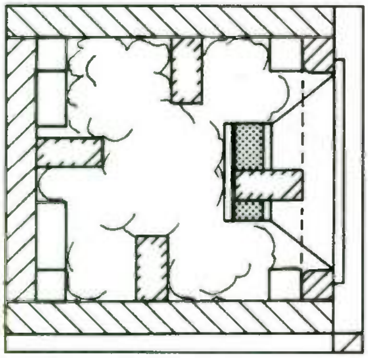
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DEPARTMENTS

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THE B-LINE: A LOWDOWN SORT OF A GUY

By John Cockroft

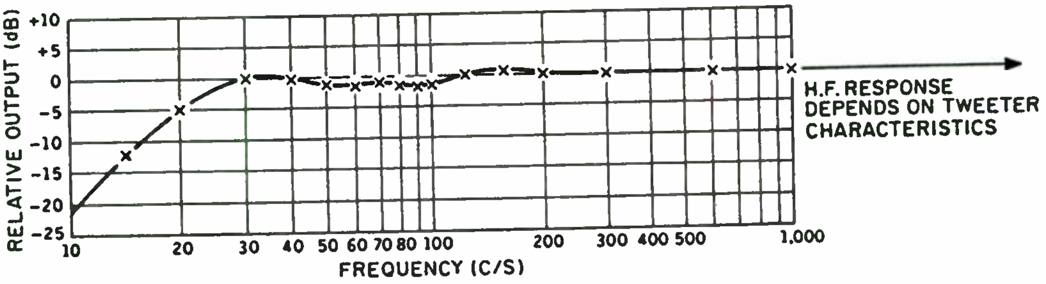

FIGURE 1: Dr. Bailey's Fig. 9 from his October 1965 *Wireless World* article. This graph was responsible for the birth of the B-Line.

The B-Line is so called as a tribute to Dr. Arthur Bailey for his pioneering work in what I consider one of the most interesting and pleasing corners—from a sonic viewpoint, at least—of the loudspeaker-system landscape. After almost 11 years of browsing and chewing my cud in the hybrid transmission-line pastures, I finally decided to make a beeline back to the source.

On what was perhaps a whim, I revisited Dr. Bailey's original article in *Wireless World* ("A Non-Resonant Loudspeaker Enclosure Design," Oct. 1965). I was mainly interested in his Fig. 9 (*Fig. 1* henceforth in this article), which showed the response curve of a commercial transmission-line (TL) system in which he was involved. He claimed the woofer had a free-air resonance of about 30Hz (in those days he said 30 c.p.s., since Hertz had yet to be honored).

Figure 1 shows a relatively smooth response to about 30Hz, rolling gradually off below that. At about 15Hz, it appears to be down about 12dB. He remarked that the resonant frequency of the speaker in the TL was just below 15Hz. The −10dB point seems to be about 0.52 F_{sa}.

I think it likely that what he took for the resonant point of the speaker in the TL was the lower impedance peak. Sometimes the upper peak in a TL is damped to the point where it doesn't obviously show up. (On occasion, the upper peak shows up, but the lower one escapes detection.)

ENCLOSURE DRAWING

I turned my attention to the drawing of the enclosure. If the drawing is made to scale (there is no comment to that effect; I'm going on faith here), the TL appears to be about 6.5′ long. This coincides with a statement I seem to remember hearing, or reading, from some source or other (real or imagined) that while Bailey experimented with an 8.8′ TL, he presented data for a 6.5′ one. I also seem to recall the source expressing puzzlement as to why he didn't explain the discrepancy.

I'm proceeding here on the assumption that the TL was 6.5′ long. Another assumption I'm making is that he used a stuffing density of 0.5 lb/ft³. I know that he used wool, for at the time he was experimenting, materials such as polyester fiber and Nylon polyamide fiber (Acousta-Stuf, introduced by Larry Sharp of Mahogany Sound) were not available. Bailey didn't actually say he used 0.5 lb/ft³, as far as I know. He advised using 1 lb of long-fiber wool for each 2–3ft³ of enclosure volume, but every reference to his TLs mentions 0.5 lb/ft³, so I'm accepting that as fact.

In *Fig. 1*, F_{sa} appears to be at 0dB. Immediately below that, the downward turn begins. F_3 appears to be at about 0.8 F_{sa}, and F_{10} is about 0.65 F_3. The point I'm trying to make is that Bailey's TL doesn't cut off at woofer F_{sa}, but, rather, about an octave below it.

If you accept F_{10} (the point where the response curve is −10dB below the midrange SPL) as the lowest point of really useful sound, you could then say that the TL length should be designed to be one-quarter the wavelength of 0.52 F_{sa}. (Just saying one octave would really be close enough, I suppose.)

BRADBURY'S EQUATION

Since the above was based on Bailey's TL and he used 0.5 lbs/ft³, we must account for that fact. L.J.S. Bradbury published an equation for the speed of sound in a fibrous tangle ("The Use of Fibrous Materials in Loudspeaker Enclosures," *JAES*, April 1976). I am using a version of it in which Larry Sharp converted kg/m³ to lbs/ft³ (in Sharp's booklet, *Quick & Easy Transmission Line Speaker Design*, Mahogany Sound; available from Old Colony Sound Lab, 603-924-6371, FAX 603-924-9467):

$$c' = 1130/\sqrt{(1 + (p/p_a))} \qquad [1]$$

where
c' = the speed of sound through the line;
1130 = the speed of sound in air, presumably at sea level and 72°F;
p = the density of the stuffing in the line in lb/ft³;
and p_a = the density of air at sea level at 72°F (0.0745).

Inserting the density values into [1].

$$c' = 1130/\sqrt{(1 + (0.5/0.0745))} = 406.9\text{ft/s}$$

Now you have the speed of sound through the TL loaded with fibers to a density of 0.5 lb/ft³, and the F_{sa} of the woofer, 30Hz, which you multiply by the factor of 0.52, arriving at 15.6Hz. Dividing the c' of 406.9 by the 15.6 (= 26.1ft), and the 26.1 by 4 (because you want one-quarter wavelength), you end up with 6.52ft.

There is a point a little farther down the response curve in *Fig. 1*, beyond F_3, where the curve passes exactly through the −5dB and 20Hz intersection. 20Hz/30Hz = 0.667 F_{sa}: this is the F_5 point. It's probably the most accurate reference I was able to make from his *Fig. 1*.

Now you should have a pretty good sense for the Bailey TL referenced to the speed of sound in the line and the woofer free-air resonant frequency. By altering the speed of sound through the line and keeping all the rest of the relationships intact, you could change the length of the line and keep the performance parameters about the same. Changing the density of the stuffing is the means of altering the speed of sound in the line.

LINE DESIGN

Perhaps a good way to design a B-Line (*Fig. 2; Table 1* is the parts list) is to select what appears to be a suitable woofer, and calculate 0.52 F_{sa}. Consider a line length and multiply it by 4. Multiplying the result by 0.52 F_{sa} gives the speed of sound in the chosen line that will cause it to be 10dB down at 0.52 F_{sa}. Calculate the stuffing density that will achieve the desired speed of sound through the line. Finally, look over the parameters you have worked out to see if they are practical.

B-Lines always have a stuffing density greater than 0.5 lb/ft^3. If they didn't, they would be Dr. Bailey's line. The B-Line presented in this article has a stuffing density of 1.047 lb/ft^3. I modified my Microline (*SB* 5/89) to a stuffing density of 1.5 lb/ft^3. After some extended listening, it sounded a bit "stuffy," so I reduced the density to 1.375. This was an improvement that sounds very solid with the Wilson Audio "Discovery" organ CD.

I improved the 10″-woofer version of my 11″ Unline by restuffing from a density of 1.125 to 1.8. I guess the length of the line has something to do with it. Sound going through high density for 11″ isn't the same as going through the same density for several feet. The Microline was about 2′ long. This paragraph might be considered a rough stuffing guide if you plan to play around with B-Lines. (The above-mentioned TLs that I modified aren't really B-Lines, but because of the B-Line, I decided to try to stuff them to higher densities to see what would happen.)

Use equation [2] to calculate the stuffing density (p) for a chosen line speed:

$$p = .0745(1/(c'/1130)^2 - 1) \qquad [2]$$

Once again c′ is the speed of sound through the fibers in the line in ft/s. For example, the stuffing density for a speed of 291.2ft/s, which is the calculated speed of sound in this B-Line, is as follows:

$$p = .0745(1/(291.2/1130)^2 - 1) = 1.047 \text{ lb/in}^3$$

MATERIAL AT HAND

When the idea of the B-Line occurred to me, I decided I could probably realize it with material I had already cut to build an 8″ Freeline. Since I had satisfied myself that the Freeline concept was practical when I built the 4″ version, I thought it more important to try out a B-Line than to build another Freeline.

Thus I had the wood cut prior to the

TABLE 1

PARTS AND MATERIALS LIST

MATERIALS

5/8″ particleboard shelving. I think five 48″ × 11½″ shelves should do. And ¾″ × ¾″ molding for the cleats. The longer cleats may be made up of several shorter pieces, if necessary.

2 ea	44″ × 8″	sides
2 ea	48″ × 9¼″	front/back
1 ea	9¼″ × 9¼″	top
1 ea	11½″ × 11½″	base
1 ea	2″ × 44″	back stiffener
1 ea	2″ × 35″	front stiffener
2 ea	2″ × 43″	side stiffeners

If you have enough scrap particleboard remaining, you could rip it into 5/8″-wide strips and substitute these for the ¾″ × ¾″ molding strips.

4 ea	44″	(c) vertical corner cleats
3 ea	4″	(x) inner base cleats
6 ea	2″	(z) short inner base cleats and base feet
4 ea	9¼″	(y) outer base cleats

You may wish to redesign these for cosmetic effect—perhaps quarter-round molding and mitered corners on the exterior cleats.

PARTS

1 ea	Woofer: Dayton 295-220 6½″ treated paper cone (from Parts Express) @ $18.50. Note: It should be possible to successfully substitute another woofer with similar F_{sa} (35Hz and Q_{ts} of 0.29). It is also possible to substitute an 8″ woofer with similar parameters. Make sure the speaker-mounting hole is repositioned so the bottom of the speaker rim is 2″ above the top surface of the base. Make the front stiffener an inch shorter so it will clear the speaker frame.
1 pr	Input terminals of your choice.
2 ea	20 oz bags of polyester fiberfill. I got mine at Wal-Mart. There will be some fluff left over.
Miscellaneous	¼″ felt. ½″ surgical or household cotton is OK, as is bonded acetate or the polyester material used for stuffing comforters. If this is blanket thin, use two layers. Carpet-underlayment felt should be readily available and is fine. It's better than the other substitutes. (Thank you, Barry Waldron.)
	white glue
	hook-up wire, 16 gauge (Radio Shack)
	Mortite or duct seal to seal speaker to enclosure
	4 ea #6 × ¾″ pan-head sheet-metal screws to mount speaker

design and I also had the woofer I planned to use—the 6½″ Dayton 295-220. This is an excellent and well-mannered woofer with a doped paper cone and a vented pole piece. I've been pleased with all three Dayton speakers I've used. They represent an excellent value and are a fine choice for those who desire good sound at a reasonable price. They are sold by Parts Express, which has pleasant folks to deal with when ordering.

I fixed the line length at 4′, so 4′ × 4 (because this was one-quarter wavelength of some frequency) = 16′. F_{sa} of the Dayton speaker was about 35Hz, and 0.52 × 35Hz = 18.2Hz. This is the calculated −10dB cut-off point. Multiplying 16′ by 18.2Hz gives a speed of sound through the line of 291.2 ft/s. I used equation [2] as shown above to calculate the stuffing density of 1.047 lb/ft^3.

I find that with the B-Line, just as with the Bailey-designed line, woofers with lower Q_{ts} sound more natural. The Dayton woofer, with a Q_{ts} of about 0.29, sounds very tight, clean, and real. On more than one occasion, I have gone to the window to locate the source of something that came from the speaker.

The calculated F_3 (0.8 F_{sa}) is 28Hz, and F_5 is 23.4Hz. All I know for sure is that the organ's 32Hz pipe on Wilson Audiophile's Discovery CD (WCD-806/8419) vibrates my floor with seemingly effortless clarity.

SUPER FOUNDATION

The B-Line adds a wonderful foundation when used with my Super Simplines (*SB* 1/96) and the second-order passive line-level crossover presented in my Simpline Sidewinder Woofer article (*SB* 4/95). This is a real bargain-basement high-end combination that will appreciate the highest quality of feeding equipment you can give it. With the system's low cost (two Super Simplines, a B-Line, and the crossover for $150 or so), you could spend more money on the electronics, to the betterment of everything concerned.

The B-Line makes use of Roy Allison's method of coupling the bass to the room by having the woofer as close as possible to the floor and one wall, and as far away as you can manage from the opposite wall. I've used this successfully with many speakers over the years (including the Simpline Sidewinder Woofer), and it works just as well here.

When it's set up correctly, you have very little sensation that a woofer is hooked up to the system. What you do notice is that the instruments play their entire register with naturalness and ease, much as they would if they were in the room with you. Of course, no system will totally give that sensation, but you'd have to go a long way up the financial scale to beat the B-Line in this respect.

B-LINE CONSTRUCTION

The B-Line is quite simple to make, especially if you cut all four sides to the same length and leave the top open. I had no choice. As I mentioned earlier, I made my B-Line from lumber salvaged from a proposed 8″ Freeline I had planned to build, so the two sides were already cut short.

For a while, lacking wood, I just left the top open. It sounded OK. Later I placed my phone book on top. It still sounded OK. Finally, a friend gave me part of an old coffee table, which I sawed into a top and glued into place.

Fasten the stiffeners to the inside faces of the front, back, and sides. Fasten the sides to the back, and glue the corner cleats in place. On the back-to-side cleats, it's a good idea to bevel one of the corners so the cleat will fit squarely in place over the bead of glue already laid down.

This isn't necessary on the side-to-front cleats, since they will be in place before the front is glued on. A few C-clamps are handy when gluing the cleats to the side-to-front location. Make sure the cleat face is lined up flush with the front edges of the sides.

I usually use white glue such as Elmer's or Wilhold. They work very well and are about half the price of the yellow carpenter's glue. I usually preglue all surfaces of all joints ahead of time by brushing on a thin coat and then letting it dry. Some builders believe the preglued coat shouldn't dry before regluing and assembling. However, I've done this for 35 years and am very happy with the results. The final coat takes hold very quickly when you preglue.

After the glue has dried, cut out the woofer hole with a sabre saw or router. Then go back and add another coat of glue

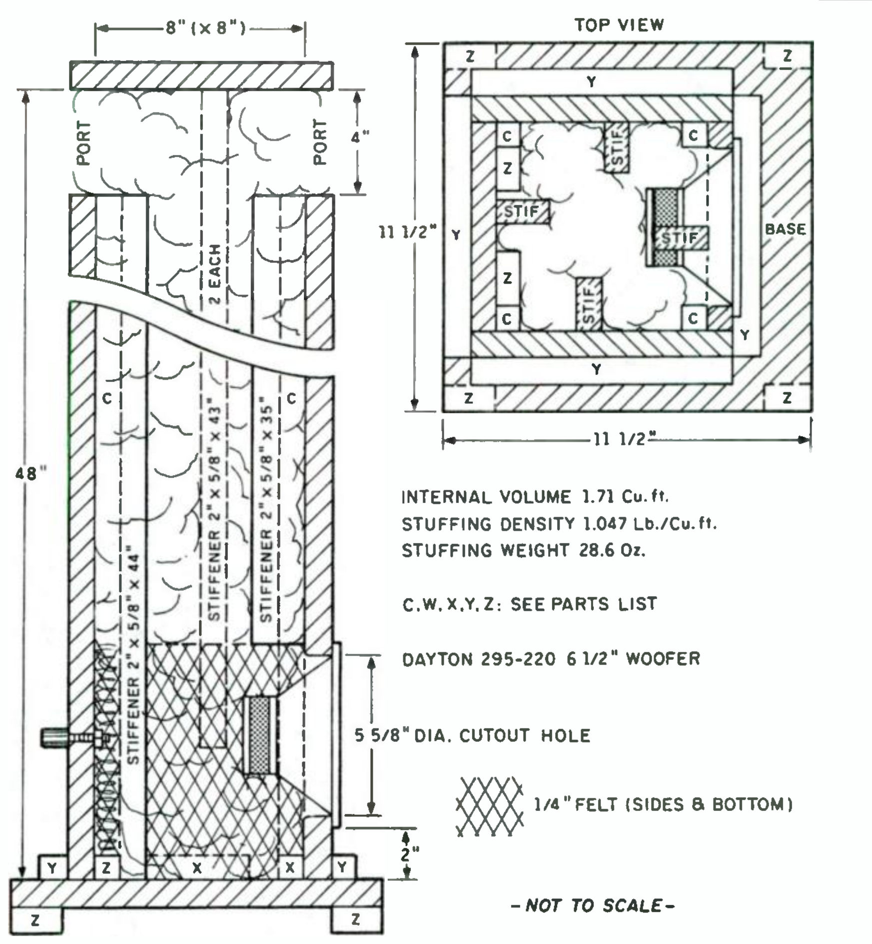

FIGURE 2: Sectional front and top views of the B-Line.

SOURCES

Marchand
PO Box 473, Webster, NY 14580
716-872-0980, FAX 716-872-1960

Parts Express
340 E. First St., Dayton, OH 45402-1257
800-338-0531
(minimum order, $20; a $3 surcharge on anything less.)

to all of the originally glued areas. Also, paint a ring of white glue around the perimeter of the speaker hole, which will give a better surface when it becomes time to seal the woofer in place. Now is also a good time to put the speaker input terminals in place and wire them. A good choice is 16-gauge or larger wire. Let the other ends of the wire flop in the breeze for now, but mark them for polarity.

STUFFING

The stuffing density of 1.047 lb/ft^3 amounts to about 29 oz of stuffing. You can use either polyester fiberfill or Acousta-Stuf, inserting most of it at this time. Ordinarily, it's better to leave the area behind the woofer unstuffed, but you can stuff it now to see how much it will take, and then remove it later. You might do the same in the area of the ports.

Try to place the stuffing as evenly as possible. If, when you have the B-Line all assembled, you find that all the measured stuffing is used up and you still need a bit more, don't feel guilty at reaching into the supply bag. The ratio of stuffing changes to sound changes is pretty much in favor of the sound. (I confess I fudged a bit up at the top. The amount between the vents looked skimpy and unattractive, so I added a bit more for cosmetic reasons.)

Now add the front panel. Be generous with the glue, placing ¼″ beads of it on the front edges of both the sides and cleats. This will cause some mess, so use newspapers under the B-Line. Get the front lined up and secure before wiping up the excess glue with a damp paper towel. It might help to remove the lower foot or so of the stuffing before putting the front in place. Save it intact for later reinsertion. Let the glue dry overnight.

ADDING THE BASE

While waiting, you can assemble the base. My prototype used short pieces of the corner-cleat material glued along the lower edges of the sides at the corners to act as feet. For use on hardwood floors, you might attach rubber stick-on feet, such as Radio Shack's 64-2342 jumbo-size self-stick feet. You should first brush a coat of white glue on the area where the feet are to go. Let it dry. If you plan to paint, or otherwise finish your B-Lines, you might wait until afterward to attach the feet. If you're into spikes, go for it.

When the glue is dry on the enclosure, set it on the base and line it up. When satisfied, scribe a line around the bottom of the enclosure with a pencil, inside and out. After removing it, glue the outside-rear base cleat and one side base cleat to the base. Make sure you have it lined up with the correct scribed lines. (Pregluing the base, the cleats, and the bottom and bottom sides of the enclosure is a good idea.)

Once you've secured the two cleats, place a generous bead of white glue on the base, between the inside and outside scribed lines and also on the inner edges of the two cleats. Set the enclosure in place, making sure its rear is up against the rear cleat. Slide the enclosure firmly up against both cleats, making sure everything is square. Clean off the excess glue. Now set the remaining cleats in place.

Another way to accomplish the above is to turn the enclosure upside down and align the base on top of it, held down with a weight until the glue is dry. I actually did it this way. The advantage of the first method is that it is quicker. All the cleats are installed, and everything is drying at the same time.

FINISHING THE ASSEMBLY

I installed ¼″ felt on the back, bottom, and sides, up to a height of about 8″ from the bottom, sticking it on with the white glue. If you can't find felt, you could use surgical cotton from any drug store. Use a layer about ½″ thick. Cut the pieces to fit between the stiffeners and the cleats. The felt is probably not necessary if the B-line will be crossed over at or below 100Hz or so.

Glue on the two 4″ top cleats. Center them on the front and back panels with their top edges flush with those of the panels. Small C-clamps are handy to hold them in place until the glue dries.

The final structural act is to glue on the top. Then replace the stuffing you removed. Now connect up the woofer, making sure the wire connected to the positive input is also connected to the positive speaker terminal. Use duct seal, Mortite caulking, or foam weather-stripping to seal the woofer, and mount it in place using #6 ¾″ pan-head sheet-metal screws. Predrill the guide holes.

SIDELINES

As you must have noted by this time, the B-Line woofer faces toward the side. This is an important design consideration. Only one B-Line is required for a stereo pair of Super Simplines. If you do decide to use two B-Lines for added power, it might be better to place them back-to-back in the center, rather than locate them near the Simplines. The B-Lines are twice as tall as the Simplines and are not acoustically transparent. If you are using satellites that have forward-facing speakers, this wouldn't be a problem (unless you placed the satellites smack in front of the woofer faces).

I did not design a high-level crossover (between the amplifier and speaker) for the B-Line, because I find them often troublesome. Furthermore, I believe that a major purpose of a subwoofer is to relieve the satellites and their amplifiers of the bass load, so they are better able to handle what they do best.

With the extreme economy of the B-Line to start with, I don't feel that it would be an awesome burden to locate an amplifier (used, if necessary) of 60W or more. Marchand makes some excellent amplifier kits (see *SB* ads). Only one channel is required. (Many current receivers have more than two channels.)

You could use an active filter (see Marchand again), but that would raise the cost a fair amount. The line-level passive crossover I designed for the Simpline Sidewinder (see *SB* 4/95) is an excellent and inexpensive substitute for an active filter. It must, however, be designed with the input impedance of the high-pass amplifiers in mind.

The Simpline Sidewinder crossover used 0.1μF capacitors for a crossover frequency of about 160Hz. This proved a fine choice for the Super Simplines and several other satellites I tried them with. If for some reason you desire a lower crossover frequency, you merely substitute larger capacitors. Here are a few alternatives that should handle most situations:

0.122μF (0.1 and 0.022μF in parallel)	131Hz
0.133μF (0.1 and 0.033μF in parallel)	120Hz
0.147μF (0.1 and 0.047μF in parallel)	109Hz
0.200μF (two 0.1μF in parallel)	80Hz
0.222μF (two 0.1 and one 0.022μF in parallel)	73Hz

ADJUSTING LEVELS

I find white noise or FM interstation hiss to be useful in adjusting the levels of the satellites and the woofer. (As a handy source of hiss, I merely turn my FM tuner to the extreme low end of the dial and enter it onto a preset push-button.) With the volume control of your system set to a low level, determine whether your woofer or your satellites are the most efficient. You do this by turning the level set controls of your amplifiers to the maximum and see which one dominates.

