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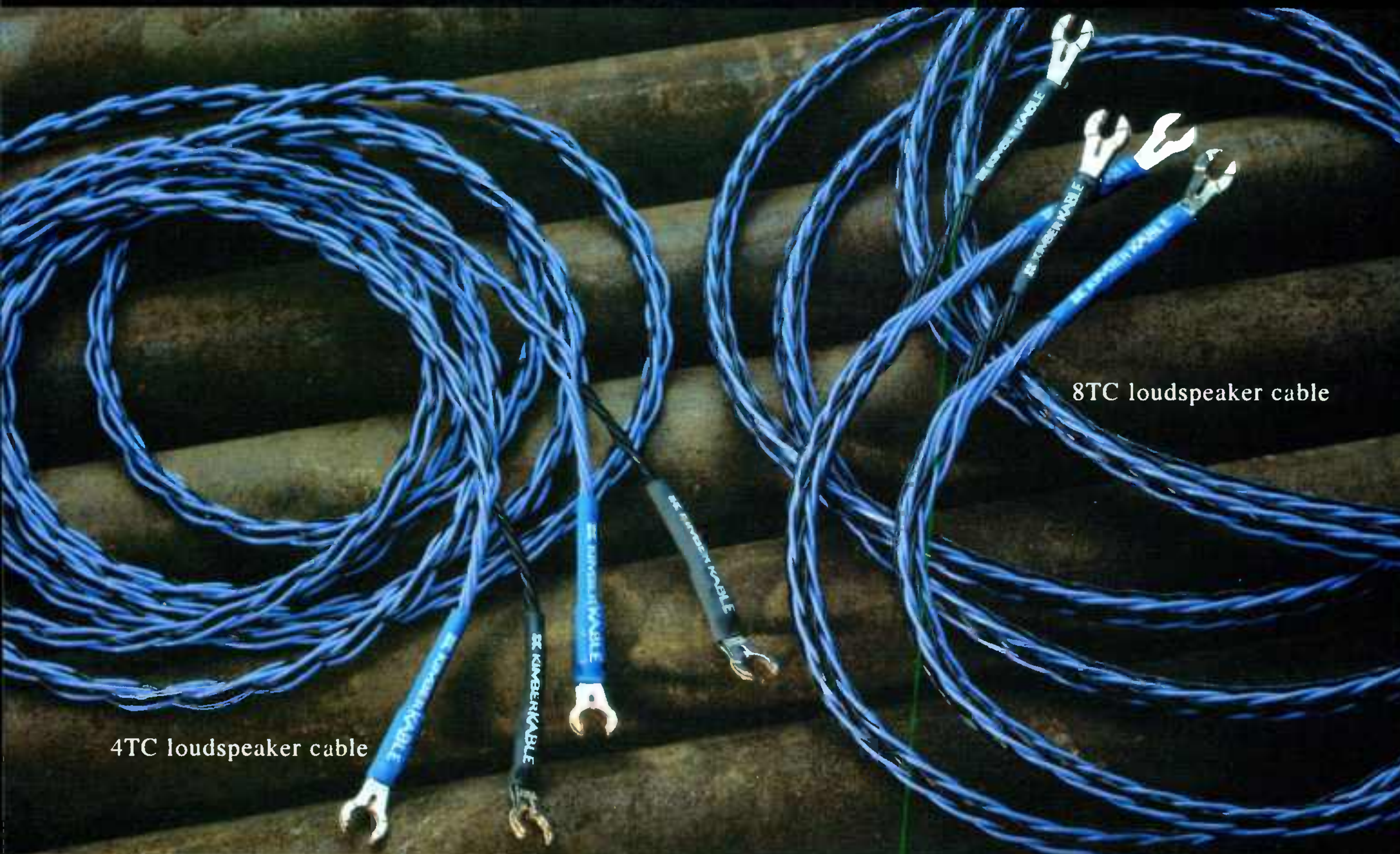


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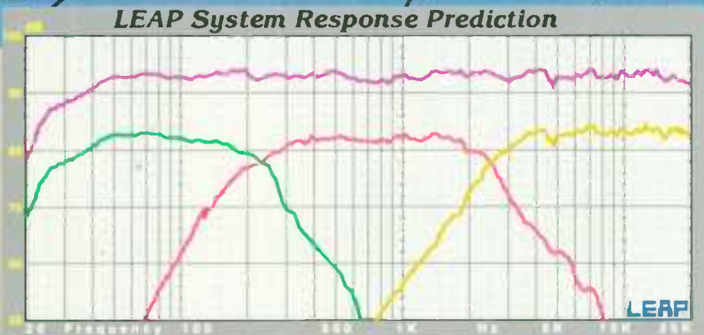



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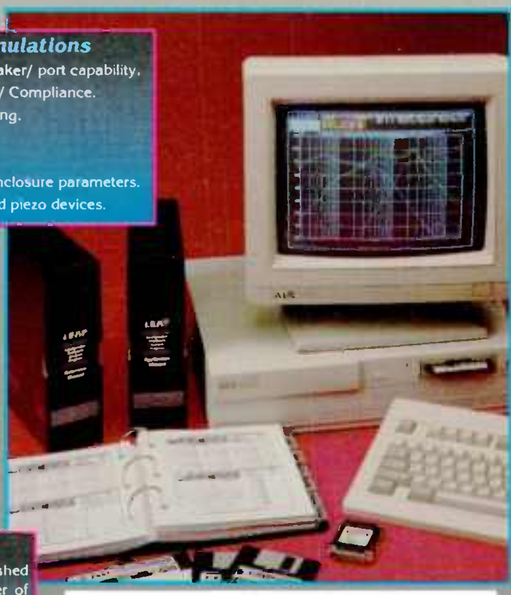

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# Good News

## TERMINATOR TWO

Music Interface Technologies (MIT) announces the replacement of the "High-End Series" models (CVTerminator Twin MH-770 speaker cable and MI-350 interconnect) with MH-770 II and MI-350 CVTerminator Twin Series Two. Each includes MIT technologies, such as the Image Specific Technology (IST™), Output Terminator Network, Input Terminator Network, CVT Coupler, and Jitter-Free Analog (JFA). Music Interface Technologies, 13620 Lincoln Way, Ste. 320, Auburn, CA 95602, (916) 888-0394, FAX (916) 888-0783.

***Reader Service #139***

## PRODUCT-LINE EXPANSION

Miller & Kreisel Sound (M&K) introduces the MX-5000THX Mark II powered subwoofer, one of six new products in its line of speaker system components. Among these are the SW-85 and SW-95, frameless in-wall speakers which won CES Innovations '98 Awards. M&K's LCR-55 is designed for use as a left-, right-, center-, or surround-channel speaker in a 5.1 multichannel satellite speaker or stereo satellite-subwoofer setup. The MX-105 is a 100W powered subwoofer and the MX-125 Mark II offers a 150W amplifier and two 12″ drivers. Like the 5000THX, both include push-pull dual-driver technology. M&K Sound Corp., 10391 Jefferson Blvd., Culver City, CA 90232, (310) 204-2854, FAX (310) 202-8782.

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## ENHANCED AKABAK

Bang-Campbell Associates introduces AkAbak 2.1, an updated version of the popular loudspeaker-design software by Jörg Panzer. AkAbak's new beamwidth display is a useful feature for two- and three-way system designers. If set to –3dB, it can calculate the horizontal or vertical lobing pattern, showing the radiation angle as a function of frequency where beamwidth drops 3dB from the on-axis level. Upgrades in version 2.1 include: enhanced import function, polar coordinates in directivity outputs, switchable input parameters (RMS or peak), and enhanced diagram operations. Bang-Campbell Associates, 3 Water St., PO Box 47, Woods Hole, MA 02543, (508) 540-1309, FAX (508) 540-8347, E-mail rhcamp@ma.ultranet.com.