Leave the least efficient unit turned up. Back off the more efficient unit until you can no longer hear it. Gradually raise the level until you can barely hear its sound above that of the other unit. Move the control slowly back and forth several times until you get the feel of when the sound just begins to blossom forth. Leave the setting there, and perhaps make a pencil mark as a

to page 62

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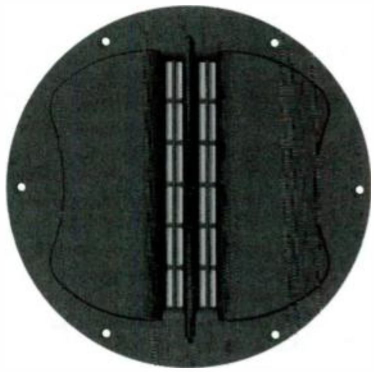

SPECIFICATIONS			
Characteristics	**Symbol**	**Value**	**Units**
Frequency Response	(±1.5dB)	1.7-21	kHz
Nominal Impedance	Z	8	Ω
Nominal Power Handling	Pnom	30	W
Sensitivity (1w/1m)	E	93.5	dB
Weight	M	0.6	kg
MAGNET			
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This tweeter has large membrane area providing higher power handling and substantially extended low end cut-off frequency.

The clamped membrane area is connected to the massive front metal plate. This combined with a special heat conductive compound provide effective cooling of aluminum conductors, dramatically increasing dynamic range of RT2.

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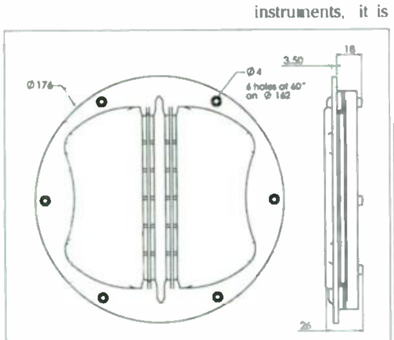

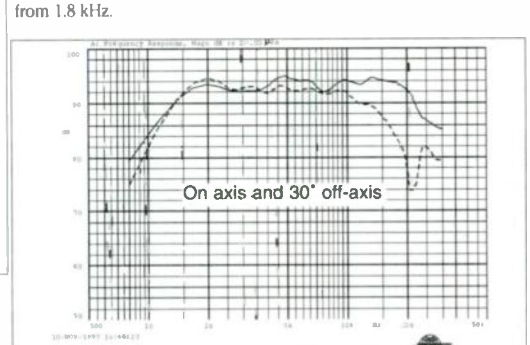

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LOUDSPEAKER PLACEMENT

By Bohdan Raczynski

At some point you arrive at the end of your loudspeaker-design process. It is probably fair to assume that much effort went into designing and building the "perfect system," possibly having anechoic flat frequency response from 20Hz to 20kHz and many other desirable features. Once you have been through the process, you are likely to agree that a lot of intellectual, physical, and financial effort went into extending the low end of the system's frequency response and achieving smooth, balanced mid- and high-end output.

There is one more challenge to consider on the way to actually enjoying the music: the listening room acoustics. Room-acoustic issues are complex, and for many people the learning factor is significant. Absorption, reflection, and diffusion are the issues you must consider, together with ray-tracing and modal analysis. In the worst case, misunderstanding in this area may obliterate most of the effort I mentioned above, and a well-designed system will lose much of its character.

The room characteristics can never be removed from the listening experience; they must be considered if you are serious about what you hear. There are "rules of thumb" and a lot of common sense involved in placing the speakers, but when it comes to showing the actual pressure distribution within the room and predicting resonances for complex-shaped rooms, the situation is quite different.

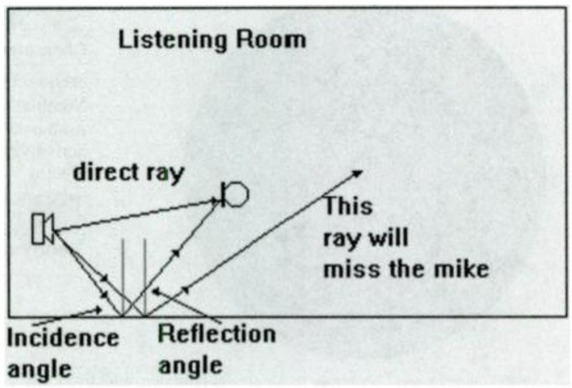

FIGURE 1: Incidence and reflection angles.

So, what would be this worst-case scenario? Of many possible factors, I pick the following three:

1. Wrong positioning of the loudspeakers.
2. Wrong location of the listening position.
3. Poor room acoustics.

As a minimum solution to the above problems, I would avoid (1) and (2) and optimize (3). This article will proceed along these lines, keeping the complexity on an introductory level.

MID-FREQUENCY

From a theoretical point of view, the average listening room must be considered as a resonant cavity below 300Hz. In this frequency range, reflections result in standing waves, and the room becomes a resonating chamber. Above 300Hz, the ray-tracing model becomes more useful. Here I assume that the ray's angles of incidence and reflection are equal. In the home situation, the shape and size of the listening room are already fixed.

In reviewing the issues associated with room acoustics in the mid-frequency range, I will start with the simple case depicted in *Fig. 1*, assuming that only two audio paths combine at the test microphone, the direct ray and a single ray reflected from the floor.[1] If the reflecting surface is hard, there is no phase change between the incident and reflected rays. Note that since the angles of incidence and reflection are equal, only one reflected ray will reach the microphone.

The difference in length between the direct and reflected rays' paths is 10cm, which happens to be half the wavelength (180° shift) of a 1.7kHz sine wave. If you add two sine waves of the same frequency that are shifted 180°, the result should be total cancellation. Indeed, this is clearly depicted in *Fig. 2*. The first null occurs at

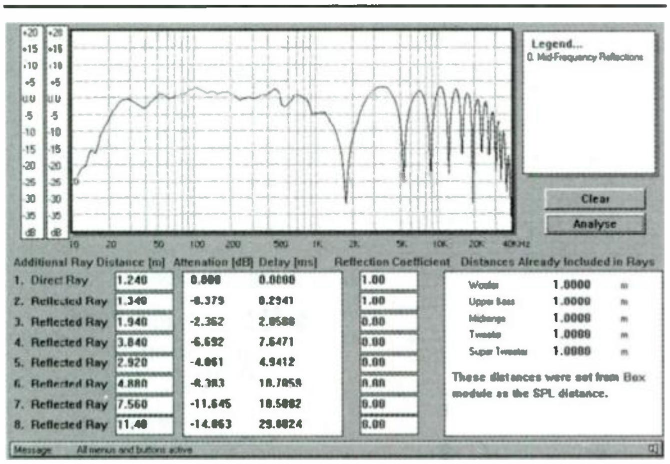

FIGURE 2: When two sine waves of the same length are added and shifted 180°, the result is total cancellation.

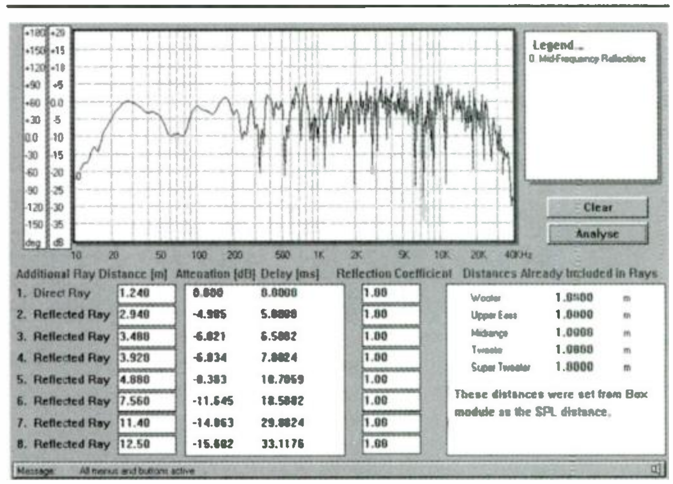

FIGURE 3: Most of the distortions are due to early reflections.

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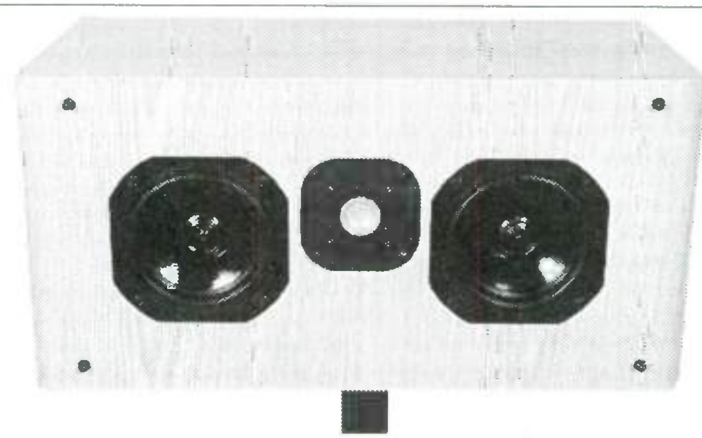

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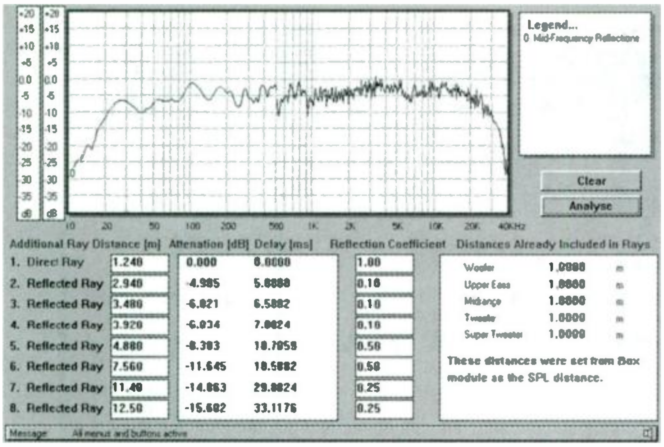

FIGURE 4: It is desirable to keep the lateral reflections only partially absorbed by the reflecting surfaces.

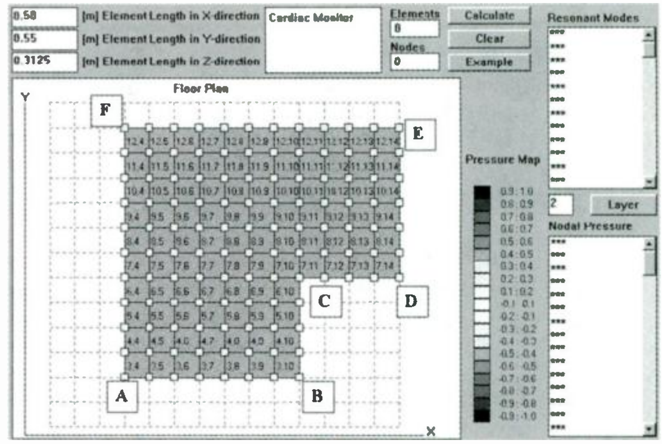

FIGURE 5: Diagram of the listening room used for further analysis.

1.7kHz, followed by a +6dB peak at 3.4kHz, where the 10cm distance is equivalent to a 360° phase shift, so both waves combine constructively. Another null then occurs at 5.1kHz, since the phase shift over a 10cm distance equals 360° + 180° (a phase reversal), and so on.

ADDING MORE RAYS

Adding more paths, each one delayed by a different amount, produces the effect depicted in *Fig 3*. In this example, eight rays are added together—one direct and seven delayed. All delayed paths are fully reflected—there is simply no absorption in the reflecting surfaces. The resulting frequency response is heavily distorted. You can perform a similar analysis for any location inside the listening room.

Are all the reflections necessarily bad? Imagine that you have placed some perfectly absorbent material on all the room surfaces, so that there are no reflections whatsoever. This is basically the situation in an anechoic chamber—the room is acoustically dead. Most people would shun such a room for listening purposes.

A solution seems to be in between those two extremes. Most distortions of the curve depicted in *Fig. 3* are attributable to early reflections that still have sufficient amplitude to compete with the direct ray. These are the first-bounce reflections from the nearest room surfaces to the listening position. You should first look at these early reflections. You can determine the paths of the reflected rays using the graphical method discussed. Then cover the reflection points with absorbing rugs or acoustical tails—depending on the required absorption.

The next step is to examine the reflections from the side walls. It is recognized that lateral reflections contribute to spaciousness and the image of the sound stage. It is therefore desirable that the lateral reflections be only partially absorbed by the reflecting surfaces.

This situation is depicted in *Fig. 4*, where three rays representing early reflections are 90% absorbed, two lateral reflections are 50% absorbed, and the back-wall reflections are 75% absorbed. Professional literature[2,3] lists absorption coefficients for a number of common building and decorating materials.

The absorption capabilities of various materials are strongly frequency dependent, and are best in the mid- to high-frequency range. Porous materials, like foam and fiberglass, are very effective at mid and high frequencies, but lose efficiency at low frequencies. Therefore, the above model and discussion are valid only for frequencies above 300Hz.

ROOM MODES

Listening-room acoustics at the low end of the spectrum tend to be one big compromise, especially in small rooms. Standing waves are a fact of life in acoustically untreated rooms, and this of course degrades the performance of a well-designed loudspeaker system. On the other hand, installation of a loudspeaker system capable of energizing the lowest room modes may well reveal that the room acoustics are less than perfect.

Room modes (natural resonant frequencies) occur across the entire frequency range. Professional treatment of the modes involves "bass traps"—typically large absorbent elements located in corners of the room. This may be readily implemented in a recording-studio listening room, but in the home it may be difficult to get all members of the family to agree to it. If this is your situation, there are a few things you may need to consider to avoid basic mistakes when analyzing low-frequency issues of the home listening room.

Every room mode has an associated acoustic pressure pattern. The pressure varies from 0 (null, no sound) to maximum (the peak of the standing wave). When music is played in the room, the modes are excited accordingly, and the pressure pattern changes and shifts dramatically within the room boundaries.

You can characterize all modes—axial, tangential, and oblique—by the following: (1) Bandwidth B—inversely proportional to the reverberation time; B = 2.2/RT60. Reverberation time depends on absorption, so the more absorption, the shorter the RT60 time and the wider the mode bandwidth. (2) Decay—again, mode decay depends on the distribution of the absorbing material in the room. (3) Density—increases with frequency. Above 300Hz, room response smooths markedly with frequency.

Let me now define the problem: you are the proud designer of a system capable of reproducing sound down to 20Hz, but when you sit down and listen to the sound, the low end is definitely missing. Assuming the problem is nontrivial, you are most likely sitting in the null of the pressure pattern for 20Hz mode. The importance of knowing your room modes and associated pressure distribution now becomes clear.

Mathematically, if the room has a simple rectangular shape, you can use an elegant formula to determine the room's natural frequencies, and further work is required to determine pressure distribution. If the room has a complex shape, the problem involves solving the Helmholtz equation in three dimensions, looking for eigenvalues and eigenvectors. This process is handled very well by the finite-element method (FEM).

If required, the FEM can be quite accurate. The accuracy depends on many factors, including the size of the element used and the order of approximating functions. The compromise on the other side involves computer processing speed and memory requirements. I therefore decided to accept errors of less than 5%, on the understanding that I'm


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dealing here with an "approximate" method.

THE FEM

Before proceeding further, a few words of explanation on the FEM are needed. This concept has been around for several decades and lends itself particularly well to solving the Helmholtz equation for complex volume shapes. Within a volume V, enclosed by a surface S, the pressure p must satisfy this wave equation:

$$\nabla^2 p + \left(\frac{\omega^2}{c^2}\right) p = 0$$

where c = the speed of sound and ω = vibration frequency.

On the hard surface, S, the normal velocity $\delta p/\delta n = 0$. The solution to the above problem, expressed by an equivalent variational principle, is:

$$\delta \int_V \tfrac{1}{2} \left[(\nabla p)^2 - (\omega^2 / c^2)\, p^2\right] dV = 0$$

The volume in question is divided into a large number of smaller elements, each having several nodes. I concentrate on an 8-node (8-corner) "brick" element with linear shape functions approximating pressure distribution within the element. The bricks are placed together to approximate the required volume and shape of the room. The solution of the problem is expected to assign each node a pressure value for every room mode (eigenvalue). When shape functions of the element are introduced into the variational principle, the equation is reduced to a matrix eigenvalue problem:

$$\left[K - \frac{\omega^2}{c^2} M\right]\{p\} = 0$$

where K is the "stiffness" matrix and M is the "inertia" or mass matrix. Now you can solve the matrix equation by standard eigenproblem methods.

Generally, the user of a FEM program must depend for the proper selection of models and algorithms on detailed knowledge of the theories, algorithms, and assumptions behind the program. The FEM knowledge base is huge and readily available; however, the immediate question is whether you need to become a FEM expert if you only need to analyze your room acoustics once.

ANALYZING FEM OUTPUT

In general, loudspeakers tend to proportionally activate those modal frequencies that have greater than zero pressure pattern at this particular location. Partial mode activation is a pressure-distribution pattern similar to the exact modal pressure pattern, but in which the maximum modal pressure is not attained. Conversely, room modes that have a null at the loudspeaker location cannot be energized. Because some absorption and transmission losses are always present in the room, the modes cannot develop infinite pressure patterns and will always decay when the source of excitation is removed. However, as long as there are reflections in the closed volume of the room, the modes will be present.

The solution frequently recommended is to install bass traps. If the economical and aesthetic factors are on your side, the problem can be solved, or at least partially eradicated. Bass traps greatly reduce reflections, preventing the standing-waves phenomenon from taking full effect, and you will gain more freedom in positioning the speakers. You simply kill the problem where it starts.

I have browsed the Internet for some help in this area, and can testify that several companies offer good solutions to this problem. Room modes you need to look at are typically located below 100Hz, so you need to make sure that the bass traps you wish to install are really efficient at low frequencies.

If, for whatever reasons, the bass traps are not an option for you, I suggest careful review of the modal pressure plots. From this moment on, I am not trying to solve the problem, but rather select the "lesser evil." Good FEM simulation software usually calculates all room modes and associated pressure patterns at the same time, so when this lengthy process is completed, you need only flip through the list of modal frequencies to get the pressure pattern displayed on the screen. You are looking for the location of pressure peaks and nulls for each mode (frequency).

Larger loudspeaker systems are typically made to stand on the floor, and for purely aesthetic reasons you will not place them in the middle of the room, but rather against a wall or even in a corner. From the pressure plots, you will notice that pressure peaks also like walls and corners. Therefore, if you end up energizing room modes, you may as well energize as many as possible. If the room has many evenly spaced modes, the sound field tends to be smoother than in a room with only a few well-separated modes. Such a room sounds boomy at those frequencies.

Next, the pressure-plot analysis should reveal the locations of pressure nulls. This is essential, since one of the issues of prime importance here is to avoid cancellation of

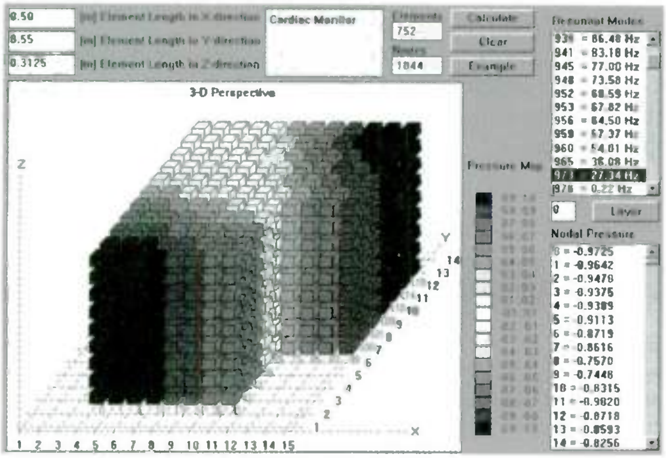

FIGURE 6: Pressure distribution of the 27Hz (lowest) mode.

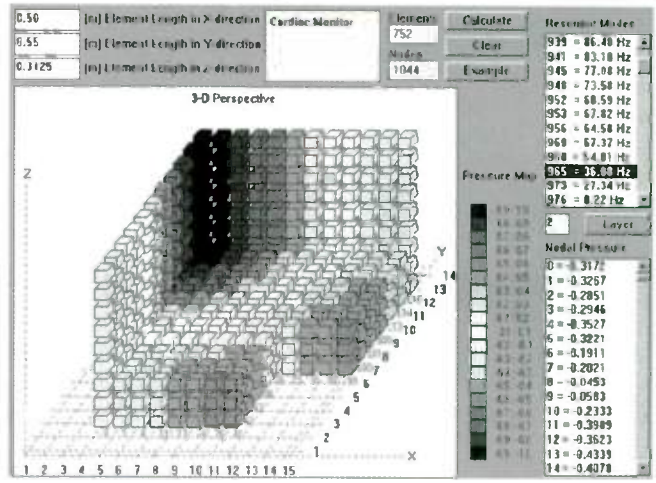

FIGURE 7: Pressure distribution of the 36Hz mode, which appears as a gently curved line running from (X = 3/Y = 7) to (X = 11/Y = 13).

sound. Having located the nulls, you at least know which areas of the room to avoid for quality listening. Many of us would accept some amplification rather than cancellation of sound (and our efforts). Moreover, if a particular mode is too loud, you can always use electronic equalization to trim it down.

The downside of living with the room modes is that the frequency response (loudspeaker plus room) *will* be irregular. That is, if you avoid a pressure null at one frequency, you are likely to sit in a pressure null of another. The question here is what frequency range is your favorite, and therefore worth preserving, and which can you sacrifice?

LISTENING-ROOM EXAMPLE

For the purpose of further analysis, I selected a listening room having the shape indicated in *Fig 5*. The floor plan is bounded by the corners A–F. The "brick element" I used to model the internal volume of the room has the following dimensions: X = 0.5m, Y = 0.55m, and Z = 0.3125m.

The FEM tool I used calculated room modes and produced the pressure-distribution patterns shown in *Figs. 6–10*. The color-coded pressure map was adjusted in

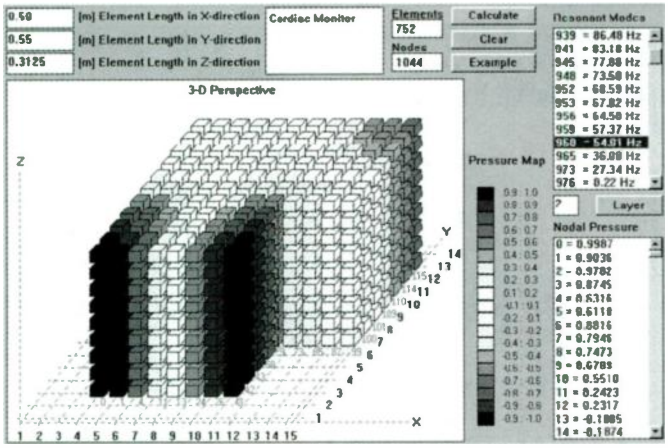

FIGURE 8: Pressure distribution of the 54Hz mode.

such a way that on a black-and-white printer, the peaks of the pressure appear black, and the nulls appear white.

ANALYSIS

1. *Figure 6* shows pressure distribution of the 27Hz (lowest) mode. It appears as a straight line between corners C and F.
2. *Figure 7* shows pressure distribution of the 36Hz mode, which appears as a gently curved line running from (X = 3/Y = 7) to (X = 11/Y = 13).
3. *Figure 8* shows pressure distribution of the 54Hz mode. The two curved lines running from the sides of the room indicate this is the higher-order mode.
4. *Figure 9* shows the 68.6Hz mode developed between the floor and ceiling.
5. *Figure 10* shows the first-order tangential mode of 73.6Hz developed between corners A and E and the ceiling.

As I mentioned, higher modes for this type and size of modelling element tend to attract a small percentage of error. You can reduce the error and increase overall accuracy by selecting elements of smaller size.

For the given room dimensions, the lowest mode is 27Hz, which can develop only if you place the loudspeaker in corner E and select your listening position in corner A (see *Fig. 6*). The area to avoid for listening is the straight line between corners C and F. The second lowest mode is 36Hz (see *Fig. 7*), and you cannot readily predict this one without the FEM method. To energize this mode, I would place the second loudspeaker right in corner F and avoid listening positions halfway along the walls from F to E and A to F, and also the middle of the room.

Two points need to be emphasized strongly here. First, by placing your loudspeakers in the corners of the room, you take advantage of what is known as "room gain." It can add as much as 10dB to your speaker output at low-end frequencies, compared with the "free space" response. Second, room modes, being based on standing-wave phenomena, also amplify the sound at specific frequencies. Therefore, you do not need to locate your listening position at nodes with 100% pressure. I would strongly suggest you aim for 40–60% pressure-node locations, while avoiding nodes of 0% pressure at all costs.

With the above in mind, you will find that placing the subwoofers in corners F and E and selecting your listening area framed by

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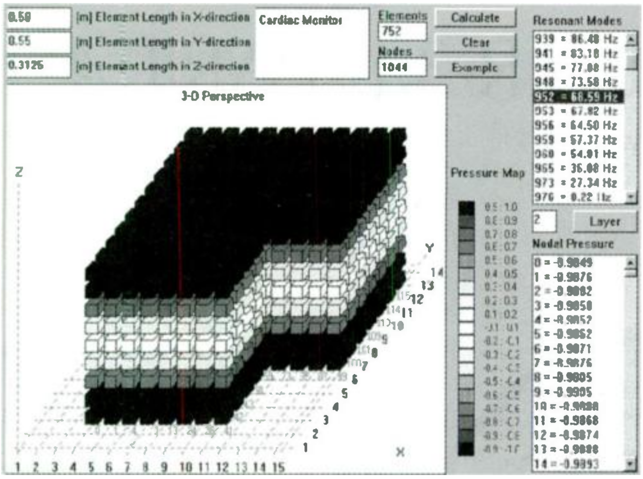

FIGURE 9: The 68.6Hz mode developed between the floor and ceiling.

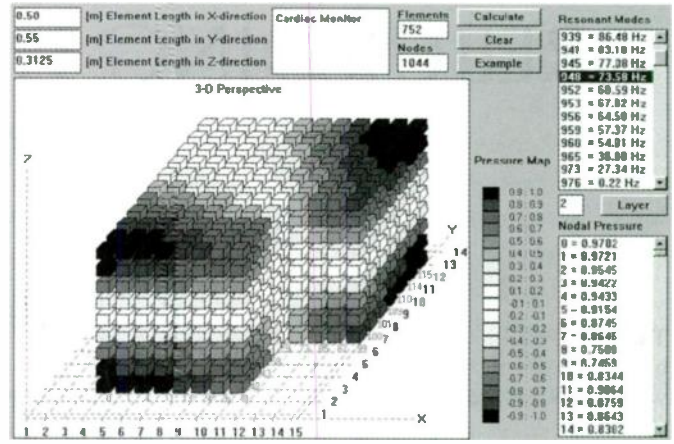

FIGURE 10: First-order tangential mode of 73.6Hz developed between corners A to E and the ceiling.

the points (X6, Y4), (X10, Y4), (X6, Y6), and (X10, Y6) ensures reasonable (not perfect) reproduction of the lowest two modes. As you can see, I would recommend a satellite system with two subwoofers and two satellites, one located in corner F and the other halfway along the F–E wall.

The higher modes shown in *Figs. 8, 9,* and *10* are useful in understanding the cost of this particular arrangement, and I suggest you draw your own conclusions here.

Some of you will be tempted to take advantage of the room modes. Say that you are interested above all in reproducing 20Hz wavelengths because you purchased these special woofers, designed this unique enclosure, and so on. In my opinion, this is quite a legitimate point of view. Today's electric bass guitars have five strings and easily generate fundamental frequencies of 20–30Hz. Special sound effects recorded on digital-video discs are also rich in low frequencies.

If you're thinking along these lines, you need to perform a modal analysis of your listening room, determine pressure-distribution patterns, and only then make an educated decision about your listening area. Having this out of the way, you can now use the ray-tracing method to improve your room's performance at higher frequencies.

REBUILDING THE AR-3a, PART 4

By Tom Yeago

Topics for Part 4 include the woofer assembly, fiddling with the box, and beginning work on AR's 1½″ dome midrange.

First of all, a woofer update. In working on a couple more 12″ woofers, I'm running into things I didn't remember in the disassembly stage (Part 3). I'm finding suspensions glued to the hardboard spacer (which is in turn glued to the steel frame or basket), and sometimes it appears that AR used hot glue, but in other places it looks like the same glue used on the surround. In either case, the best way to get the cone suspension free of the frame is to use solvent as before. But instead of waiting 20 minutes or so for the solvent to work, pop the woofer in a plastic bag, seal, and let it sit overnight.

To separate the cloth suspension flange from the hardboard, I filed the end of a hacksaw blade until it was like a dull knife, not sharp. I was able to work this under the suspension and, because it was so long, easily work it around the flange, prying and wedging the glue joint apart. Actually, the solvent serves to weaken the hardboard more than soften the glue, but the two come apart nicely. If you have trouble, it's better to destroy the hardboard spacer than to waste the suspension.

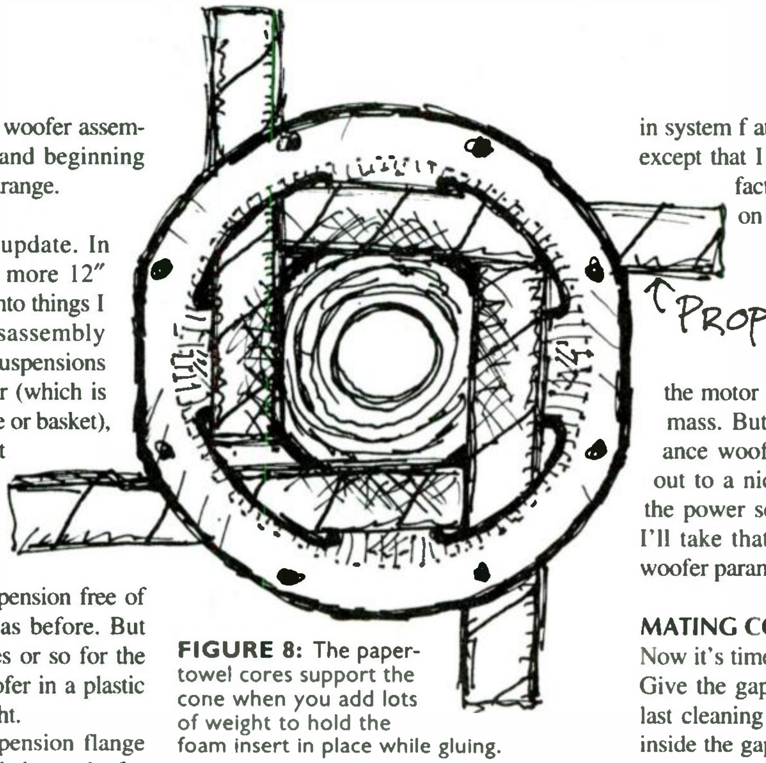

FIGURE 8: The paper-towel cores support the cone when you add lots of weight to hold the foam insert in place while gluing.

FINAL ASSEMBLY, AT LAST

We're almost, but not quite, ready for final assembly. First, run a trial Bl by temporarily installing the cone assembly, shimming the motor former from the pole piece with playing-card strips. Then use masking tape to hold the spider and surround against the frame, establishing alignment. I'm serious; I have done this. Remove the card shims and carefully bounce the cone a little. Probably to your amazement, it will not rub.

Now run the Bl test, using weights and DC through the motor coil. You should be at Bl = 16, or just slightly more. I got Bl = 16.2 for my stamped-frame woofer. If you're off, I don't know what to say. Make sure there's no steel "shorting" the two magnet faces. Add more backing magnets to stifle fringe flux. If you're at your wit's end, just work with what you have, using your best judgment to make adjustments to M_{ms} that will give you a Q_e, f_s, and efficiency you can live with.

I want to brag a bit here. Do you know how impressive a 16 Bl is? If memory serves, the 12″ woofer in Now Hear This's 3.3, which has been advertised in *SB*, has a Bl of 12+. Look through your spec sheets. Okay, the Now Hear This (NHT) unit has a big cone for a 12″ woofer (S_d = 560cm^2, vs. 425cm^2 for this AR) and a truly prodigious excursion capability (X_{max} = ±13mm, I believe, versus ±6.4mm for the AR).

Now you can plug in the numbers, and you'll find I get a Q_e = 0.17. I'm guessing Q_m equals 3, or thereabouts. This gives me a Q_{ts} of 0.16. With a V_{as} of 340 ltr and a 50-ltr box, we're looking to multiply everything important by $\sqrt{(6.8 + 1)}$, or 2.8. This results in system f at 35Hz and a system Q of 0.45, except that I have some series resistance to factor in, so we're coming in right on target at a system Q of 0.5.

However, just as interesting is that the efficiency numbers work out to a wash; i.e., we wind up with the same efficiency as the stock woofer—the motor improvements offset the added mass. But since this is a higher-impedance woofer (R_{dc} = 4.5Ω, which works out to a nice manageable 6Ω in circuit), the power sensitivity is down a dB or so. I'll take that any day. *Table 2* shows the woofer parameters.

TABLE 2

RELEVANT DATA AND PARAMETERS: WOOFER

	M_{ms}	C_{ms}	f_s	V_{as}	BL	R_{dc}	Q_e
Stock	82g	1.3mm/N	15.5Hz	340 ltr	7.6T-m	2.5Ω	0.34
Modified	125g	1.3mm/N	12.5Hz	340 ltr	16.2T-m	4.5Ω	0.17

MATING CONE TO FRAME

Now it's time to mate the cone to the frame. Give the gap, pole face, and top plate one last cleaning with masking tape. Keep at it inside the gap until nothing more adheres to the mastic. Clean the coil and motor former, too, and the underside of the spider.

Use playing-card strips for shims between the pole piece and the inside of the motor former. Two card thicknesses worked for me, but your woofer might be different. Make adjustments with strips of masking tape until the shims give a tight but slidable fit of the motor down in the gap. You want your shims down deep so they'll index with the lower portion of the pole piece. Make sure that the spider flange just touches the frame, with ¼″ of the motor in front of the top plate.

Slide the woofer cone back and forth, double-checking that the clearance is okay. Twist the cone so the lead attachment loops on its bottom are aligned, one to the existing terminal board, another to an empty ear. Your shim strips should be spread symmetrically around the inside of the former, but make sure there's no shim over the gap in the former (since it's likely to be irregular here).

Mix up some epoxy and spread a thin coat on the frame and the spider flange. Now slowly slide the cone assembly in to a depth where the flange hits the frame, but isn't stretched in or out. Clamp the flange to the frame as best you can. I made do with clothespins and a couple of layers of cardboard cut to shape.

It's a good idea to monitor the progress of the epoxy you mixed up but didn't use, and just as it begins to stiffen and set, apply pressure to the joint one last time, pressing down with your fingers. Then replace the clamps. Mask off the top of the motor former with strips of tape so nothing falls down there. Let it set for 24 hours.

THE SURROUND

Now for the surround. Clean off the frame flange with isopropyl and white vinegar. Then slide the cone forward (it's still shimmed, remember) so you have a little working room between the surround flange and frame. Spread a coat of RTV (Room Temperature Vulcanizing) on both surfaces and let them start to cure for two minutes or so. Then tap the cone at the center until it moves down and the surround flange is seated on the frame.

Now tap lightly on the front of the flange to make sure the tacky RTV surfaces adhere. Keep at it a minute or two, until you're sure the surround is sitting in proper position on the frame. Then tap the cone 1/8″ or so farther in, flexing the surround slightly and putting a little pressure on the glue joint where the half-roll ends. Double-check to see that everything's even. Clamp with more cardboard and clothespins, and let it set another 24 hours.

When the time is up, pull out the shims, and you should have a proper, freely mounted cone. If you have small fingers, you might want to smear a little more RTV on the inside, where the half-roll meets the frame. Use just a little RTV on a fingertip, reaching around up inside between frame and cone, doing one section at a time.

FERROFLUID IN A WOOFER GAP?

I remember reading about only one speaker with a liquid-cooled woofer. When I started playing around with this AR project, I half expected I'd need to resort to ferrofluid in the gap to get the system Q down where I wanted it. But heatsinking the motor to the rest of the speaker via liquid in the gap is still a very useful feature. So I decided to put some ferrofluid in the gap, but only on the inside, between the former and the center pole, and even then I wouldn't fill this gap full.

I'm not sure, but it stands to reason that

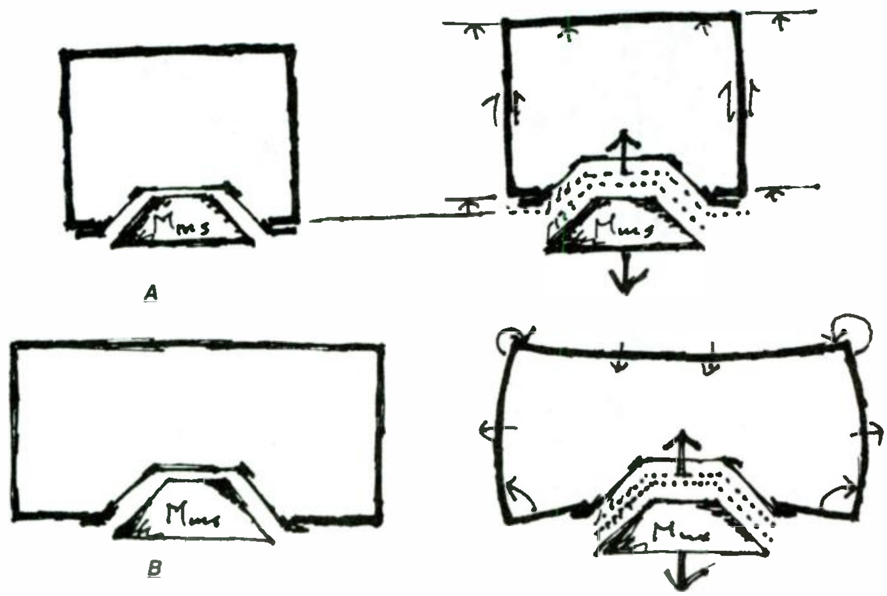

FIGURE 9: My notions of how box walls become lively. It's not the sound, but the structurally borne vibrations. ***A*** depicts the dominant activity of a small box (compared to woofer-frame size) with a strong front baffle. ***B*** shows how a larger box is more prone to vibrate.

ferrofluid between the wire side and the top plate would soon be sprayed out of the gap into the structure's innards and the spider's bottom, which does no good to anyone. But the inside of the motor is just smooth former surface, not likely to spray the fluid anywhere. Also, with my souped-up magnetic field, the fluid has that much more incentive to stay put.

Moreover, if I fill only half this space, the fluid should be held smack in the middle of the gap—where the field is presumably strongest—and furthest away from the ends of the motor coil, which could let the fluid leak through to the other side, where it would be spewed away as speculated above. The bore in the pole piece means that no air is trapped under the foam insert to blow the fluid out. So the motor is partially liquid-cooled and modestly damped by the fluid. I'm guessing I have an Q_{ms} in the 3 range—a lot of heat, anyway. It's a pretty big chunk of wire.

Since you know the thickness of your shims and the other dimensions of the gap, you can figure out how much magnetic fluid you need to fill the gap half full. For me, it was only $0.35cm^3$, which I measured and added to the gap using a 1 mltr ($1cm^3$) graduated pipette from Electronics Goldmine's strangely fascinating catalog. (Cheap, too, but a $10 minimum.) It's also strange to see the magnetic field suck fluid from the end of the approaching pipette. Cover up the gap again with tape.

Now is a good time to take care of any odd housekeeping items such as attaching the second terminal lug and soldering onto the terminals the flexible tinsel leads from the woofer (those loops made on the bottom of the cone in Part 3's Fig. 7, remember?). Oh, and replace that windowscreen on the back of the magnet structure. (Recall that you had to take it off to bolt the pole extension via the vent bore.)

FINAL ASSEMBLY

You already know the foam insert fits perfectly, so all you need to do is slather on the epoxy and do it, right? Well, up to a point. You're going to weight down the insert to hold it in place, but you can't let the weight push the cone down so far that ferrofluid will slurp through the former gap to the other side, so you must support the cone. But you can't just use dowels or sticks, because they might deform the cone.

I used four cardboard cores from paper-towel rolls, stuffed some sticks of cardboard inside them to give more strength, flattened them a little so they'd conform to the cone, and inserted them pinwheel style between the cone and frame. Thus they don't go all the way through, so all four cores bear their fair share of the load (*Fig. 8*).

Now mix up some epoxy and spread a generous layer on the cone. Also, daub some on the tabs of foil/tissue at the insert's perimeter. Daub some more on that felt circle, around the edges where it will press against the end of the motor former, and give a good coat to the outside of that exposed ½" of former.

At this point very carefully lay the foam insert in place. Make sure the motor former slides into the hole and doesn't cut into the foam. Once you've started it correctly, twist the insert slowly down into position so that the leads rest back in the grooves you made earlier in the foam. Press down, firmly and evenly, until the foam is seated and the little tabs rest tightly against the cone surface.

Now lay a saucer upside down on the skin and start piling on the weight. Keep adding it until you're satisfied the insert is firmly settled, but not so much that the paper-towel-core props might give way. Five pounds or so should do it. If any glue oozes out past the edge of the skin, even it out with your finger. Let it cure 24 hours.

You now have a very capable woofer—labor intensive, sure, but ridiculously cheap. And heavy. Mine tipped the official postal scales at 15 lbs.

ZOBEL THAT MOTOR

In keeping with my professed preference for textbook crossover filters, it was necessary to compensate the woofer to present a simple resistive load for the crossover. A rough impedance curve indicated that the woofer bottomed out at 6Ω—a very satisfactory result. So I Zobelled to this, experimentally, and wound up with a 6Ω resistance in series with what I suspect is about 48μF. I say suspect because I used two nominal 16μF electrolytics (loose tolerances, tending toward the low side) and four 4.7μF film caps. I get a nice 6Ω from 400Hz, where I started measuring, to about 800Hz, then a slow droop to 5.4Ω at 1.5kHz. I believe this is sufficiently resistive to allow for the textbook crossover solution.

Now, all this seemed ordinary enough

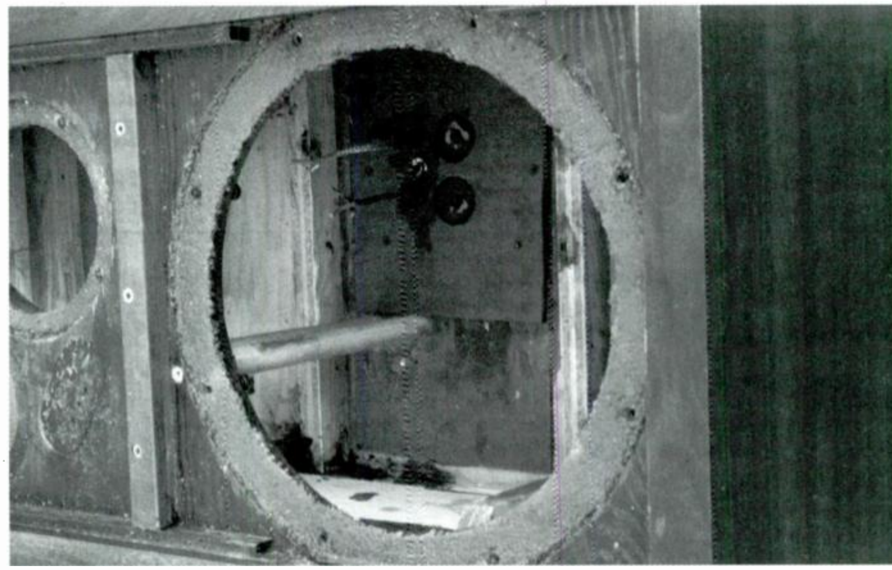

PHOTO 9: This shows most of the minor bracing added to the stock box. The maple cross-brace is above the woofer cutout. Inside are the two front-to-back dowels and the masonite plate fastened to the stock crossover board (note the relief work that allows installation of stock pots). Just visible to the left is a piece of sheetrock stuck to the side panel. Also, note the homemade gaskets.

TABLE 3

RELEVANT DATA AND PARAMETERS: MIDRANGE DOMES

	M_{ms}	C_{ms}	f_s	V_{as}	Bl (est.)	R_{dc}	Q_e*
Stock	1.5g	0.4mm/N	205Hz	155cm^3	3.25T-m	2.7Ω	0.5
Modified	1.7g	0.4mm/N	190Hz	155cm^3	5.8T-m	4.0Ω	0.24
	R_{ms} (est.)	Q_m	Q_{ts}*	Q_{cb}	f_{cb}		
Stock	1	1.9	0.4	1.0	500Hz**		
Modified	6	0.34	0.14	0.28	400Hz		

* Level-setting pots, resistors, and crossover components in series with the motor coil will affect this directly. These are free air figures up to the "cb" numbers.

**A guess here, because most of the enclosed air is coupled through the resistive restriction of the motor former/pole piece crevice. The rough impedance curve I ran on a stock midrange also indicated 500Hz.

until I did a little ciphering and found (according to my *Radio Data Handbook*) that my motor coil should have 1.6mH of inductance all on its own, in free air. And if I took the simple-minded approach and designed for 6Ω, I'd get 44µF in the Zobel. Where, I want to know, is all the complexity? Why is my motor acting like a simple inductance? Doesn't the proximity of all that steel count for anything?

Does this relatively high flux density (about 1.2T) drive the steel in the structure far enough toward saturation that it resists AC flux from the motor coil? It's not supposed to be this easy—yet another argument for expensive, high-flux speaker designs. That reminds me: Thiel is famous for its highly compensated first-order systems, with short-coil motors in the better models. This suggests relatively low flux density in the steel. I wonder if this complicates matters when it comes to building conjugate impedance circuits?

BOXWORK

I'll keep my comments about finishing very brief. Suffice it to say I used scrapers (sandpaper is idiocy when a scraper will do) and rubbed in linseed oil. I cut the oil with turpentine, and added a little polyurethane to the mix early on (everyone has his crank concoctions). This type of finish takes months to build up properly, but considering the rest of the project, you've got nothing but time. I filled any nasty nicks or bumps with a putty made of sawdust and glue. Finished like this, walnut looks terrific.

Bracing was nothing fancy (*Photo 9*). I made sure all the joints were sound, filling anything suspicious with gobs of my sawdust-glue putty. Then I improved the stock bracing by shimming the brace ends to the adjacent panels and to other braces, where they were adjacent. This is tedious, but it helps if you use masonite for the shims, because you can easily split it to the needed thickness. I added still more sawdust/glue to likely spots. Then I smeared DAP along any joints likely to leak.