***Reader Service #137***



## PSB CELEBRATED

PSB Speakers received two CES Innovations '98 Awards for its Stratus Gold*ⁱ* full-range speaker system and Stratus subwoofer series. The Stratus Gold*ⁱ* is a bass-reflex tower speaker with 1″ aluminum-dome tweeter, 6″ midrange, 10″ woofer, and 4Ω impedance. The Stratus subwoofer series includes the SubSonic 3*ⁱ* and SubSonic 4, both of which offer a 15″ driver and 300W of steady-state power (700W peak). The SubSonic 4 also features digital signal processing and an infrared remote control. PSB, 1600 Providence Hwy., Walpole, MA 02081, (508) 660-8300, FAX (508) 660-8373, Website www.psbspeakers.com.

***Reader Service #136***

## WHAT'S YOUR SIGN?

Gemini Sound released its XRS series of loudspeakers recommended for full-range applications or for use in conjunction with subs for extended bass response. Each in the series contains woofers with die-cast aluminum frames, tuned and ported cabinets made of ¾″ Oriented Strand Board, and vented magnet structures. Gemini Sound Products Corp., 8 Germak Dr., Carteret, NJ 07008, (732) 802-6004, FAX (732) 969-9090, E-mail int-sls@geminidj.com, Website www.geminidj.com.

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JOHN STUART MILL

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# About This Issue

**Paul Sechi**'s quest to design the ultimate speaker unfolds in this issue. On this leg of his journey he achieves some of his goals with a two-chamber reflex design ("Double-Chamber Reflex Enclosure," p. 8). Extensive measurements and analysis reveal an impressive-sounding enclosure.

**Paul Kittinger** presents another design and construction project—this one an improvement on his Isobarik tower speaker design (from *SB* 5/97). In this sequel, the author presents a less complex design that produces more power ("An Isobarik Tower—The Sequel," p. 14).

We are pleased to reprint in this issue an article entitled "Reference Monitor" from *Loudspeaker Projects*. Originally published in *Hi-Fi Luidsprekers*—from the editors of *Elektuur* magazine—this construction piece features a top-class tweeter, the Revelator from Scan-Speak.

As evidence that we're getting down to the wire in this series, **Tom Yeago** leads us into the final assembly stages of the AR-3*a* project. This time we'll tackle the magnets, plates, and domes of the drivers ("Rebuilding the AR-3*a*, Part 5," p. 36).

In the review spotlight is a crossover kit from Marchand. Reviewer **Ken Ketler** puts this active crossover kit together and demonstrates how it provides a pleasing enhancement to your subwoofer/satellite setup ("Test Drive," p. 44).

**Mike Klasco**'s series entitled Trade Secrets (p. 47) is a nice blend of history, industry perspective, and practical information about the use and manufacture of speaker components. His most recent topic is magnetic structures and baskets.

Also, speaker expert **Vance Dickason** tests two new drivers—metal-dome tweeters from SEAS ("Driver Report," p. 52).

*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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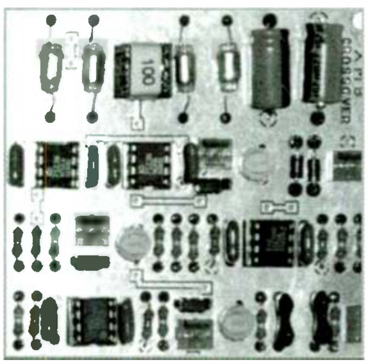
32



44



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# DOUBLE-CHAMBER REFLEX ENCLOSURE

**By Paul Sechi**

Having completed my final year of an Electrical Engineering Degree in Australia and being unable to find employment, I decided to read my three years worth of *Speaker Builder* thoroughly. I was most surprised to find two articles on the double-chamber reflex enclosure, written by Mark J. Thompson (1/92 and 6/92).

The title "double-chamber reflex enclosure" stems from the acoustic radiation of the enclosure, that is, from the loudspeaker itself and the vent of the second (or bottom) chamber that radiates into free space. This enclosure was the one I had selected as the basis of my final year's project (*Fig. 1*)—hence my surprise.