Next I added a brace to the front baffle, over where the single stock brace is glued. I used 1″ × ½″ maple and glued and screwed it (three 2½″ deck screws through the baffle into the brace below).

After that, I firmed up the back panel by gluing and screwing a chunk of ¼″ masonite through the stock hardboard (which AR used to mount the crossover) into the back panel. This also reinforced the back cut-out area where the input is hooked up. I also worked glue into all accessible crevices, inside and out, and tightened down the screws.

I then added two front-to-back braces, using ¾″ hardwood dowels, just above and left of the woofer cut-out. The fitting must be precise. You can even notch them on the front to help out the front brace. Then I predrilled panels and dowels and glued and screwed them in place, using 3″ deck screws.

FILLING THE CRACKS

I reworked the joint at the back, too. AR used what looks like plaster in this crevice. What was loose I replaced with my sawdust glue. What wasn't loose I reinforced by working wood glue into it. One of my cabinets wasn't stained on the back, so I fixed that with the world's cheapest stain—add a dollop of roofing tar to mineral spirits.

There's an oval cut-out in the baffle where AR brought the wire through for connecting the two dome units. I filled it to grade inside and out. Then I used a Waylands' Wood World tip and added an aluminum angle iron (1″ legs) to the inside of the front baffle, running between the midrange and tweeter cut-outs—three screws, plus DAP. I also cut some slabs of wallboard (approximately 6½″ × 4″) and DAPed them to the middle of the side panels.

As a convenience, I made some 8″ nylon-webbing handles, grommetted the holes, and fixed them to the back by screwing through the back panel into the braces with 2½″ deck

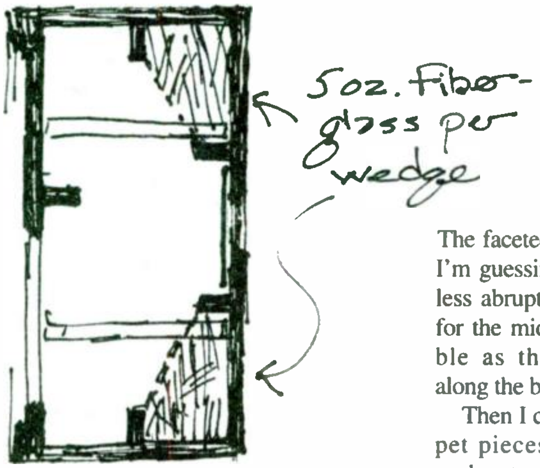

FIGURE 10: Fiberglass packed into the back corners and held with screens stapled between the braces. The rest of the void received 20 oz of Dacron fluff.

screws. Do this. These boxes weigh approximately 65 lbs.

I filled in the baffle's corners—around the woofer—by gluing on little triangles of ½″ MDF. What could it hurt? Around the midrange and tweeter, I glued facets of sheetrock. The mass couldn't hurt, and what bending friction they might offer could help.

The faceted surfaces, I'm guessing, offer a less abrupt transition for the mids and treble as they travel along the baffle.

Then I cut the carpet pieces you see and stapled and DAPed them on, a concession to diffraction control (*Photo 9*). It makes the speakers look great once you peel off the grille. After installing the crossover, I added some more dowel bracing, two side-to-side pieces held just with glue and a tight fit, since screws weren't feasible.

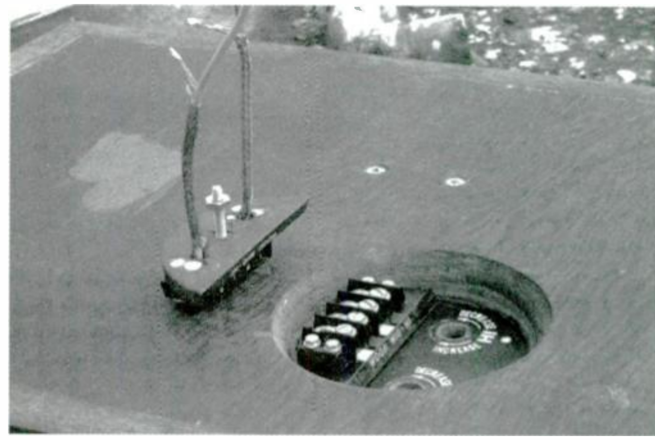

PHOTO 10: The input-connector arrangement, showing one terminal strip installed and the bottom of another.

BRACING PHILOSOPHY

As I suggested, I believe most of the energy is fed into the panels via the speaker's frame. After all, a good mechanical connection exists there, which means that if you wish to stifle the panels, you must pay attention to how the source (the speaker frame) interacts with the box (*Fig. 9*). This suggests that you need a front baffle as small and strong as possible, concentrated bracing near the source of vibration, and braces across opposite walls.

A small baffle forces the speaker frame to try to move the entire box as a unit, a simple mass. A large box is just asking for flex. I see mass, especially in the speaker frame, as a good thing, since the motor must move this mass before it can flex the cabinetry.

GASKETS AND CONNECTIONS

I made my own gaskets, since anything's better than Mortite. I cut out circles of carpet for the woofer and midrange, and of felt for the tweeter, and cut holes with a ¼″ punch. Then I saturated all the gaskets with DAP and used more DAP to glue the gaskets to the baffle. When you're cutting new gaskets, get them exactly right, or they'll cause no end of trouble. I also daubed a bit of Mortite on the driver-mounting screws to seal the threads.

In the connection department, I didn't like AR's knurled-nut arrangement, and I wanted the option of biamp-capable connections, so I mounted a four-position terminal strip on a half-moon of masonite (*Photo 10*). I ran the wiring through the two outer holes in the AR backplate, and used the center hole to mount the half-moon. I applied DAP to seal.

COSMETIC STUFF: GRILLE AND CLOTH

If you intend to save the beige cloth, first pry out all the little staples holding it and carefully pry the fabric from the frame. Then sew a "zig-zag" stitch twice around the edges so it doesn't fall apart when you wash it. Get the linen good and clean, removing stains with lemon juice or any other antistain potions. There'll be a hole in a corner where the badge screws into the frame, but any other small flaws can be easily repaired by anyone who reweaves fabric. Try a seamstress or tailor.

Stretch out the cloth as best you can and iron it flat. Then go to work on the area in front of the tweeter with a stiff brush. It should be on the threadbare side to better let the treble through, but you don't want to be too obvious about it. Vacuum off the fluff and shave it clean with an electric razor.

Mend the frame as needed, paint it black, and drill a 1/8″ hole where the badge will attach. I stretched fiberglass windowscreen across the frame, to give a little support to the linen, which goes on next.

Carefully stretch the linen back on, getting it straight and taut. Fix it in place with a normal paper stapler, flattening the corners. You paid attention to how the corners were done before you took the linen off, didn't you?

I folded up some felt into funny shapes, as you can see (*Photo 11*), and stapled them to the inside of the frame between the Velcro® strips. This is yet another nod to the diffraction bogey. Staple on your Velcro. I stapled a little tab on the bottom to tug on when removing the grille.

BRASSWORK

There's no point to this project unless you refurbish the classy, brass gravure AR badge. Just go at it with 400-grit wet-or-dry paper, wetted down with isopropyl. Tape the paper to a flat work surface, then tape a straightedge on top as a guide. Take off the old finish, always rubbing with an edge against your guide. This will retain the brushed look of the badge. Keep at it until you're down to clear brass. Then clean, dry, clean again (with masking tape) and, in a clean work area, spray on a good coat of clear acrylic. Let it dry in a clean area—no dust allowed.

Now pull the steel core out of a 1/8″ aluminum pop-rivet and thread it onto the back of the AR badge to use as a nut to hold the badge to the frame. Take off the rivet, tap it into the 1/8″ hole in the frame and screw the badge into it from the front; much better than the way AR did it.

STUFFING

You have a 40-ltr box, not counting driver intrusion. I figure that with stuffing the woofer sees a 50-ltr box, driver intrusions notwithstanding. For stuffing, I layered 5 oz of the fiberglass I originally pulled out of the boxes back into the two rear corners, and kept it in place by stapling windowscreen between the braces (*Fig. 10*). The rest of the internal volume is occupied by 20 oz of Dacron fluff. The glass wool could as easily be confined by felt. I didn't want to do all my stuffing with fiberglass because I was afraid the woofer would inhale small bits through the bore I drilled through the pole.

I figured the fluff would filter out any ambitious migratory fiberglass. But standing waves weren't that big a deal because I was crossing over the woofer at 500Hz or so, where the wavelength is 27″.

MIDRANGE DOMES

Now back to the grinding work of taking drivers apart, puzzling out their innards, and bending them to our nefarious ends. The midrange domes have stock specs and parameters as in *Table 3*. I know M_{ms} because years ago I was given a pair of much-abused AR-5s. I cannibalized their dome units for this project, but there was precious little to cannibalize from the midranges because a previous owner had unscrewed and made off with their magnet structures. So for M_{ms}, I cut out the dome and half of its surround and weighed it: 1.5g. I reckoned flux density for the gap to be about 1.4T if everything fit.

When you take the flange-cum-dome off the top plate, mark its alignment so it will go back the same way. Now fill a big coffee can or similarly sealable container 1/3 full of acetone. Scrape off whatever glue shows around the joints, and plop the magnet structure into the acetone to soak for a couple of days. You might as well soak all your midrange and tweeter assemblies at the same time. I like a coffee can because I can use a square of Al foil as a gasket between the can and the plastic lid.

Round off the bottoms of the 8-32 screws that hold the flange to the top plate just enough so they're smooth—no sharp edge on the bottom. You do this because (assuming you have a later-type midrange, with

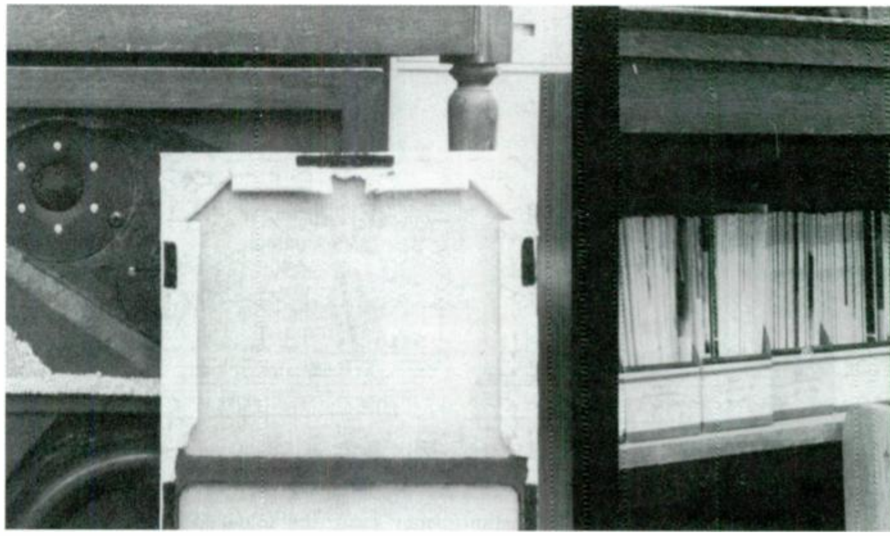

PHOTO 11: The grille frame surrounding the domes and the faceted sheetrock on the baffle. A piece of carpet is stapled below the domes in hopes of ameliorating diffraction. The black rectangles on the grille-frame perimeter are Velcro.

four of these screws) you will tighten them to pry the top plate loose from the magnet, and if a sharp point presses against the magnet, it may chip off a piece, an event you wish to avoid.

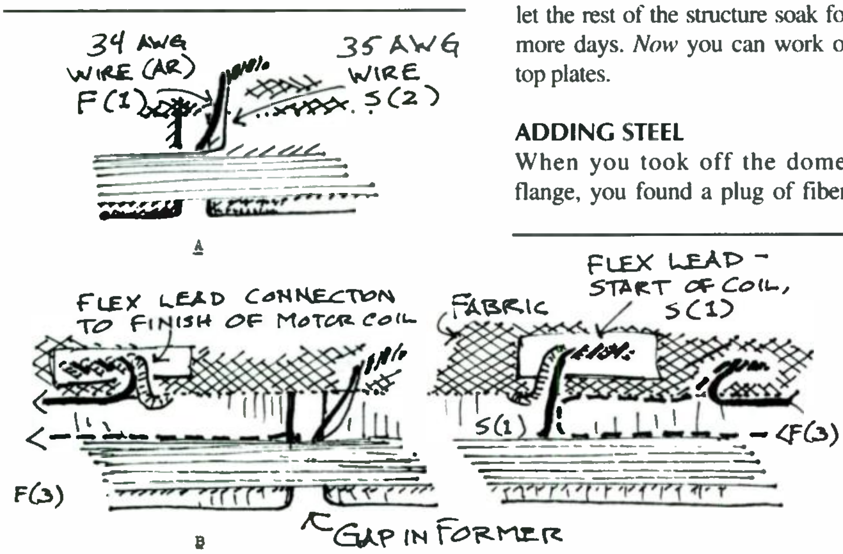

FIGURE 11: Winding details for the midrange motor coil. ***A*** shows how the finish of the first layer, F(1), is brought up through the former gap to be soldered to the start of the second layer, S(2), drawn as a thin line. ***B*** shows the finishing details of the third layer, F(3), drawn as a dashed line. The wire emerges from the gap, continues around to where S(1) begins, then is dressed up out of the magnetic gap to meet the length of 34 AWG wire left attached to the flex lead. All is securely epoxied.

After the assemblies have soaked for 3–4 days in the pot of acetone, take them out and screw in the blunted 8-32 screws until you've popped the top plate free of the magnet. Pull out the fiberglass from inside the magnet structure, squeeze out the acetone, and let the rest of the structure soak for two more days. *Now* you can work on the top plates.

ADDING STEEL

When you took off the dome and flange, you found a plug of fiberglass under the dome. In addition to damping, this piece also serves as a spring, pushing the dome forward so the motor coil is centered in the gap. Without it, the bottom of the motor coil is flush with the bottom of the 0.15″-thick top plate.

The motor coil is about 3mm tall and has two layers, with 14 turns on the first (inside) layer and 12 turns on the second. I make it 34-gauge wire, giving an R_{dc} of about 2.7Ω. I should mention that these, like virtually all domes, are short-coil/long-gap motors.

I have reservations about using a plug of fiberglass as a locating element, and I wanted more excursion capability (X_{max}) anyway, so I added some steel to the bottom of the top plate—0.05″, to be exact. That makes the gap 0.2″ tall, 5mm for all practical purposes, and gives me an X_{max} of ±1mm; not bad.

I made the extension by drilling out the center of a 2″ fender washer, centering it on the top plate and attaching it by drilling and tapping the top plate for three 4-40 screws (*Photo 12*). Once I had screwed and epoxied the washer into position, I used a half-round file to bring the hole in the washer to exactly the same diameter as the stock hole.

The trick here is to paint the face of the gap in the top plate with a magic marker;

then, using a file whose rounded face closely matches the curve of the gap, file carefully until you start taking ink off the top plate. This is easier than it sounds, and the face of the gap isn't finished very well by modern standards, anyway; it's a simple stamping. If you have a router, chuck a cylindrical rotary file in it and use that instead. A file works fine, but a router makes this operation a piece of cake. Once you have the diameter right, check your gap for thickness. These washers are typically 1/16″ thick. You might wish to dress the gap down closer to a total of 0.2″.

You should also make sure your top plate is good and flat. Take a straightedge to it, and if it's warped, you can file it down flat by hand easily enough.

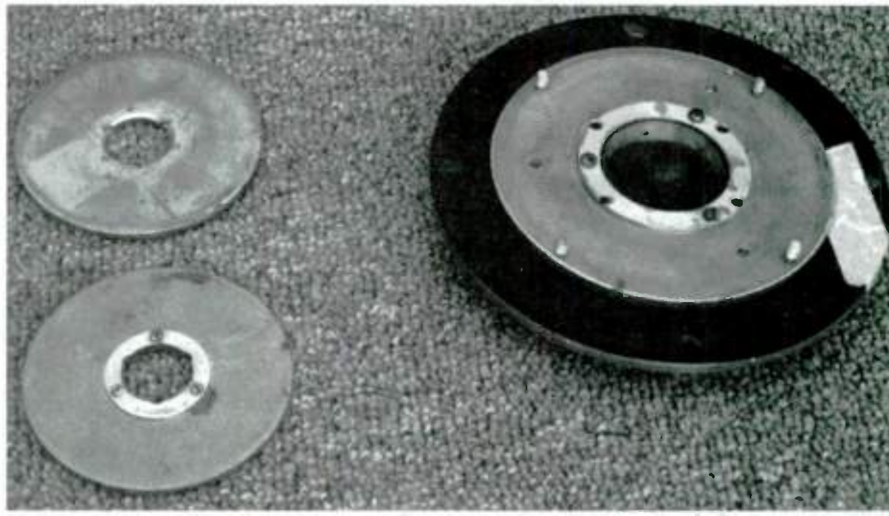

PHOTO 12: Modified dome top plates. The assembly at the right is the midrange top plate with front flange and dome screwed in place. Note the gap extension screwed to the bottom, and the four chamfered 1/8″ vent holes connecting the air under the surround with the air under the top plate. Some 2mm vent holes in the motor former are also visible. At left are treble top plates.

STIFFENING STEPS

First clean the back of the fabric dome. (Understand that you just wish to have the *dome* stiff here, not the fabric surround.) I used a toothbrush and a pencil eraser. Mask the aluminum former. Now you rub about 0.2 cm^3 of epoxy into the fabric where it will do the most good. To give you an idea of how much that is, a one-cent US coin's volume is 0.36 cm^3. So you're going to apply about half a cent's volume of epoxy.

Mix up about a "cent" of epoxy, divide it in half, and then start putting little dabs around the edge of the dome. I used a 1/8″ steel rod, but the shaft of a drill bit would be as good. Taking glue from only one of your two blobs, place the dabs in a circle about 1cm apart and about 6mm from the (masked) aluminum former. Using the rod or drill bit this way lets you apply dabs of the same size, and by comparing the dwindling size of your blob to the untouched blob, you have a good idea of how much glue you're putting on.

After applying a circle of blobs, work the epoxy into the fabric with your finger (clean hands!), going around in little and big circles until it is pretty evenly spread.

Then apply another series of dabs farther in, spread with your finger, and so on until you have a good even coat across the whole dome. It'll soak right in.

Note how much epoxy is left, which should give you a feel for how much you've applied. After about an hour, the epoxy will have soaked in and set, and the cloth will no longer look shiny. Mix up a little more glue and apply another coat, but now just around the edge, coming in maybe ½″ from the former. This application won't soak into the fabric, so a little will go further. After a day or so, your dome will be about three times as stiff as stock, with only 0.15g or so mass penalty.

I also drilled a series of eight 5/64″ holes in the former, close to the front, to equalize pressure differences between the under-dome and under-surround air volumes, since I planned to use ferrofluid in the gap. Get these holes nice and clean. One way is to drill them with a smaller bit and enlarge them by twisting with a round needle file until you're satisfied.

MORE MOTOR MEDDLING

I, of course, wanted more R_{dc} and more wire in the gap. I was shooting for a 6Ω system by this time, and I figured I could do a more precise job of assembly than AR did. I decided to take off AR's second layer (12 turns) and add my own layer of 13 turns, plus a third layer of seven turns, both with 35-gauge wire. This came to 34 turns and about 4.0Ω. I calculate this to be a 0.5dB drop in efficiency and, assuming 6Ω and 4Ω units, about a 2.5dB drop in sensitivity, assuming the flux density remains constant. That's good, since I still reckoned I had 2 or 3dB on the woofer.

How to wind such an addition? Well, think about it. You wish to wind a two-layer nested, continuous coil on top of a one-layer coil. Check back to Fig. 1 in Part 2. There's no reason not to nest your two-layer coil into the existing layer (AR's 34 gauge).

It's probably easiest to think about this process as starting in the middle. That is, feed enough wire off the main bobbin to wind the final layer onto a second bobbin, which you attach to the plastic flange for later use. Then start by winding the second layer onto the first, but winding backwards in the sense that the first turns are actually the finish of the second layer. When you finish winding this layer, you'll solder it to the finish of the (stock AR) first layer.

Then you take the second bobbin (attached to the flange, you remember, so it could turn with your workpiece) and wind that third layer "frontwards," from top to bottom, the first turns being the start of the third layer. The last turns are the finish, when you must bring the lead back up through the gap in the former to solder it to the lead that connects it to the outside world.

PUZZLES OF COIL-WINDING

It's difficult to explain. I can only tell you to think it through and fool around with something like twine around a paper tube until you understand what I'm talking about.

Assuming you're following, go ahead and take off AR's second layer. You're going to leave a couple of inches of wire still attached to AR's flexible lead, so begin by lifting the finish of AR's second layer with a needle and, not breaking the wire, lift two or three inches free of the coil. Cut and tape that lead out of the way.

Now go back to the cut end and just unwind the rest of this layer. But when you get to the bottom and start to unwind the last turn of the first layer, stop. See how far around you still must go (continuing on the last turn of the first layer) to get to the gap in the former, add a couple of inches, and cut.

Take these two inches and continue, adding to the first layer, until you get to the gap. Then go down and up through the gap on the inside, and to that you solder your "start" for the second layer. Clean the glue from this little length of wire as best you can, and glue it in place with epoxy. Make a nice crisp bend as you go inside and up the gap in the former. Tape everything in place so it lies smoothly, and wipe off excess epoxy.

Now you need a way to hold the motor coil out far enough away from the flange so you can get to it, and some way to mount the flange so it will turn. Make a little jig, carving up a piece of foam so it fits the front of the dome, then mount the jig, centered on your drill's rubber sanding disk. Then duct-tape the flange hard against the sanding disk, letting the foam cup push the motor former out where you can get to it. Run the drill a couple of revolutions, centering the flange, and you're ready.

PREPARING THE COIL

You wish to form a good nest between the first and second layers, so clean the glue out somewhat by "playing" the coil a few times with a needle. Clear out the flaking bits of glue with masking tape, do a little more cleaning with abrasive pads, and still more with isopropyl and tape.

Good magnification and strong light are essential. You have only 20 turns to add, so go slowly and steadily. Break off a couple of lengths of 35 gauge wire so you'll have a feel as to how much tension it can take (not much). Cut half a dozen small pieces of masking tape and stick them where they'll be handy if you need them.

Feed about 4′ of 35-gauge wire off your main bobbin, through the gap in the former from the inside. Wind this wire on a small bobbin and tape it out of the way on the flange or what the flange is attached to. Now epoxy this wire flat in the gap, and secure it with tape.

After an hour this will have set, and you can start winding the second layer off the main bobbin. Mix up a mote of epoxy and spread it on the coil, mount the bobbin so it feeds freely, and start winding. Kinks in this size of wire are a serious nuisance, so be careful. You're winding from the bottom up, and need to get this wire into the groove as soon as possible.

Wind slowly and carefully, counting the turns. You've probably noticed that AR did not wind its coils with the turns closely packed; this makes your job easier. Keep good tension on the wire, but be careful.

As you finish up, the groove runs out. There should be a little epoxy on the former just above the coil. Keep winding part of another turn in this epoxy (and hard against the first turn of the AR layer) until you come around the gap.