## PROJECT SPECIFICATIONS

Initially the project guidelines were to analyze, build, and test an enclosure that was an extension of the standard sealed or vented box. These enclosures had already been researched thoroughly over the past two decades, and there was no point in reinventing the wheel. The definition I used in my project was "an extension to a standard loudspeaker enclosure design is the use of multiple chambers and/or multiple vents within the one main enclosure."

The initial objectives of the acoustical and electromechanical properties are:

- to obtain the lowest possible rolloff frequency without over-driving the loudspeaker itself;
- to achieve a flat frequency response from the design;
- to obtain the steepest possible rolloff rate at low frequency.

After lengthy consideration of these guidelines, I thought that if I could combine all three elements in one design, I would have achieved the loudspeaker designer's dream.

## ACOUSTICAL-RADIATION ANALYSIS

I derived the analysis of the enclosure's acoustical-radiation transfer function from first principles, excluding the vent and enclosure losses of each chamber. I divided the transfer function into the denominator and numerator terms as polynomials of frequency.

The denominator polynomial was of sixth order, compared to a vented enclosure's fourth-order, indicating that the system's rolloff occurs faster. The numerator was a third-order polynomial, compared to a vented system's zero order, and the numerator thus posed some design limitations.

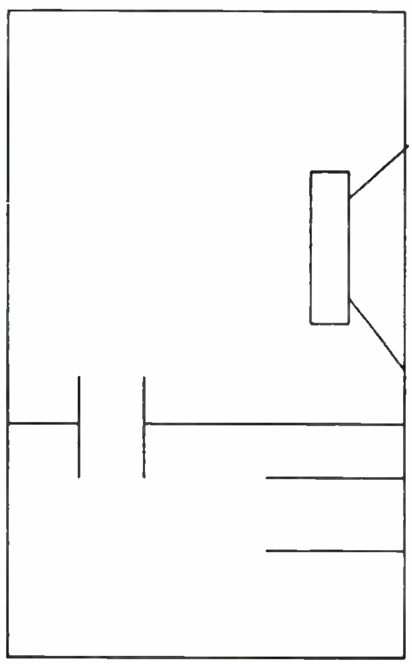

**FIGURE 1**: The double-chamber reflex enclosure.

The denominator polynomial indicated a rolloff rate of 36dB/decade, which is very steep and usually found only in bandpass subwoofer designs. The increased rolloff rate enhanced the possibility of lowering the rolloff frequency compared to a vented design. The rolloff rate and the dual chambers might also reduce the cone displacement at low frequencies.

All hopes of the denominator's frequency response having magical properties quickly faded when the numerator's frequency response was plotted as a hyperbolic function. Such a response reduced the ability to obtain the flat frequency response of the overall system. Two ways to ensure a flat response were either to reduce the numerator's resonance to well below the denominator's rolloff frequency, or to increase it to a suitable frequency away from the bottom three or four octaves of operation.

The acoustical-radiation transfer function was of the form

$$E(s) = \frac{s^{-1} \times H + s^{-3} \times A}{1 + s^{-1} \times B + s^{-2} \times C + \cdots + s^{-6} \times G}$$

where s = jw, in the complex frequency domain, and A, B, ..., G are coefficients of the terms of the polynomials representing the numerator and denominator.

## DENOMINATOR ANALYSIS

The denominator polynomial was originally aligned to Butterworth sixth-order filter coefficients. I analyzed each term to fulfill the Butterworth coefficients. The analysis showed that the first chamber—housing the speaker itself—had a volume dependent on the loudspeaker parameters and $f_o$, the box resonant frequency. The second chamber's volume depended on the loudspeaker parameters and both chambers' tuned frequencies.