ADDING A SECOND LAYER

Now, remember the wire that emerges from the gap here and goes to your second bobbin? You wish that wire clear of any more turns from the main bobbin. So detach it from the flange, loop it down over the motor coil, and tape the second bobbin out of the way inside the dome. Now wind a couple of turns off the main bobbin to hold the tension, tape the end, and cut the main bobbin free. You've just added a 13-turn second layer (plus a couple of extra turns to tie off).

Bend down close and inspect your work. The turns should be tight and even, secure in the groove. No skipping ahead or doubling back or climbing over turns. Mix up another mote of epoxy and spread it on the coil, getting a good even coat.

Now it's time to wind on the last layer. Retrieve the second bobbin from inside the dome and mount it so it feeds easily. You'll be turning the former in the opposite direction from when you wound the second layer. Get a good crisp bend in the wire coming out of the gap, and away you go.

Now, recall that you need only seven turns on this layer. So feed into the groove and climb up on top of the second layer at once. In fact, on your first turn, skip over two or three turns (making a steeper pitch) so that on the second turn the wire will nestle into the groove toward the middle. Wind five

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tight turns normally, then take another steep-pitch turn to get to the bottom of the motor coil. At the end of turn 7, you'll be back at the gap. Take another turn to hold the tension, then duck through the gap and tape off the end to the inside of the motor former.

Inspect for a good wind, smooth out any small globs of epoxy, and pluck off any fibers and scrape off any dust. Then give the coil a final thin coat of epoxy, just to fill in the grooves. If everything looks good, let it set for 24 hours. Sometimes you can repair minor problems by shoving the wire around with a needle. Just be sure to smooth down the finish.

TYING UP LOOSE ENDS

You still must wire the new windings into the circuit. Connect the beginning of the second layer to the finish of the first layer, which emerges from the former gap at the top of the coil. Undo your "tie off" turns and arrange things as in *Fig. 11*. Just don't strip the enamel off the wire until it's clear of the aluminum former and safely on the insulating fabric. Twist, solder, clip off the excess, dress it down flat, and hold it in place with epoxy.

Getting the finish of the third layer connected is a little more involved. First undo the "tie off" turns and unwind until you get to the end of turn 7, right there at the former gap. Feed the wire inside the former and up through the gap (there are already two runs of wire in this gap), dressing it to lie flat. Pull the wire through the gap in the former so it emerges at the top of the coil. Be wary of kinks.

Now continue making a partial turn, the "right way" around at the top of the coil, flush against the former and the motor coil, until you get to where the first layer starts with the lead in from the flexible lead. See *Fig. 11* again. This gives you a complete number of turns on the motor. Now bend it crisply up toward the fabric, and make sure the partial turn is properly glued down.

Now find the length of 34-gauge wire you left attached to the other flexible lead. Wind this around to meet the finish of the third layer, scrape the insulation, twist, solder, and epoxy it down on the fabric so that everything's insulated from the former. Note in *Fig. 11* that I ran these wires along the bottom of the fabric. Just get them clear of the magnetic field. I forgot to sketch in the holes I drilled in the former; they're up at the fabric-former junction, also well clear of the magnetic field. Check for continuity and that there is no short to the former.

If I were doing this over again, I'd probably make the third layer nine or ten turns instead of seven, bringing the total to 36 or 37 turns. Double-check your work, making sure the current is kept going the same way around all three layers, that nothing protrudes, and that your motor former is still round. Now mount the flange and dome assembly to the top plate, fitting for the best clearance.

The dome should move in and out freely. If not, rotate it 90° and try again. You want nice, consistent clearance. If things seem pretty good no matter how you mount the flange, use a piece of paper to check for an even clearance. Mark the parts so you can put them back together the same way.

If you have clearance problems, it might be some grit in the epoxy. Shave it off. If the problem is eccentricity, you'll need to adjust by enlarging the countersinks for the mounting screws to bring things true. Just take your time.

In Part 5, we'll finish the midrange domes, and start work on the treble domes, leaving all the good stuff like listening and testing to Part 6.

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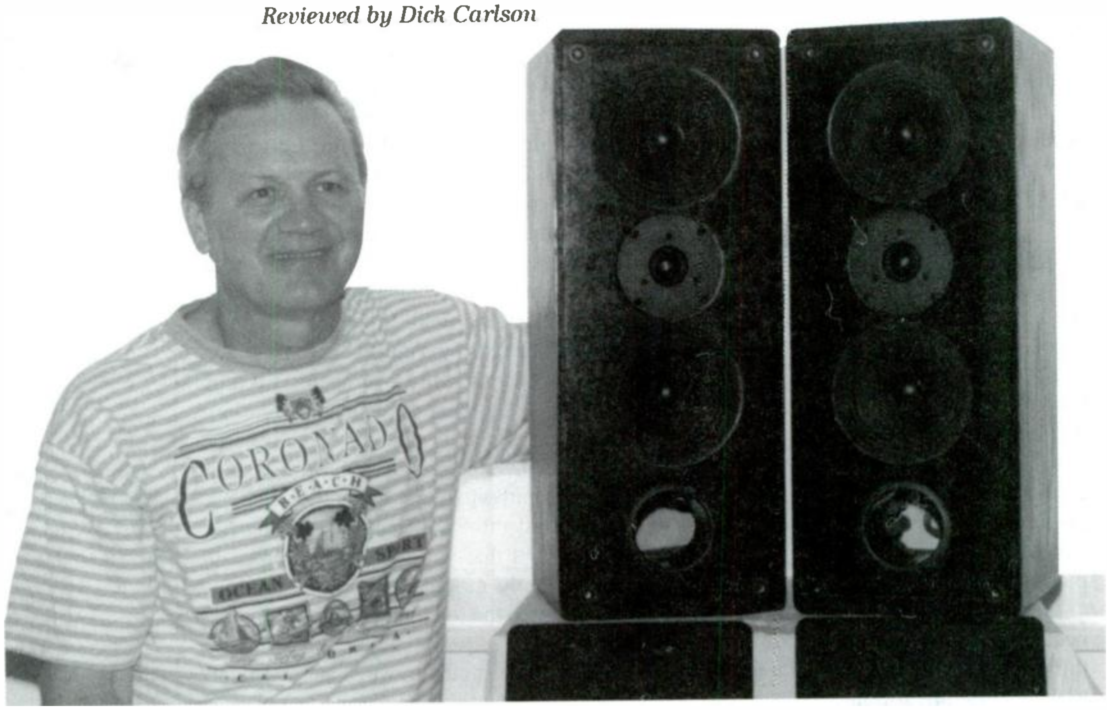
Kit Review

DUAL 5″ VIFA KIT

Reviewed by Dick Carlson



Author with assembled speakers.

Dual 5″ Vifa Kit #300-760, *Parts Express, 725 Pleasant Valley Drive, Springboro, OH 45066-1158, (800) 338-0531, $199.90.*

The Vifa Kit came packed in three boxes containing cabinet parts, grilles, drivers, crossover components, speaker wire—everything. An inventory revealed that all materials were accounted for (*Photo 1*). Judging by the quality of the parts, I saw that this project, when completed, would represent a mid- to high-end product.

CONSTRUCTION

I advise you to read the instruction manual *before* attempting to assemble the kit. This will eliminate any surprises and avoid frustration and grief later on.

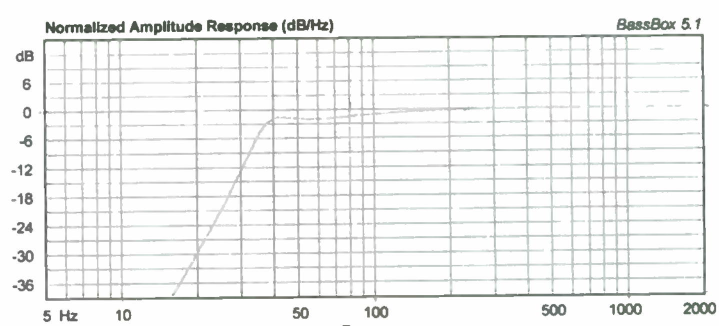
The cabinets are made of oak-veneered ¾″ MDF, with solid red-oak (radiused) corners. Splines are used in the construction, and although they make for sturdiness, they detract from the overall appearance. I prefer mitered corners, because, when done properly, they do not show any surface anomalies.

A ¾″-thick shelf brace reduces vibrations and increases cabinet strength. The rear panel is made of ¾″ nonveneered MDF, and the front baffle is a 1¾″-thick piece of nonveneered MDF. The thick baffle not only reduces cabinet flexing and vibration, but provides the strength necessary to support the four holes for the three drivers and the vent.

Crossover assembly instructions consist of a diagram and about half a page of text. In assembling the crossovers, I had to drill extra holes on both boards to accommodate one of the capacitors, and to enlarge several holes on the board for the larger inductor. The crossovers took about two hours to assemble, including all soldering. The components are first class. Polypropylene capacitors are used for the tweeters. Inductors

Loudspeaker Parameters
--General Information--
Company: Vifa
Model: P13WG-00-08
Note/SN: 5-inch woofer
--Mechanical Parameters--
Fs = 60.0 hertz
Qms = 1.700
Vas = 0.300 cu.ft
Cms = 0.167 in/lb
Mms = 0.265 oz
Rms = 4.452 lbs/sec
Xmax = 0.118 in
Sd = 13.3 sq.in
Dia = 4.1 in
--Electrical Parameters--
Qes = 0.680
Re = 5.5 ohms
Le = 0.7 mH
Z = 8.0 ohms
BL = 4.8 N/A
Pe = 40.0 watts
--Combination Parameters--
Qts = 0.480
ηo = 0.380%
Sens = 88.00 dB (1 watt)

--Multiple Drivers--
Number = 1
Single
Wiring: single
NetZ =
NetRe =
NetSens =



Internal Box Dimensions
--box--
Vol = 0.700 cu.ft
Shape. Square Prism(s)
h = 21.50 in
w = 7.50 in
d = 7.50 in
no = 1

Box Parameters
Custom Vented Box
Vb = 0.700 cu.ft
Fb = 40.6 hertz
F3 = 37.6 hertz
QL = 7.0
Fill = heavy
Ports = 1 (round)
Dv = 2.75 in
Lv = 9.99 in

FIGURE 1: BassBox kit calculations.

are Perfect Layer and CFACs for low-pass and high-pass filters, respectively (*Photo 2*).

I called Parts Express to ask for woofer parameters, since I was not familiar with this one, and talked with Paul Holsopple, who proved to be very helpful. Then, I modeled the woofers using BassBox 5.1, which predicted an F_3 of 37.6Hz. Nowhere in the kit manual did I find any performance specifications.

The vent tubes furnished with the kit are 2¾″ in diameter. The Parts Express manual says to cut the tubes to 3″ in length, but BassBox calculated 10″ tube lengths (*Fig. 1*). It has always amazed me that, using the same theoretical vent-calculation algorithm, the calculations can be so different. Refer to the accompanying BassBox 5.1 data for Thiele-Small parameters, box data, vent calculations, and resulting low-frequency prediction. Paul informed me that the low-frequency modeling was performed using L.E.A.P.

CABINET DETAILS

The cabinet fill is 2½″-thick acoustic foam patterned after an egg carton (*Photo 3*). It's really top-quality material, and a generous amount is supplied with the kit. The instructions recommend using an X-acto knife to cut the material, but a good, sharp pair of scissors will work quite well.

The grilles are made of ¾″ particleboard (*Photo 4*). I recommend painting the grilles flat black before wrapping them with the supplied grille cloth (*Photo 5*); otherwise, the tan color of the particleboard shows through the cloth. There are no instructions for grille-cloth application or for preparing holes for the grille snaps. Parts Express admitted to this oversight and assured me the assembly instructions would be revised to include them. The grille cloth is made from single-knit polyester, and is acoustically and somewhat visually transparent (*Photo 6*).

The vent tubes are made of thin, black plastic, slightly flared at the exterior end, and the instructions require cutting them to a specific length (a hacksaw works quite well for this). To mount the vents, apply a bead of silicone glue around the base of the vent flares and press them into the baffle cutouts.

Wood screws are supplied for mounting the drivers (*Photo 7*) and input cups. (I prefer machine screws with T-nuts for the drivers, but that's a personal matter.) If you overdrive the wood screws, the threads will strip out the wood material, and you are then faced with replacing the screws with larger ones or filling in the screw holes.

The input cups are of good quality, but are rectangular, which requires cutting a rectangular hole on the rear panel of each cabinet (*Photo 8*). I prefer round input cups, because the holes are easier to cut with a circle cutter. The input cups did not include the foam gaskets normally found on them, but you can use the driver sealer left over after mounting the drivers—more than enough is furnished. The terminals are large and gold-plated, and will accommodate large wire (10-gauge) and support the use of single or dual banana plugs.

GLUING AND WIRING

Before gluing in the shelf brace (*Photo 9*), determine which end is to be the top, then mark the inside according to the instructions. Apply glue to both sides of the braces to assure a permanent fill and no rattles. The inclusion of ¾″ dadoes on the inside of the cabinets would be helpful to allow for a generous amount of glue for a secure fit.

The supplied internal wiring is 2-conductor, 14-gauge Sound King, high-definition, low-loss, oxygen-free copper wire. It's very good wire, but in my opinion, 16-gauge would have been better for two reasons.

First, it's easier to manage and solder to crossover terminals (the smaller-gauge wire will pass through terminal holes after tinning the ends, but 14-gauge will not. I had to use an awl to enlarge the terminal lug holes on the crossovers to accommodate the larger-gauge wire. Second, the 16-gauge is easier to use with the supplied wire connectors. It was almost impossible to crimp the connectors to the 14-gauge wire, so I soldered the wires to the drivers.

You should be very careful to measure the wiring to the exact length, or you will find yourself short of speaker wire. I ran short of the wire, so I spliced a short length of 16-gauge to the 14-gauge wire. Not the best solution, but it worked.

FINGER-PAINTING

When you're applying glue, the instructions recommend using a small brush, but I find that applying directly from the bottle, then spreading the glue by finger works best. Besides, the only thing that needs

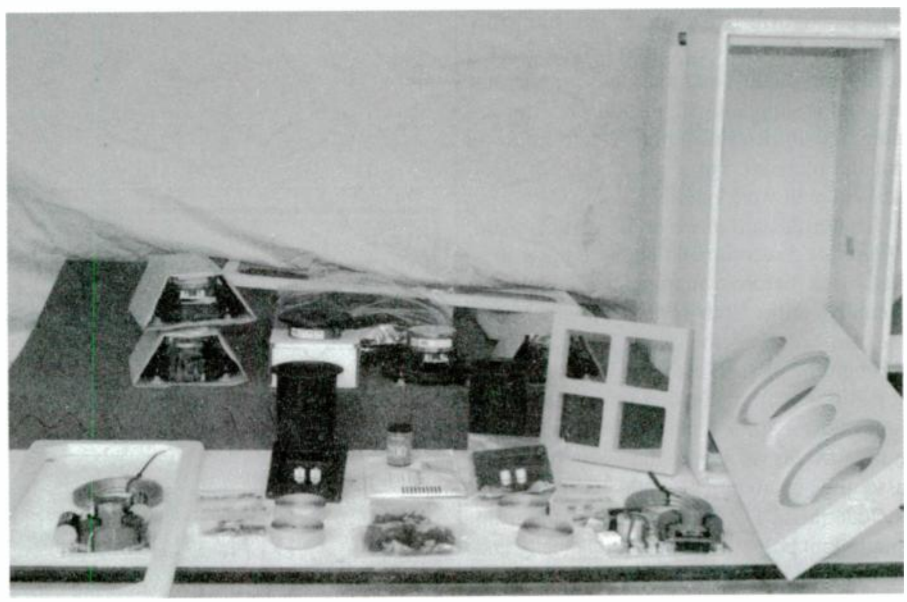


PHOTO 1: Kit parts, drivers, and cabinets.

PHOTO 2: Assembled crossovers.

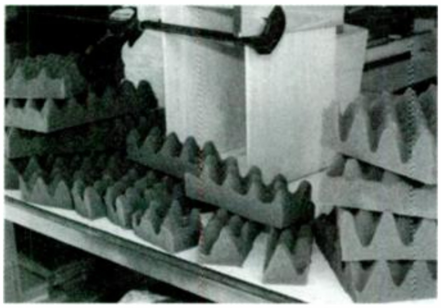


PHOTO 3: All foam pieces cut to proper length.

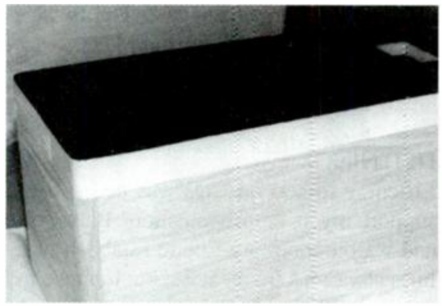


PHOTO 4: Drilled pilot holes on baffle for grille snaps.

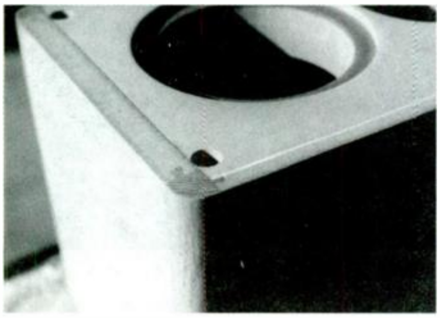


PHOTO 5: Use masking tape around cabinet edges, then paint.

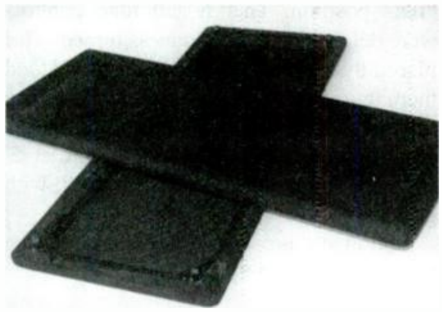


PHOTO 6: Grilles complete, nicely trimmed, and glued.

cleaning afterwards is your finger—but keep a clean, wet rag handy to wipe off any excess glue from veneered surfaces; otherwise, the stain will appear a lighter color.

When I attempted to install the baffle (*Photo 10*), I found the cabinet dimensions slightly decreased (probably from clamping when installing the shelf bracing). I removed $^{1}/_{32}$″ from one end, and it fit perfectly. To prevent the cabinet dimensions from changing, be sure to put the baffles in place *before* gluing in the shelf brace.

I had to fill in a lot of cracks on the rear panels of both cabinets, for some of the factory-applied wood filling had cracked and fallen out. One of the cabinets had exposed nail heads, which I countersunk, filled, and sanded. I sanded the MDF baffles, panels, and sides with an orbital sander using #220 sanding disks. Do not get carried away with sanding veneered surfaces, or you'll sand through the veneer.

GRILLE PROBLEMS

Drilling holes in the grilles to accommodate the grille snaps is not an easy task, nor is it fun. Novice assemblers will encounter some frustration, while experienced builders will complain, since the manufacturer does not include any assembly instructions for the grilles.

Drilling holes for the grille snaps requires precision. The required holes for the female pieces are $^{29}/_{64}$″, while the male pieces require a $^{9}/_{16}$″ hole. This means that if you do not already own them, you must purchase these specialty drill bits that cost about $10 each. I strongly recommend that you first drill small pilot holes in the grilles, then use the grilles as templates for the holes on the cabinet faces.

Align both grilles back side down (on top of each other) and mark the location for each hole (four holes in all—one at each corner). Using a small drill bit ($^{9}/_{100}$″ or so), carefully drill each hole completely through both grilles (I used a drill press for this procedure to ensure correct alignment). For good grille preparation, refer to my article on "Professional Looking Grilles," *SB* 2/91. [Perhaps $^{1}/_{16}$″ pilot holes through the grille frames into the cabinets, with the frames taped down, would locate centers for both frame and cabinet holes accurately. —Ed.]

It is very difficult to apply silicone sealant on the inside joints of the front baffles, especially if you have large hands. I recommend applying silicone glue from a tube, and, with a rubber or surgical glove, pressing the bead of glue into the joints to ensure a good seal. Use a mirror to confirm your work.

I painted the front and rear baffles using a foam roller and black gloss enamel paint, getting by with one coat and not much paint. Use masking tape to line the veneered edges of the cabinets. If a little paint gets through the tape, don't worry; sand it off after it has thoroughly dried. The odd thing about this process was that the finished rear panels had a smoother surface than the front baffles—even after two coats of paint.

I used Watco Danish Oil Finish, which is my personal preference, instead of the varnish the instructions suggest. The finish is rich, but not glossy. The stain takes a few minutes to apply using a brush, rag, or heavy-duty paper towels (*Photo 11*).

LISTENING

Listening to several CDs was necessary to support my overall evaluation. Pink noise and warble tones are fine to establish baselines at various frequencies, but to make my evaluation believable, I needed to listen to music—all kinds of music.

I set all controls on the preamp to the "flat" position. That is, all tone controls were defeated and the loudness turned off. I placed the speakers about 10′ apart and toed them in towards my seating area, which is a full-size sofa about 8′ in front of the speakers. The speakers were located at least 5′ from any corner and 3′ from any wall, with grilles removed.

Following are my impressions of the music using a variety of CDs.

- "Believer" from "Dear Sir: A Tribute to Wayne Shorter," by the Dale Fielder Quartet, provided a clean definition of all instruments. The sax and cymbals were very clear, and the piano was precise. However, I was not that impressed with the low frequency response. Bass was somewhat muddled.
- "Unforgettable" from "Pure Schuur," by Diane Schuur, provided clear and lifelike vocals. Drums were crisp and precise, and the sax was also clear and well defined. Bass on this CD proved to be clean and quick. Very surprising!
- "Manteca" from "Manteca Afro-Cuban Influence," by Shorty Roger (1958 recording on CD). Percussion was amazingly clear and precise! Brass sections were very real and powerful. Drums had remarkable depth and body. The overall soundstage established by these speakers provided a very good emulation of the entire session in spite of the fact it was recorded nearly 40 years ago! Incredible! I could follow the bass throughout its ranges. The bongos and congas sounded clean and pure in tonality.
- The vocal in "Hyper-ballad" from Björk's "Post" was crisp, but somewhat subdued at times. Bass was present only in the middle to upper registers. Sub bass or lower bass was completely missing, which reinforces my recommendation to augment these speakers with a subwoofer. Instrumentation was electronic or synthesized but had a strong presence. That's when I noticed some noise. At first, it was subtle, and then it grew louder with stronger portions of the cut. Perhaps this is the way Björk mixed the tune. At any rate, I was a little annoyed by it.
- These speakers transformed into the beauties they were intended to be when I played "Summertime," by Shelly Mann, from the album "Shelly Mann and His Men at the Black Hawk, Vol. I." The trumpet, played by Joe Gordon, was very crisp, natural, and breathtaking. Monte Budwig on the bass was very mellow, yet authoritative, and I could clearly hear Monty making adjustments on the bass as he began to play. The sweet and articulate sound of the sax, played by Richie Kamuka, projected so well I could hear the reed effect while he blew a riff. Victor Feldman's piano, although in the background, set a club presence throughout the cut that made me feel as though I were sitting there watching his every move. The sounds of the brushes against the cymbals by the master, Shelly Mann, were striking, and completed the awesome reproduction of this nearly 40-year-old vintage recording captured so beautifully on this Contemporary CD. On the same disk, the tune "Our Delight," a more upbeat and lively recording, made these Vifa units perform to their fullest. Such great sound stage and performance can only be witnessed live at a club that offers a great ensemble like this one did. I closed my eyes and for a moment I was there—snapping my fingers and tapping my foot to the beat of the band. God, what incredible speakers!
- "Concerto in G Minor for Organ, Strings, and Timpani," by Poulenc; Berj Zamkochian, organist, and Everett Firth, Timpanist; Boston Symphony Orchestra,

PHOTO 7: Gasket material on driver ready to mount.

PHOTO 8: Input cup. Add foam gasket material before installing (I used 1/8″ × 1/4″ foam weather stripping, because I wasn't sure if there was enough gasket material supplied with the kit).

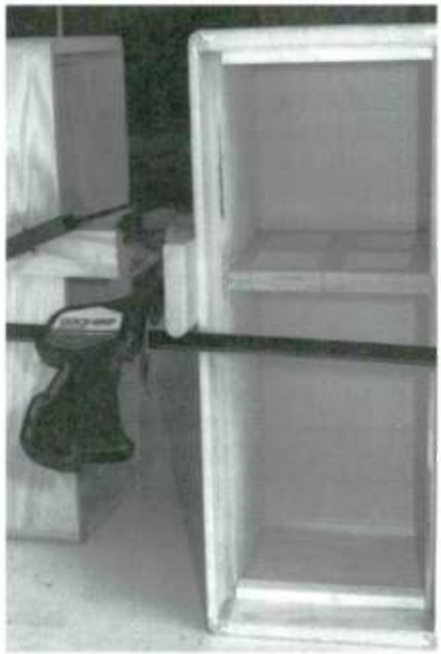


PHOTO 9: Shelf brace.

PHOTO 10: Front baffle glued and clamped.

Charles Munch, Conductor. This recording was the showstopper. It seemed to reveal any and all anomalies and quirks of the speaker system. At first, I noticed very good reproduction of the bass violins, and a delightful presence in the strings section. Then all went to hell when I noticed the scratchy sounds coming from both speakers—more noticeable in one than the other. I muted the system and inspected the speakers, and found that each of the four woofers, when I gently depressed the woofer cones, scraped either the magnet poles or the sides of the voice-coil formers. Apparently, these were either defective when I received them or they overheated during my testing.

I reported the defective-woofer dilemma to Parts Express, and received replacement woofers in less than a week.

My conclusion on techno music, hard rock, and electronic or synthesized music is simple—don't even think about using these speakers for this type of music, at least not without a subwoofer and some serious low-frequency protection. These speakers, as good as they sound, will not stand up to the low-frequency dynamics of this kind of music. On their own, they cannot handle the power. They must be protected by a high-pass network, then augmented by a subwoofer.

OVERALL EVALUATION

The speakers are well designed and would look great in any room, but speaker stands are a must. I made my own, which place each speaker about 15″ off the floor. The overall sound is a little heavy (too much upper bass), and the lower bass is weak—just not apparent. High frequencies can be heard well on axis, so the speakers need to be toed in towards the listener to take full advantage of the MTM configuration.

On the whole, however, these speakers work well. They have a warm sound, but for serious listening, they must be augmented with a subwoofer. Low frequencies drop off very rapidly at about 60Hz. I recommend using a high-pass filter (12dB/octave) at 300–500Hz to provide adequate low-frequency protection.

For the novice builder, this is a good project. However, you must be patient and forgiving. For example, the assembly and finishing instructions are somewhat misleading. They assume all is perfect, but this is not the case. If you do not possess a drill press and perhaps other wood-working power tools, you will need the help of someone who does. It's not a good project for procrastinators—it demands completion of each phase to ensure continuity of thought.

TESTING

For each test, I used a Carver Model PM-1.5 power amplifier, a Marantz Model 3250B preamp, a Rane true $^2/_3$-octave real-time equalizer and spectrum analyzer, a Realistic sound level meter, and the *Stereophile* Test CD 3, using tracks 17, 18, and 19 to test low, midrange, and high frequencies, respectively. For the results, see *Tables 1, 2,* and *3*.

For system calibration, I used pink noise from *Stereophile* Test CD2 to establish a baseline sound pressure level (SPL) of 90dB. —*DC*

TABLE 1

LOW-FREQUENCY TEST

FREQUENCY	TEST #1 (dB)	TEST #2 (dB)	TEST #3 (dB)	AVERAGE dB SPL
200Hz	98.5	98.6	98.5	98.5
160Hz	98.5	98.5	98.5	98.5
125Hz	86.0	86.0	84.0	85.3
100Hz	82.5	82.5	82.5	82.5
80Hz	86.0	86.0	86.0	86.0
63Hz	87.0	87.0	87.0	87.0
50Hz	81.5	81.2	81.5	81.4
40Hz	73.5	73.5	73.5	73.5
31.5Hz	67.3	66.2	67.0	66.8
25Hz	62.0	62.0	62.0	62.0
20Hz	N/A*	N/A*	N/A*	N/A*

* — Insignificant measurement.

TABLE 2

MIDRANGE TEST

Comments: I detected an annoying metallic or scratchy sound from one of the speakers at 500Hz and again at 630Hz. This was not apparent in the other speaker.

FREQUENCY	TEST #1 (dB)	TEST #2 (dB)	TEST #3 (dB)	AVERAGE dB SPL
250Hz	98.0	98.5	98.0	98.2
315Hz	94.0	93.6	93.4	93.7
400Hz	94.0	93.0	94.0	93.7
500Hz	91.5	91.5	91.5	91.5
630Hz	90.0	89.6	89.0	89.5
800Hz	90.0	91.0	89.5	90.2
1kHz	89.0	89.0	88.5	88.8
1.25kHz	91.0	91.0	91.0	91.0
1.6kHz	90.0	90.0	89.5	89.8
2kHz	88.0	88.0	88.0	88.0

TABLE 3

HIGH-FREQUENCY TEST

FREQUENCY	TEST #1 (dB)	TEST #2 (dB)	TEST #3 (dB)	AVERAGE dB SPL
2.5kHz	89.7	90.0	89.5	89.7
3.15kHz	93.0	93.0	92.8	92.9
4kHz	91.0	91.0	90.8	91.0
5kHz	91.0	90.5	90.3	90.6
6.3kHz	91.5	91.0	90.8	91.1
8kHz	90.5	90.5	90.3	90.4
10kHz	90.2	90.2	90.1	90.2
12.5kHz	88.0	88.0	87.9	88.0
16kHz	86.0	86.0	86.0	86.0
20kHz	80.0	80.0	80.0	80.0

PHOTO 11: Completed speakers and grilles.

TESTING THE VIFA MTM LOUDSPEAKER KIT

By Joseph D'Appolito

I ran a series of impedance, frequency-response, and distortion tests on the Vifa dual 5″ MTM speaker kit assembled by Dick Carlson. *Figure 2* is a plot of system impedance over the full audio range. Nominal impedance is 4Ω. The minimum impedance of 3.5Ω occurs at 240Hz. The 13Ω peak at 1.8kHz is caused by interaction between woofer and tweeter crossovers, which form a parallel resonance at that frequency. Although not shown, phase angles lie between ±40°. This should be a relatively easy load for most amplifiers.

The system is vented, but the double-humped impedance characteristic centered at 75Hz is almost completely suppressed. This indicates a very low box Q due to an overly damped enclosure. I'll say more about this shortly.

A composite on-axis frequency response for the system is shown in *Fig. 3*. The curve is smoothed with 1–6 octave averaging, as are all subsequent frequency-response plots. Quasi-anechoic data above 250Hz taken with the microphone placed on the tweeter axis at a distance of 48″ is combined with near-field woofer and port data below 250Hz to obtain the full-range curve. The plot is normalized to 1m to get system sensitivity. Average sensitivity in the two octaves around 1kHz is 89.2dB SPL/2.83V/1m. However, there is a 1.9dB step-up in response at 1kHz. Sensitivity in the octave below 1kHz is 87.9dB. In the octave above 1kHz it is 89.8dB.

The −3 and −6dB points on the low end are at 90Hz and 74Hz, respectively. This low-end extension is very poor in relation to the ultimate capability of the Vifa 5″ drivers. A properly executed vented system using these drivers should provide a low-end f_3 of 45Hz.

You see an explanation for this poor performance in *Fig. 4*, which shows woofer and port near-field responses and their complex sum. A vented system should show a deep notch in woofer output at the box-tuning frequency. Notches of 15–25dB are common (see my tests of the Audax A651 kit in *SB 6/97*). At this point, almost all acoustic output should be coming from the port. The whole purpose of a vented system is to extend bass response while limiting low-frequency cone excursion.

There is only a very mild dip in the Vifa 5″ MTM woofer response. Furthermore, the increase in system output contributed by the port is less than 4dB! This system acts more like a closed box. Removing one of the 5″ drivers, I found the enclosure lined on all sides with 2″ acoustic foam. The foam occupied roughly 70% of the total volume. This much damping material kills the box Q.

Figure 5 is a cumulative spectral-decay

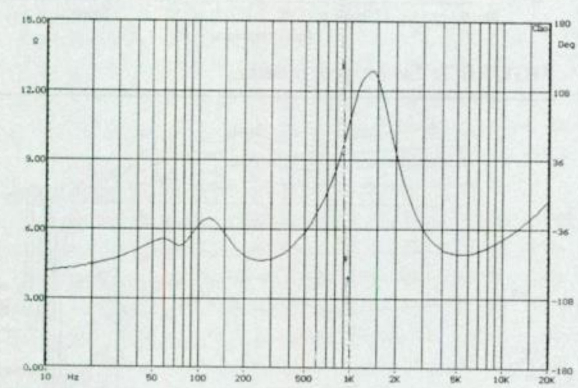


FIGURE 2: MTM system impedance plot.

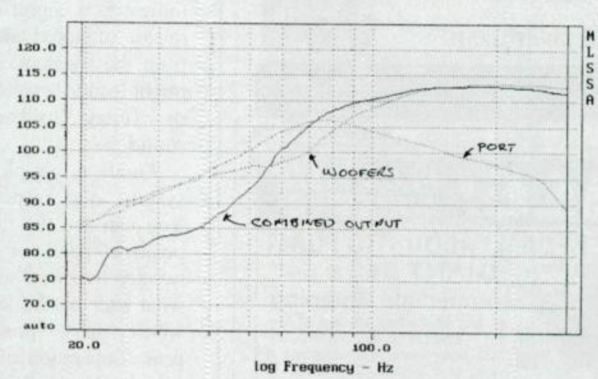


FIGURE 4: Near-field woofer and port outputs and their sum.

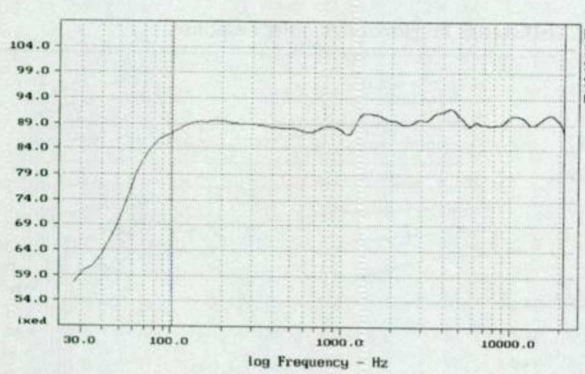


FIGURE 3: System response at 48″ on tweeter axis.

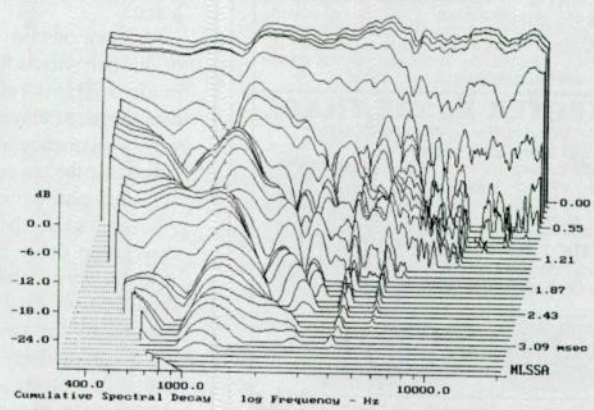


FIGURE 5: Cumulative spectral decay.

plot of the system. This plot shows the frequency content of the system-decay response following an impulsive input at time zero. On this plot, frequency increases from left to right, and time moves forward from the rear. The first 3.2ms are shown with a total dynamic range of 37dB. The high-frequency response decays rapidly, being down 37dB in about 1.2ms with no significant ridges. The two minor ridges appearing at 3.5 and 5kHz about 1.8ms out in time are down 33dB and should be inaudible.

There is a significant ridge just above 1kHz lasting over 3ms. This is associated with the response step at 1kHz and indicates a significant release of stored energy from the woofers. This might lead to a softened or fuzzy midrange sound.

Figure 6 is a plot of system step response. You can see the initial positive peak of the tweeter followed somewhat later by the larger woofer-pair positive peak. Separation of the two peaks is 0.25ms. The woofer and tweeter are in phase, but this system is not time-coherent.

A more precise view of this behavior is found in *Fig. 7*. This is a plot of excess group delay in ms versus frequency referenced to the tweeter's acoustic phase center. Above 10kHz, the excess group delay is essentially zero, which it should be since it is referenced to the tweeter. Excess group delay rises with decreasing frequency to a plateau of 0.21ms below 2kHz. This plateau is a better measure of woofer delay relative to the tweeter.

This behavior is

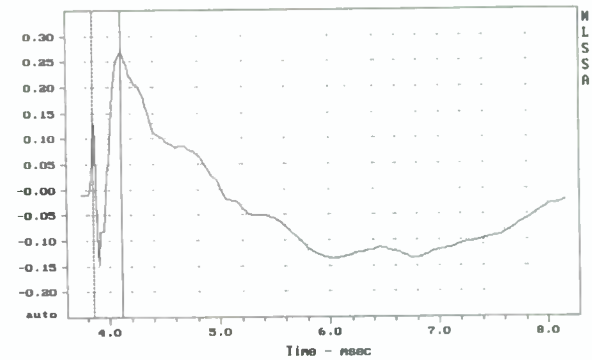


FIGURE 6: Step response.

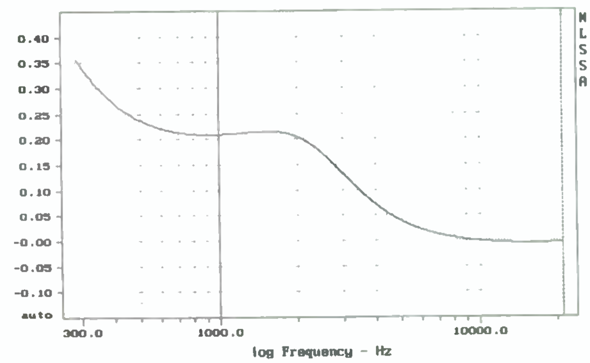


FIGURE 7: Excess group delay.

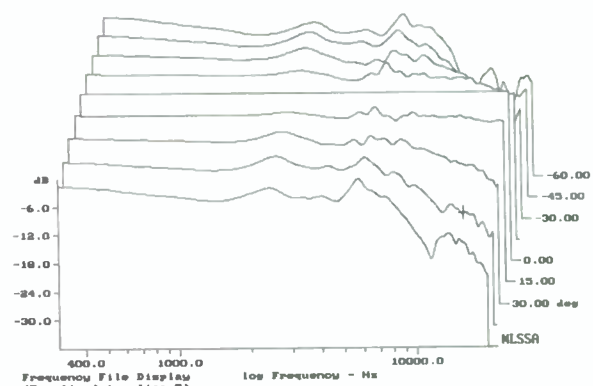


FIGURE 8: Horizontal polar response.

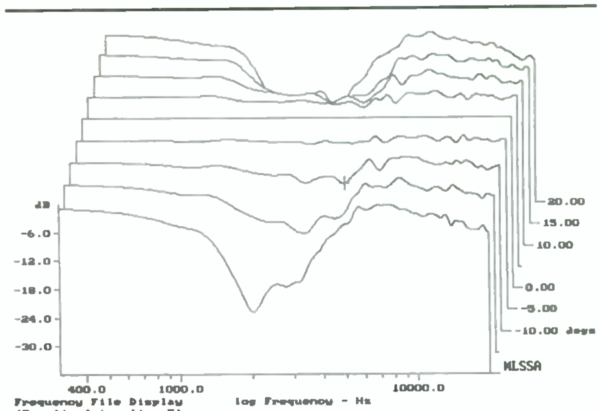


FIGURE 9: Vertical polar response.

characteristic of the higher-order all-pass crossover networks. Even if the drivers are "time-adjusted," this delay would be present. Below 500Hz, excess group delay begins to rise again. This is caused by the low-frequency rolloff of the system.

Figures 8 and *9* examine system polar response. *Figure 8* is a waterfall plot of horizontal polar response in 15° increments from 60° left to 60° right when facing the speaker. All off-axis plots are referenced to the on-axis response that appears as a straight line at 0°. You can see the expected rolloff in tweeter response at higher frequencies and larger angles, but off-axis response out to ±45° is very smooth and similar in character to the on-axis response.

Left-right symmetry is excellent. This system should image very well. Off-axis response at ±60° does peak about 3.8dB at 4.3kHz relative to the on-axis response. Conceivably, this could mar timbral balance in live rooms due to side-wall reflections, but I doubt it.

Figure 9 is a waterfall plot of vertical polar response in 5° increments from 20° below to 20° above the tweeter's axis. The ±5° curves are within ±0.8dB of the on-axis response. The ±10° curves dip 4.8dB at 4.4kHz relative to the on-axis response.

Corresponding numbers for the ±15° and ±20° curves are 10.8dB and 24dB at 3.1kHz and 2.1kHz, respectively. (This last figure suggests a crossover frequency around 2kHz.) Although not shown, vertical polar response at ±7.5° is within ±2dB of the on-axis response. This translates into a vertical sweet spot of 2.5′ extent at a listening distance of 10′.

Figure 10 compares on-axis response against response measured 5° below the tweeter axis. The −5° curve is offset 10dB for clarity. The −5° response is much flatter. This indicates a small mismatch in mid-bass drivers which leads to a cancellation of response ripples in the vertical off-axis position.

Digressing for a moment, the symmetric dips in off-axis vertical response are characteristic of an MTM system using even-order (i.e., in-phase) crossovers. MTM geometry has become popular for center-channel speakers in home-theater systems. When placed horizontally, however, the dips cause highly colored center-channel sound for listeners who are well off-axis. Odd-order crossovers greatly reduce off-axis dips, but the MTM geometry is still best suited to vertical orientation and L-R channel use.

Figure 11 shows the average response of the Vifa 5″ MTM above 200Hz over a horizontal angle of 60° (±30°) in the forward direction. Response is flat within ±1.6dB from 200Hz to 10kHz, and is down 3dB at 19.5kHz. This is excellent forward-sector response. This system delivers uniform response over the primary listening area. Image stability should be excellent.

Harmonic-distortion tests were run at an average SPL of 90dB at 1m. The microphone was placed at 20″ to reduce room contamination. Only the first 20ms of data were analyzed at each frequency to further reduce room contamination.

* * *

The Vifa 5″ MTM kit was tested in the laboratories of Audio and Acoustics, Ltd., using the MLSSA and CLIO PC-based acoustic data-acquisition and analysis systems with an ACO 7012 ½″ laboratory-grade condenser microphone and a custom-designed wideband, low-noise preamp. Polar-response tests were conducted with the Outline computer-driven turntable, on loan from Old Colony Sound Laboratory.

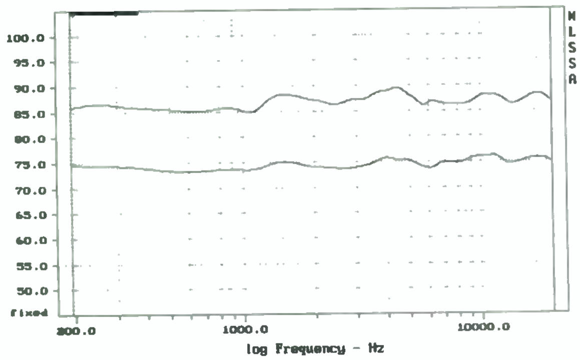


FIGURE 10: On-axis (upper curve), −5° (lower curve).

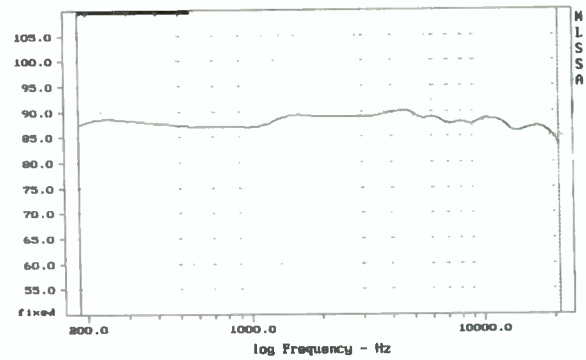


FIGURE 11: Average response over horizontal window of ±30°.

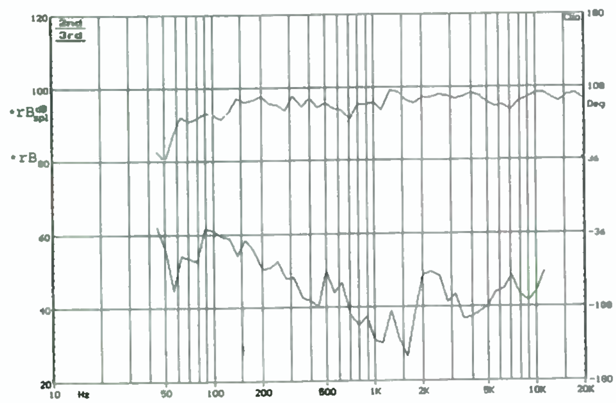


FIGURE 12: Second-harmonic distortion.

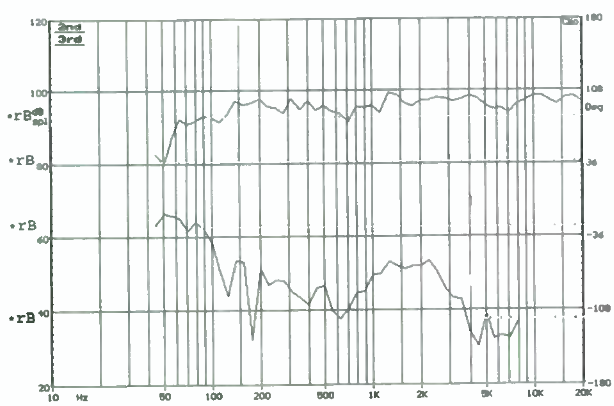


FIGURE 13: Third-harmonic distortion.

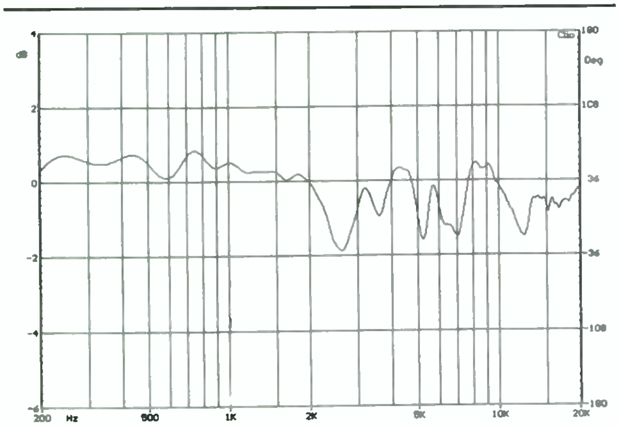


FIGURE 14: Effect of grille on frequency response.

Figure 12 plots second-harmonic distortion versus frequency in one-sixth octave steps. In this figure, the upper plot is frequency-response SPL and the lower plot is distortion SPL. Second-harmonic distortion at 50Hz is 24dB below woofer output level, or about 6.3%. At 100Hz, the number is −31.4dB, or 2.7%. Distortion falls below 1% for all frequencies above 130Hz. The jump in distortion between 1.6 and 2kHz is due to the transition from woofer to tweeter output. Tweeter distortion, however, is below 0.5% at and above 2kHz.

Third-harmonic distortion levels are plotted in *Fig. 13*. Third-harmonic distortion at 50Hz is 14dB down, or 20%. This high level of distortion is a direct result of the overdamped enclosure that does little to reduce woofer cone excursion at low frequencies. At 100Hz, the figure is 34dB, or 2%. Third-harmonic distortion is below 1% at all frequencies above 130Hz, and at or below 0.5% at most frequencies above 300Hz. There is a slight rise to 0.6% in the crossover region.

Finally, all of the above tests were conducted with the grille off. *Figure 14* shows the *change* in response over the 200Hz to 20kHz range with the grille on. Woofer response changes by 1dB or less. The grille introduces 2dB peak-to-peak ripples into the tweeter response.

Manufacturer's response:

First and foremost, a thank you to Dick Carlson for his review of the Vifa kit and to Joe D'Appolito for thoroughly testing the speaker. Dr. D'Appolito's test procedures are full of useful information on how to properly test a loudspeaker system and will be appreciated by anyone involved in speaker design, whether novice or professional. Mr. Carlson's favorable comments regarding the sound quality of these loudspeakers are particularly satisfying, since great care was taken in drive-unit selection and crossover design.

Parts Express is improving the cabinets in the following ways. The cabinet will not have splines, so that the veneer is wrapped continuously around the corners, eliminating any surface abnormalities. Dado cuts will be provided for shelf-brace installation, and, lastly, the front baffle and grille frame will be predrilled for greatly simplified grille-frame mounting.

Regarding the low-frequency performance of the Vifa kit, we agree it would be greatly augmented by the addition of a subwoofer, and you should consider one to get maximum performance from this system. Also, we will begin shipping 1″ foam with the kit to reduce box damping, instead of the currently supplied 2″ type.

In closing, we believe purchasers of this system will be very satisfied with the performance, aesthetics, and value that it provides.

Paul Holsopple
Parts Express

Loudspeaker *Design Software*

from Old Colony Sound Lab

SOF-BAS
BassBox 5.1 For Windows $ 99.00
from Harris Technologies
A great program which aids in the design of bass loudspeaker enclosures.

SOF-BOX
BoxResponse $ 50.00
Robert M. Bullock and Robert White
This software can be used for designing closed, vented, passive radiator and other loudspeaker types.

SOF-CAL1*
CALSOD Standard v. 1.40 $ 69.95
Witold Waldman, Audiosoft
With CALSOD, you create a data file from which all your required system response functions are automatically calculated.

SOF-CAL2*
CALSOD Professional v. 3.10 $ 269.00
Witold Waldman, Audiosoft
The professional version of CALSOD adds many features to the Standard version above including the ability to import files from analyzers like IMP, MLSSA, LMS, System One and SYSid.

SOF-FWK
Filter Workshop for Windows v. 1.01 $ 79.95
Frank Ostrander
This program combines a useful set of passive network design tools with an instructional resource for network design.

SOF-HOR Bass Horn Design $ 19.95
A.L. Senson
This program calculates dimensions for a catenoid, exponential or hyperbolic bass horn and prints out in less than a minute. It provides a horn's general data as well as giving you the dimensions to design your enclosure.

SOF-MOD1*
Boxmodel for DOS $ 59.95

SOF-MOD2
Boxmodel for Windows $ 74.95
Robert M. Bullock and Robert White
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SOF-PSH
Professional Loudspeaker Design Powersheet
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LOW-DISTORTION SPEAKER DESIGN

By Mike Klasco

In *Speaker Builder* magazine, most discussions relate to the construction of speaker systems rather than to the essentials of the components. In this series, I will take a close look at the components themselves, supplying an inside perspective on how they work and what makes them work better. These articles will provide a quick overview of cone drivers in general, followed in future issues by a look at specific topics, such as ferrofluids, magnetic systems, voice coils, tweeter design, and so on.

Most transducers (a fancy name for a driver) are comprised of a motor, cone assembly, and frame. The elements of the motor typically include a ferrite ring magnet sandwiched between a steel back plate and steel top plate. A steel rod is centered inside the ring magnet and the top plate, forming the voice-coil gap. A coil of wire is located in this gap, with a cone and spider attached to one end (*Fig. 1*).

A dust cap is glued to the cone or directly to the bobbin upon which the voice coil is wound. The spider and the surround form the compliant suspension used to control the movement of the cone assembly. Both the magnetic system ("motor assembly") and the cone assembly are attached to the frame. Each part contributes (or detracts) from the clarity, definition, linearity, and overall sound quality of the driver.

CONE DRIVERS

Let me begin with the cone. Most often it is a specialist paper cone manufacturer that fabricates speaker cones, but a few of the larger speaker companies have in-house cone-production facilities. Sheets of paper pulp, typically purchased from companies in the US or Canada, are soaked overnight. Pieces are then torn off and thrown into a water-filled pulp beater.

The beating process disperses the fibers while also refining them. Additives are thrown in and all of this is blended, poured, molded, and cooked. Then, the cone bodies are trimmed and a surround is glued on.

If you are a speaker engineer designing a woofer and need a cone, then you probably have catalogs from Rapid Die and Molding (RDM), Hawley, LCC, NuWay, Mogami, and Kurt Muller on your desk.

Let's take a closer look at this process, since the cone is the most critical factor in a speaker's sound quality. Most cones are formed from a stirred and beaten paper pulp that has been mixed with many additives. A pulp's fiber length, density, and "secret sauce" are all factors that affect a cone's performance for subwoofers, midranges, high definition, high efficiency, high output, or somewhere in between.

There are three common types: pressed, semi-press, and non-press cones. In the case of the pressed cone, the pulp slurry is dumped into a bin and drained through a fine mesh screen. The paper fiber solids remain on this screen after the liquids have been drained out of the bin. The "carcass" is

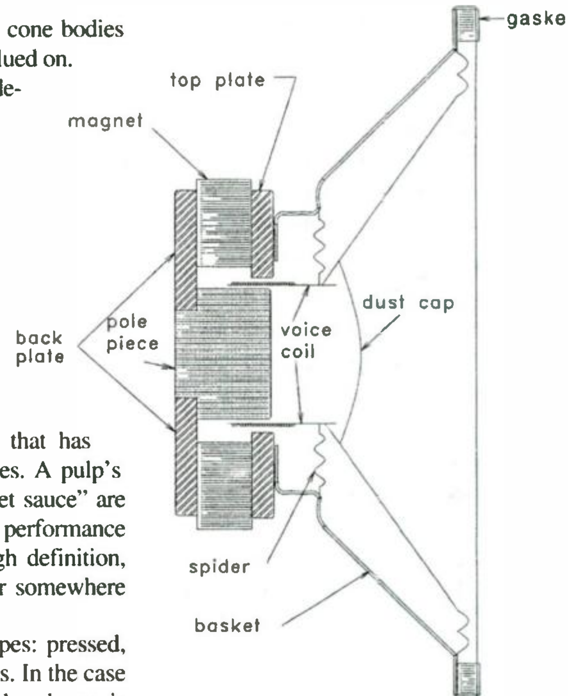

FIGURE 1: Cross-section of a common low-frequency driver. (Reprinted from Vance Dickason's *Loudspeaker Design Cookbook*, Audio Amateur Press, 1991).

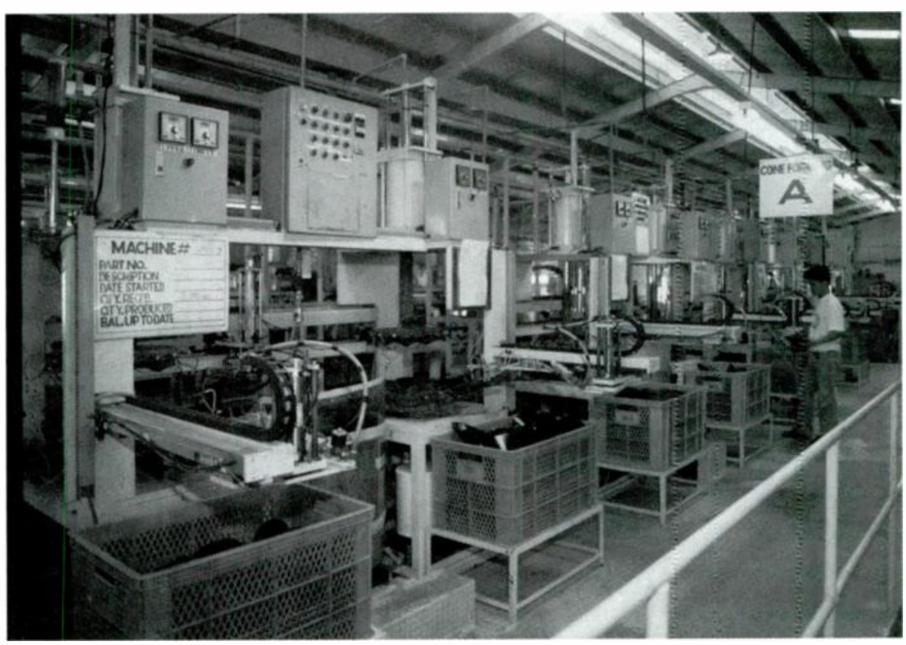

PHOTO 1: Automated cone manufacturing at Dai-1chi; this machine outputs pressed, semi-pressed, and non-pressed cones at a rate of over one million per month.

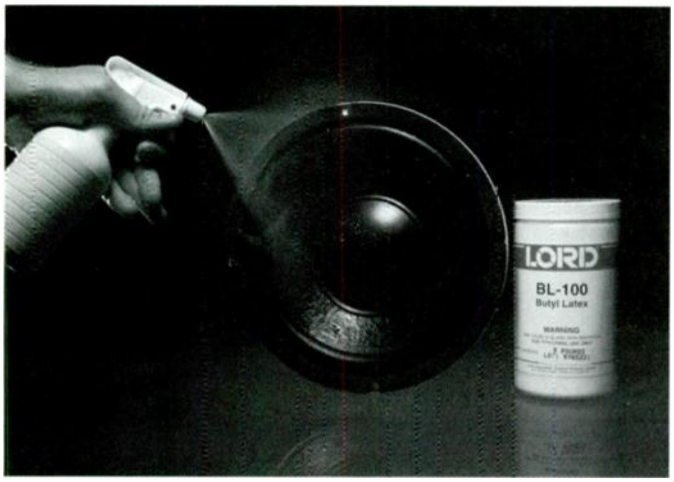

PHOTO 2: This metal cone is being treated with Lord Corporation's BL-100.

removed from the mesh and deposited onto the cone pressing machine (*Photo 1*). Heated positive and negative metal cone-shaped forms then press the pulp. Water drains out of the pulp and the dried cone is removed from the tool.

COMPROMISING CONDITIONS

If the cone's density is too low, then the cone may not be rigid enough. When the cone is too hard and thin, breakup ("cone cry") and other spurious noises will be more noticeable, especially on deep bass excursions or at high sound levels. The cone density and pulp composition affect the internal loss of the cone material, which contributes to the sound quality of the speaker. If the cone is too hard (low internal loss), then not enough of the mids and highs will be absorbed as this energy travels up the cone toward the surround. Also, the dispersion narrows at higher frequencies, and these factors will result in a rougher, peaky sound quality. To soften the cone, a flocked poly pulp is sometimes added to the paper pulp.

The larger the voice coil is for a given size cone, the greater the structural integrity of the cone body, making it less susceptible to breakup. Also, if the cone is deep, it is less likely to "ash-can," buckle and emit spurious noises. The driver cone shape, or profile, is a critical factor in the sound quality and performance of the speaker. If the cone is straight-sided (perhaps with concentric reinforcing ribs molded in the cone body), it will be strong and rigid at very low frequencies. For woofers that must have a response extending into the midrange, a curvilinear cone body shape is common.

Decoupling rings, which look like ribs, can be molded into the cone body. A cross-section of the cone would show that while ribs are composed of added material on the face of the cone, decoupling rings are concentric cone corrugations. These corrugations allow the cone's effective radiating area to decrease with rising frequency. The off-axis response tends to look better over an extended frequency range with decoupling rings, allowing the designer to use a higher crossover point between the woofer and tweeter (or midrange).

The angle at which the cone body attaches to the voice-coil form is important. If the cone meets the voice-coil former at too sharp an angle, the high frequencies will reflect back rather than transconduct into the cone body, resulting in a ragged response. Cone body weight is also important—when it's too light, the cone may distort and produce "cone-cry" at high sound levels or at high excursion. If it's too heavy, the efficiency will suffer.

The recent trend of adding Kevlar® fibers to the pulp reduces the cone body weight, while retaining high strength. These Kevlar-fiber paper cones are audibly cleaner, especially with wide dynamic-range music. They have lower acoustic distortion and an extended top-end response, and are physically stronger than identical pulp (without the Kevlar) for the same mass and cone shape.

CONE OPTIONS

Polypropylene cones are popular for both high-end audio and autosound, since they do not absorb moisture and can have low distortion. Avoiding moisture absorption is more important than you might think; the cone mass, Q, resonance frequency, and box tuning (on vented designs) can all shift significantly with humidity.

The conventional method of forming poly cones is thermoforming, in which the cone is heated until it is soft and then pressed (often by vacuum pressure) into shape. Infinity and other brands offer injection-molded poly cones which are more consistent, but require a large investment in tooling. Poly comes in different grades and its performance is dependent on additives. As with vinyl records, if poor production runs are chopped up and recycled into new runs, the cones' performance and consistency will suffer. Much like paper, poly uses many additives and fillers—mica, carbon black, and talc being the most common. The main supplier of poly sheet for speaker cones is Transilwrap Co.

Another development is the use of woven carbon fiber or Kevlar mat saturated with poly or other thermoplastics. Extremely high sound levels can be achieved with very low distortion using this formulation. These cones are quite expensive, but achieve very high performance. One supplier of these cones is Taiwan Bor Ying ("Nuance" brand) from Taiwan.

FIGURE 2: Three different surround profiles. (Reprinted from Richard Honeycutt's "Loudspeaker University," *VC* October 1995, p. 27.)

DRIVER SUSPENSION

The suspension is another key element in the driver's operation (*Fig. 2*). Most common is the half-roll foam or premium rubber edge, which provides high compliance resulting in

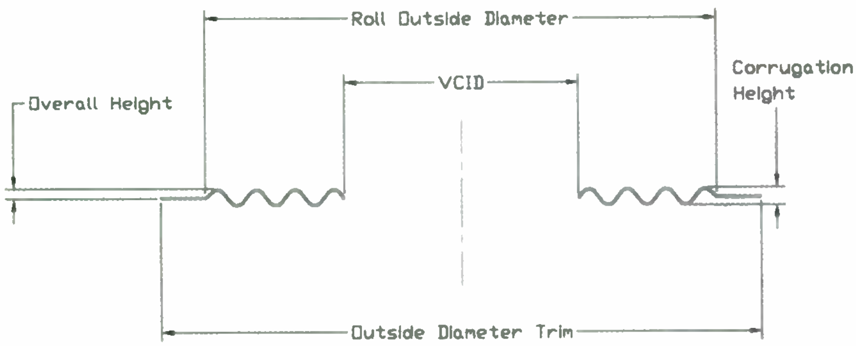

FIGURE 3: A flat spider. (*Figs. 3* and *4* reprinted with permission from NuWay.)

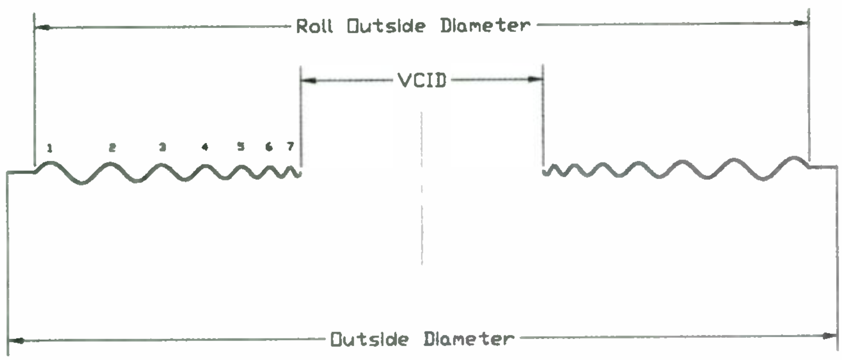

FIGURE 4: Bump (cup) spider.

an extended bass response. Treated fabric edges are occasionally used with "M-shaped" surrounds, providing good control of the cone, good compliance, and low distortion. The larger the diameter of the roll edge, the greater the excursion capacity. But the downside is that with a large surround, the edge resonance will drop in frequency. Edge resonance usually surfaces as a notch in the response and is caused by a standing wave in the surround. Sound travels up the cone, reaches and excites the surround, and (especially over a narrow frequency range) some energy reflects back into the cone out-of-phase. This causes cancellation and results in the response notch. Large surrounds have notches lower in frequency than small surrounds—a 5″ cone may have an edge resonance of 2kHz, while that of a woofer may be 500Hz.

There are various ways a speaker designer may attempt to minimize this problem. You may put damping solution on the surround, use an adhesive with good damping characteristics between the edge and cone, select a heavier and "more dead" cone that will absorb more of the highs before they reach the cone termination, and so on. One effective treatment is Lord's BL-100, which can be applied even to assembled drivers (*Photo 2*).

THE SPIDER

The spider, or damper, is the part of the suspension found at the apex of the cone, where it meets the bobbin, called the neck joint. The spider is usually made of woven linen treated with phenolic adhesive. Cotton is the most common and least stable material, poly cotton has become more popular for better drivers, and higher budget types that require long-term performance are using polyamide aramid fibers such as Nomex®.

Under heat and pressure, the spider's contours are formed. The spider is a key element in keeping the voice coil centered as well as providing the cone assembly's restoring force. Spiders are either flat (*Fig. 3*) or bumped (*Fig. 4*) on the outside edge. Bumped spiders may not have linear compliance when going forward or backward, which results in higher third-harmonic distortion. The largest US supplier of spiders is NuWay, with over 90% of the business.

Next issue, I will take a look at the driver's motor: the magnetic system and the voice coil.

Driver Report

PEERLESS CSX 257 H 10″ WOOFER

By Vance Dickason

This driver report explores the Peerless (Denmark) CSX 257 H 10″ woofer.

Features: The CSX 257 H is part of Peerless' CSX lineup and includes such characteristics as the company's new "sandwich" cone (layered multiple-material cone composition), thick steel frames with low-profile surface-mounting capability (countersink not required), linear restoring force spider (flat spider), inverted dustcap, and aluminum shorting ring for lower second- and third-harmonic distortion (*Photo 1*).

Measurements: I used LMS to generate the impedance plot in *Fig. 1*, and exported the data to LEAP software for T/S-parameter calculation. *Table 1* shows a comparison of measured parameters for the two samples submitted and the manufacturer's published specifications. The specifications measured using the LEAP-curve fit methodology were very close to the Peerless factory data obtained using the Bruel and Kjaer laser velocity transducer.

I then used this data to perform computer-box simulations showing the function of this driver in both a sealed and a vented box. *Figure 2* demonstrates the frequency re-

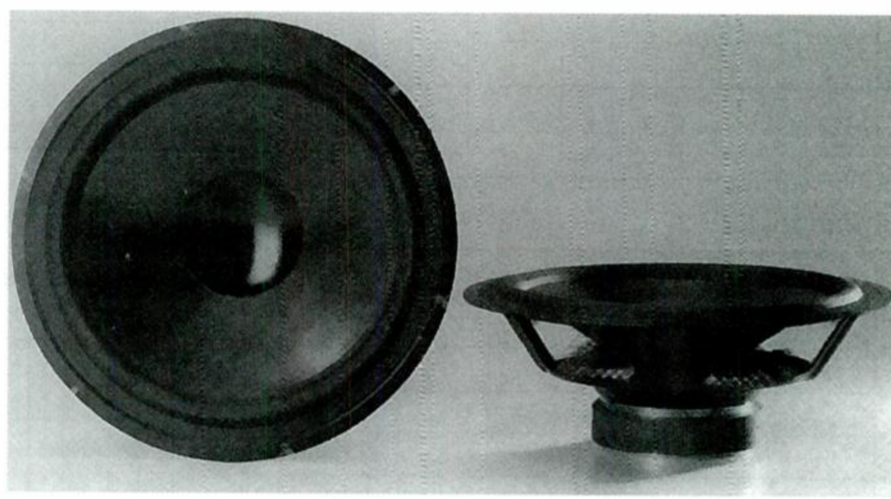

PHOTO 1: The CSX 257 H drivers from Peerless (Denmark).

TABLE 1

LEAP MEASUREMENTS COMPARED TO FACTORY SPECS

MODEL	SAMPLE A	SAMPLE B	FACTORY
S97051			
f_S	44.8Hz	44.3Hz	45.1Hz
R_{EVC}	5.83	5.81	6.0
Q_{MS}	2.39	2.47	2.52
Q_{ES}	0.60	0.61	0.65
Q_{TS}	0.48	0.49	0.52
V_{AS}	21 ltr	22 ltr	22 ltr
Sensitivity	87.8dB	87.7dB	87dB
X_{MAX}	2mm	2mm	2mm
831965			
f_S	64.6Hz	63.1Hz	68.6Hz
R_{EVC}	5.82	5.82	6.0
Q_{MS}	3.03	2.97	3.26
Q_{ES}	0.59	0.56	0.58
Q_{TS}	0.49	0.47	0.49
V_{AS}	6.6 ltr	7.1 ltr	6.3 ltr
Sensitivity	87.7dB	87.9dB	88dB
X_{MAX}	3.5mm	3.5mm	3.5mm

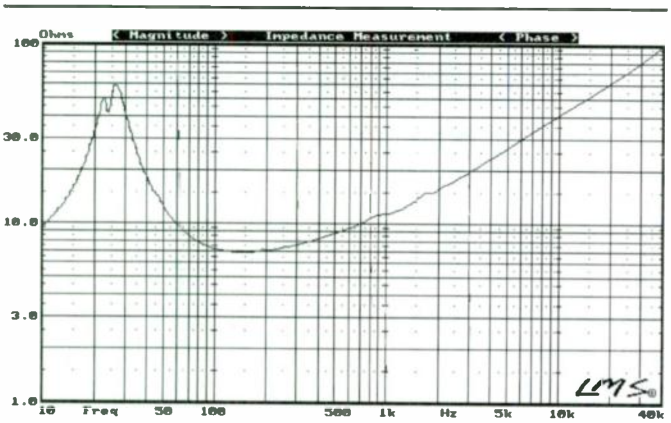

FIGURE 1: Peerless CSX 257 H impedance plot.

sponse of the woofer simulated in a 1.45ft^3 sealed box at 2.83V and 10V. The f_3 at 2.83V is 45Hz with a −3dB phase angle of 94°, roughly equating to a system Q_{TC} of 0.8 using a 0.5Ω series resistance to represent network and lead-wire DCR. The 10V curve at about 100dB represents the maximum linear operating envelope of the driver, as illustrated by the group-delay and cone-excursion curves in *Fig. 3*. Maximum excursion at 10V is 4.8mm, just slightly over the X_{MAX} + 15% criteria for 3% THD.

Figure 4 displays the woofer's 2.83V and 10V performance in a 2.35ft^3 vented enclosure tuned to 27Hz (a QB3 type of alignment). The f_3 is 31Hz at 2.83V, while the output at 10V is up to 101dB at the peak before rolloff. *Figure 5* depicts the group-delay and cone-excursion curves with the X_{MAX} + 15% criteria for maximum linear output occurring at a low frequency of about 23Hz, which is below 90% of most program material.

I measured the frequency response of this driver for both on- and off-axis on a 33″ × 12″ baffle (*Fig. 6*). The response is quite smooth and free of annoying cone- and edge-resonance break-up problems. Crossover to a high-frequency driver could be executed as high as 1.5kHz with this driver, although two-way 10″ speakers are not as popular anymore.

Figure 7 compares the SPL for the two samples, showing a very close frequency response match in this high-quality driver. For more information, contact Peerless Fabrikkerne A/S, Motorgangen 2-4, DK-2690 Karlslunde, Denmark, (+45) 4-615-3311, FAX (+45) 4-615-1171. The CSX 257 H is available to consumers from: Madisound Speaker Components, (608) 831-3433, and Circle Sound, (213) 384-1137.

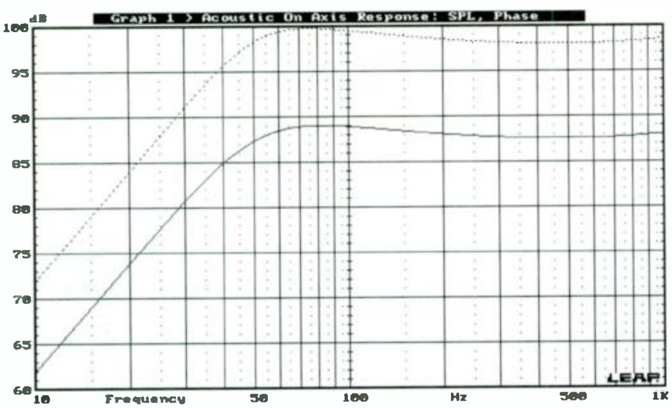

FIGURE 2: Sealed-box simulation (solid = 2.83V, dot = 10V).

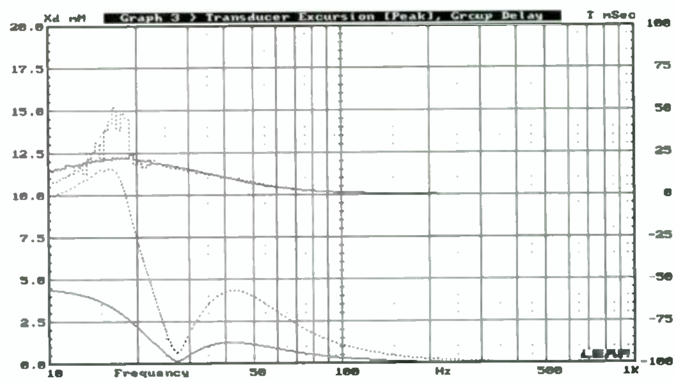

FIGURE 5: Group-delay and cone-excursion curves for *Fig. 4* (solid = 2.83V, dot = 10V).

FIGURE 3: Group-delay and cone-excursion curves for *Fig. 2*.

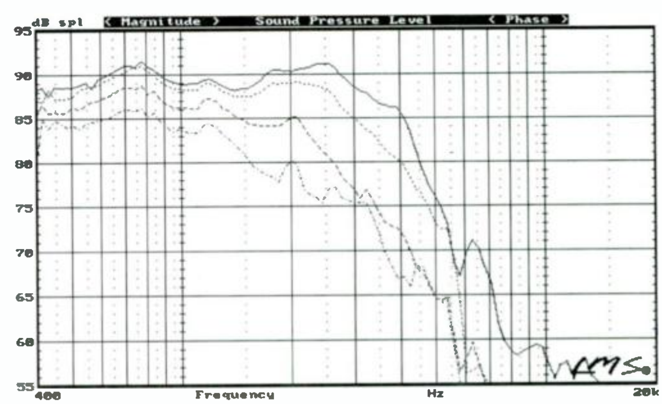

FIGURE 6: Frequency-response curves (solid = 0°, dot = 15°, dash = 30°, dash/dot = 45°).

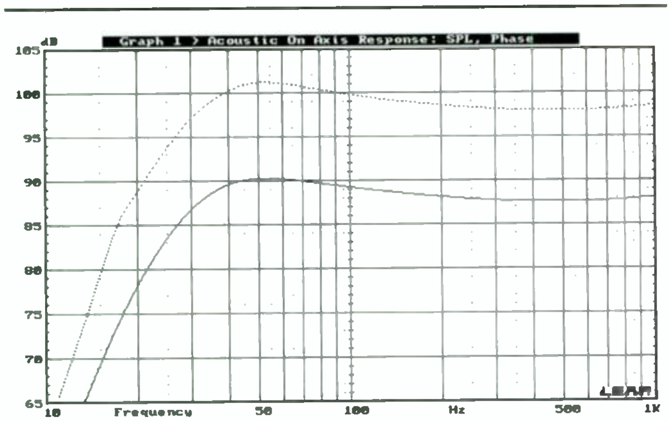

FIGURE 4: Vented-box simulation (solid = 2.83V, dot = 10V).

FIGURE 7: CSX 257 H SPL comparison for two samples.

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AD INDEX

Dynaudio MDY-4 speaker kit from Madisound, $225. Two-way system includes 6½" 17W75EXT bass-mid, commercially built oak cabinet, Dynaudio crossover. Needs pair of D28/2 tweeters. From Madisound, this kit costs $620. Also selling **Klipsch** powered subwoofer, $150. Contact Jerry, jaguar@exec-pc.com, (414) 784-4726.

Cleaning my attic: full sets of *Speaker Builder* (premiere issue onward) and *Audio Amateur* (also with #1); *Speaker Builder*, $50; *Audio Amateur*, $75; or both for $100. All in A-1 condition. You pay shipping! Bill Schweber, PO Box 543, Sharon, MA 02067 or FAX (781) 784-8874.

Bag End Infrasub 18 powered subwoofer, 400W integral amp, crossover, plays 8Hz, mint, can ship, $1,250 plus shipping. Nakamichi 6702X cassette player, rack mount, black, top quality, $450; Pioneer Spec IV power amp; Altec 816 horn-loaded speakers with 515G, 299, 1285B; Sonic Frontiers CD transport. (914) 688-5024.

WANTED

Plans for Dick Olsher's Poly Natalia speaker system; need cabinet specs, material list, etc. Daryl, (508) 366-8949. Call collect before 9 p.m. Leave message and number if no answer and I will return your call.

One Altec 811B and one Altec 802D or equivalent. All manner of equipment or cash to offer in exchange. Jack Rumora, (216) 997-8977 or (614) 685-2612.

Strathern speakers (ribbon) as used in Infinity QRS systems working or not. (714) 901-4956, leave message when to call back.

JBL Century L-100 speakers, three sets of Alnico drivers, all pristine, $500/set; JBL L150 three-way speakers, new woofers, pristine, $450; Bose 901 Series III speakers, all new drivers, pristine, $400; Sansui receiver 9090 110W/channel, large transformer, mint, $300; four JBL 2404 H bi-radial horn drivers, high-frequency with JBL 1¾" aluminum diaphragm, mint, $125 each. (301) 596-5637.

For information about submitting a Classified ad, please refer to page 61.

SB *Mailbox*

THE PARADE GOES ON

I hate to rain on anybody's parade, but Jeffrey Viola made some errors in his construction of the Daline ("Doing the Daline," *SB* 8/97).

First, he said he used a Focal T90ti02, yet the picture shows a Focal TC90Tdx. While functionally these are probably identical, anyone looking to build this system might be confused.

He also chose to disregard the cabinet plans and build an extra-thick version. This is not a bad idea, but if he was impressed with the review he saw on this system, why change anything? He also chose to alter the crossover by using different parts than specified in the Orca plans. If I have learned anything about speaker building, it is don't mess with what works. Lower-resistance coils may seem like a good idea, but designers usually choose their components for a reason. The upshot is now he needs the Zobel network, which was not part of the original plans.

Last, he stated that the system sounded terrible when he first listened to it, and seeing the woofers moving rapidly in and out, he surmised they needed to break in. Speaker break-in takes about one minute, not hours. That he perceived it as sounding better later is more a sign of Mr. Viola getting used to the sound of the speakers rather than the speakers being played for several hours.

Mike McKelvy
Mikeylikst@aol.com

Jeffrey Viola responds:

Good catch, Mike—the tweeter in my Daline Speaker is a TC90Tdx! Two years ago when I ordered T90TiO2s from Zalytron, they were kind enough to give me the latest version—the TC90Tdx. However, the boxes were marked T90TiO2, so I was none the wiser!

As far as "disregarding the cabinet plans," the internal dimensions, particularly the line, upper chamber, and rear port, were exactly the same as the original plans—down to the French millimeter! This being my first speaker, I was not about to tinker with those. However, I did feel confident in trying to build a better cabinet, since we all know any commercial speaker is built to a "price point"; that is, engineered using tradeoffs in drivers, cabinet, and crossover-parts quality and construction. I was inspired by Zalytron's version of the Daline 6.1, which has a 2″-thick cabinet.

As far as the crossover mods, I, like you, learned that designers choose their components for a reason. However, you could argue that I improved upon the original design by adding the Zobel, which is a pretty standard thing. It certainly sounds better with it!

I assure you that the woofers took more than a "couple of minutes" to break in. I would estimate that I played tracks from ten albums over two nights before excess cone movement ended. Once it did, the sound "locked in"; even my nonaudiophile wife heard the difference! I mentioned it in the article only because it caught me by surprise.

Finally, I embarked upon this project for three reasons: to build something useful with my own two hands, to have fun doing it, and to learn.

Not only did I accomplish all of the above, but now I have a pair of great-sounding speakers. And with what I've learned, my next ones will be even better!

"SUPER" SPEAKERS

I recently finished installing John Cockroft's crossover circuit in the Super Simplines (*SB* 1/96). I have always appreciated the beautiful musical quality of these unique speakers, and it was a pleasant surprise to learn they could be even better. Would Mr. Cockroft explain his new circuit, the differences between it and the original crossover, and why it sounds so much better?

I strongly encourage fellow speaker builders to build these deceptively simple, yet elegant-sounding speakers. They go down to an amazing 40Hz or 45Hz and have an exceptionally clean and coherent sound.

I liked the sound so much that I decided to try Caddock resistors in the tweeter circuit. I hesitated before putting $10 resistors in a circuit that uses a $6 tweeter, but I was not disappointed. I guess the Caddock's ability to keep both current and voltage in-phase in that application is very important. For comparison, I should note that the Super Simplines, with the new crossover, are equal to my highly upgraded $3,600 transmission-line speakers, except in the bass. Even my wife prefers Mr. Cockroft's "little beauties." With the new and highly recommended Bybee Quantum Speaker filters, the Super Simplines far surpass the big speakers without the filters. I know, $600 filters on $150 speakers seems pretty counterintuitive. But, remember the Caddocks.

I congratulate John Cockroft on an exceptional design and his ability to ferret out those inexpensive components with extraordinary sound quality.

Gordon Burkhart-Schultz
Castro Valley, CA

John Cockroft responds:

Thanks for your kind words regarding my Super Simplines and my new crossover (Fig. 1). *I'm very pleased that the results are reproducible. I should add to avoid reader confusion that the crossover discussed here is indeed a new one. It isn't the one I wrote about in "Tools, Tips, & Techniques" (SB 2/97) (although you may salvage and use the coil, as well as the 3Ω resistor, from that one in this new one).*

The new crossover is one of several retrofitted crossovers I have designed for my various speaker systems as a result of a conversation I had with Totem Acoustique CEO and designer, Vince Bruzzese. In his latest creations, Vince uses an inductor in parallel with his tweeters, rather than a capacitor in series. The most important advantage of this is that all signals that go through the speakers come directly from the amplifier. All of the signal-shaping reactive components carry their cargo to ground in silent bliss. This being the real world, there is a 3Ω resistor in series with the tweeter to bring things into sonic balance. The sound of this crossover rivals the sound of an active crossover I once used on the Simpline in a past incarnation.

Since the part of the signal that goes through the inductor and capacitor goes to ground, I see no reason to choose expensive components for these units. In a similar crossover I tried both a 14-gauge Perfect Lay inductor and a 21-gauge cheapie inductor. At the levels I play music in my apartment, both inductors presented the same sound. It might be prudent, if sound levels will be quite high (on a larger system than the Simpline), to use a heftier coil or capacitor than the smallest and cheapest variety. But if your tastes are less than robust and you have a pocketbook to match, you should probably spend your cash more strategically than on an expensive coil or cap. I used the specified CFAC coil for the Simpline because it was the actual unit in the previous Simpline crossover, where it was in series with the woofer.

But perhaps there is another side to this. An article ("Inductors for Crossover Networks," SB 7/96) by Richard and Erin Honeycutt shows a comparison of low- and high-Q coils (Fig. 3, p. 37). The higher one rolls off in the classic asymptotic manner, while the lower begins rolling off at a shallower rate after starting out in correct fashion. Since the part of the signal that goes to the speakers should be the inverse function of what gets rolled off to ground (I assume), it makes sense to use the coil with the most accurate roll-off rate.

I've made another assumption that with a normal first-order crossover (series cap in the high-pass section and a series inductor in

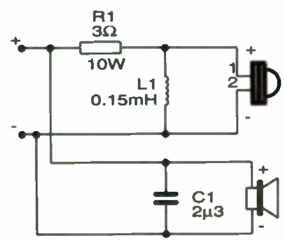

FIGURE 1: The new Super Simpline crossover.

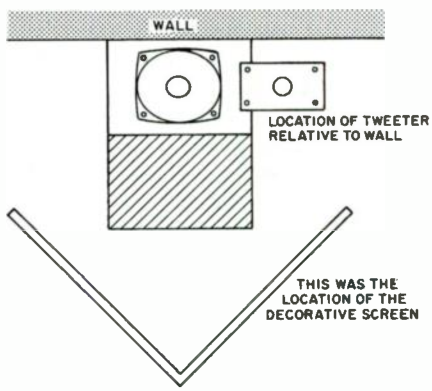

FIGURE 2: New speaker orientation.

the low-pass section), there is a 90° phase lead in the high-pass section. I think this is because the signal going to the speakers passes through the reactive elements. I believe that this doesn't occur in the crossover of this discussion. If this is so, in effect it pushes the acoustic center of the tweeter back 90° towards the woofer's acoustic center, bringing the two centers into closer alignment. This could be another reason for the sound's clarity when using this type of crossover.

*With this in mind, I rotated a Super Simpline 90° from its normal position. Instead of the tweeter body sticking out into the room (which gives it a longer path to the wall than the woofer to partially adjust for the 90° lead), it now rests parallel with the wall (*Fig. 2*). Its path length is now the same as that of the woofer.*

Again with this in mind, I used, on another larger system, a crossover of this type. I used a 6½″ woofer and Vifa tweeter with the horn-loaded 1″ dome (with the double magnet). The sound was some of the most natural I've heard. The woofer, by the way, was a 6½″ MCM woven carbon fiber cone woofer. This is one of the most beautiful sounding raw speakers at any price, and it rolls off nicely with no help. It works beautifully with the above-mentioned Vifa tweeter (especially if the Vifa is modified as described in a "Tools, Tips, & Techniques" piece by Larry Van Wormer in SB *7/96).*

As you know, I brought my Simplines to you and listened to your souped-up ones as well. I was quite pleased at the way your Simplines responded to all the high-end type, high-quality additions you surrounded them with. I realized that they are creatures of true blood and that they can run with the royalest of the royal.

You hadn't yet added the Caddock resistors, so I didn't hear them. I think they might have improved things. I'm not as certain that their addition to a stock Super Simpline (when you realize a single Caddock represents 25% of the entire cost of a Simpline) would be as worthwhile. The improvement would probably be masked by the line impurities you bought all the other equipment to remove.

Adding $600 filters and $10 resistors to $40 speakers adds up to $650, and I don't know of a $650 speaker that can do what your $650 Super Simplines can do. (But we both know that the $40 stock Super Simplines come mighty close.)

If you have a Super Simpline modified to the standard shown in SB *2/97, you have to remove only the current coil and capacitor. The 3Ω resistor can stay. You can reuse the 0.15mH coil, but hook it up in parallel across the tweeter terminals and hook the new 2.3µF capacitor across the woofer terminals. I used a 2.2µF Solen cap and a 0.1µF poly cap, although using all poly caps should work as well.*

If you plan to build the Simplines from scratch, I refer you to SB *2/93 for the original Simpline article,* SB *3/93 for a letter that points out the mistakes in the article,* SB *1/96 for the Super Simpline article (which adds the tweeter), and finally* SB *2/97 for the Super Simpline Phoenix upgrade (which performs an electronic appendectomy and adds some more stuffing).*

HELP WANTED

I am a speaker-building hobbyist and wish to ask some questions and offer a suggestion.

I am interested in finding more information about subwoofer designs that utilize the servo-control technology, which uses a sensor on the voice coil with a computer-monitoring circuit and a feedback mechanism that interacts with the subwoofer amp that is of the "switching" design variety. Other than Velodyne and Infinity, I am not aware of any other speaker manufacturers that use this technology. Unfortunately, I have not seen much about this technology in *SB*. Do you know of any speaker manufacturers that will sell servo-controlled raw drivers and the necessary amplifier or amplifier-interface equipment? Where can I find more information on this topic?

Although *SB* often features interesting and controversial speaker-design articles and projects, I wish to see more information about new technologies and high-end, large-diaphragm bass speaker designs. I rarely see articles about projects utilizing drivers larger than 12″, but when I do, they're often geared to professional or sound-reinforcement applications. I can't remember an article using an 18″ driver. Although speaker designs utilizing large bass drivers involve large box volumes, isobaric, servo-controlled, or mass-loaded designs can often bring box size back into reason.

I also wish to see more information about speaker-design technology, such as the Parasound GMAS, with a claimed 12Hz frequency response. How did they do that? How about the Paragon Acoustics Vargas speaker that claims 12Hz response ±1dB! How is this possible? Using BassBox, I can't get *any* driver in *any* size box to do this gracefully. How about Bob Carver's new subwoofer?

Zane N. Edge
9500 Red Bird Lane
Alpharetta, GA 30202

I am only recently smitten with the bug to design and build my own speakers, and to bring first-quality home theater to my house.

To this end, most of the steps ahead of me are fairly clear, but I am at a loss to determine how to select the drivers around which to build my enclosures. The problem is this: since the parameters of the enclosure are dependent upon the specs of the drivers, I want to be sure that I have selected high-quality drivers before going any further, and I find there is a bewildering array of drivers of all types with ostensibly good specifications, yet some are three times the price of the others that would appear to be equivalent (in print). This seems to be true even within the stock of a single manufacturer, let alone among different manufacturers.

Can you recommend a source of in-depth information regarding the differences between driver types, models, and manufacturers?

I notice that a large number of high-end speaker-system manufacturers use "soft dome" tweeters, which leads me to surmise that these are a superior type for some reason. However, I also notice that titanium tweeters cost significantly more. Why?

Arlen Grainger
graingera@rwcl.scitexdv.com

Readers with information about these topics are encouraged to respond directly to the letter writers at the address provided.—Eds.

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The B-Line

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locating reference. This should be quite close to the correct listening setting.

Begin your evaluation by listening to something with which you are very familiar. Carefully listen to the upper bass and lower midrange areas. Do these areas sound as clear and clean as you remember? If they don't, you have the woofer level a bit too high.

With the smallest movements you can make, begin to turn the woofer level down. Listen carefully after each small adjustment. At the first location where the upper bass and midrange sound right to you, make another pencil mark. Leave the level in this position until you have done a lot of listening with a lot of material. Then let your conscience and taste be your guide.

If, at the beginning, the upper bass and midrange did sound as clean and clear as you remember they should, raise the woofer level the smallest amount you can and listen carefully. Continue this until the upper bass and midrange first begin to sound muddy, then back off just a hair until they sound right. Again, mark the location with a pencil and listen to a lot of samples, adjusting according to your taste. At this point, I leave you on your own.

PLACING THE SPEAKERS

If you intend to use the B-Line with a pair of Super Simplines, a good way to start is to place the Simplines 7′ to 8′ apart, and, if possible, 3′ or more from any side walls (this last isn't a terribly important consideration). Place the B-Line between them, somewhere near the center, with its back close to the wall. The woofer can face to either side you wish.

Now it appears that I put the cart before the horse. I should have told you how to set the speakers up before discussing the adjustment process, but I think you'll get the idea. In my setup, the Super Simplines work best when wired up in opposite polarity to the B-Line. I hope you enjoy your B-Line system as much as I have enjoyed mine.

OF NOTE IN
Audio Electronics

Issue 1, 1998

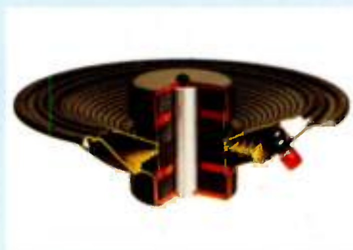
- A Universal CD-Player Digital Output, Part 1
- Much Ado About Jitter
- Calculating Optimum Snubbers
- Product Review: Dscope
- Book Review: *Build Your Own High-End Audio Equipment*

Twenty Years and More. . .

The 1978 C.E.S. in Chicago was the very first time that Morel Acoustics USA, Inc. presented their product to the public. It became clear, early on, that the loudspeaker industry was in need of high quality speaker drivers. Shortly thereafter we introduced several drivers and established the MDT-28/30 as one of the most popular and highly demanded tweeters on the market.

Through the course of the years Morel brought many unique and innovative products to the speaker industry. The introduction of the 3″ voice coil in a 5″ basket, using hexagonal shaped aluminum wire, utilizing a double magnet system and ducted design woofers and mid-basses are a few examples of the company's breakthroughs. Also introduced were the Integra concept (single motor system for both the tweeter and woofer) and the Push-Pull 8″ and 10″ subwoofers (dual motor system, dual voice coils with a single cone).

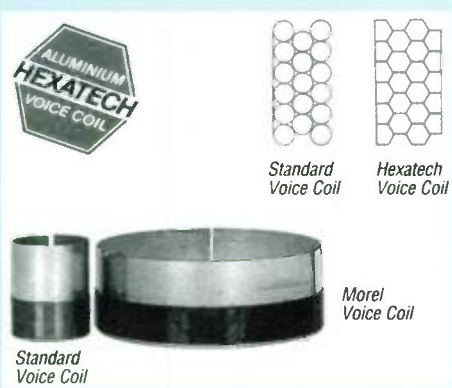
Integra



Push-Pull

Double Magnet

Morel Acoustics USA, Inc. has come a long way since 1978. Currently, the company has a diverse line of exciting products which includes over 40 models of tweeters, midranges, mid-basses, woofers and subwoofers. Being a leader in the field of speaker design, for our 20th year anniversary we are scheduled to launch several new products that are sure to attract attention.



Typical double magnet ducted woofer.

Double magnet tweeter

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