I calculated the $Q_{opt}$ of the Butterworth alignment (where $f_s = f_o$) to be 0.259. Similarly, for a fourth-order Butterworth vented design, this figure is 0.382. The loudspeaker selected for the project was the very capable Peerless CC6.5 woofer, provided by Brad Serhan of Orpheus Loudspeakers in Sydney, Australia. The data-sheet Thiele/

### ABOUT THE AUTHOR

Paul Sechi was born and raised in Australia, where he worked for nearly three years on MW/satellite communications and high-reliability projects. Currently, he is working overseas in the MW communications field for a GSM provider. As much as possible, he listens to music and searches for the ultimate speaker design.

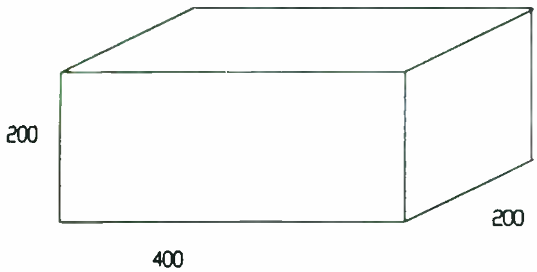


**FIGURE 2:** Top-chamber internal dimensions.

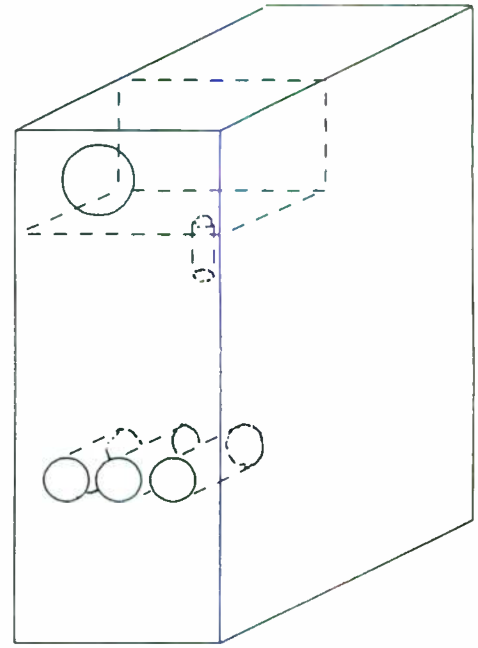

**FIGURE 3:** Bottom-chamber internal structure.

Small parameters for the unit were $Q_t = 0.37$, $f_s = 40Hz$, and $V_{as} = 24$ ltr.

The Peerless unit had too high a total Q for the Butterworth filter alignment to achieve the original design goals. Reducing the loudspeaker total Q is much more difficult than increasing it, and with no other driver available to me at the time, I chose another sixth-order filter alignment.

The next alignment I analyzed was the 0.01dB ripple Chebychev, in which the ripple content of the filter in the passband was most acceptable in the loudspeaker-design criteria. I calculated the $Q_{opt}$ for the design at 0.43, which allowed me to use the Peerless unit with an $f_0$ less than $f_s$.

Articles by Augspurger[1] and Weems[2] suggest that there is a ratio of the two chambers' resonant frequencies and volumes. However, computer simulation of the frequency response of the enclosure ratios yielded discouraging results; likewise for the chamber-volume ratios.

## FINDING THE KEY

I scrupulously examined the denominator term for errors and false assumptions that might explain the unimpressive simulation results. I discovered that a constant factor that had been used but not analyzed provided the key to the correct ratio of chamber frequencies; I was then able to calculate the chamber volumes as per the prior analysis.

The 0.01dB Chebychev alignment produced 19.1 and 373 ltr for the top and bottom chambers, respectively (the loudspeaker is mounted in the top one). The resonant frequencies for the top and bottom chambers were 36 and 23Hz, respectively. Unfortunately, the enclosure was too large for one person to handle, and there was the problem of controlling the standing wave in a 400 ltr enclosure.

The next sixth-order Chebychev filter coefficients I tried were those of the 0.05dB ripple, still within the acceptable criteria of the project design. I calculated the $Q_{opt}$ for this design at 0.3667, allowing me to use the Peerless unit with an $f_0$ very near $f_s$. The

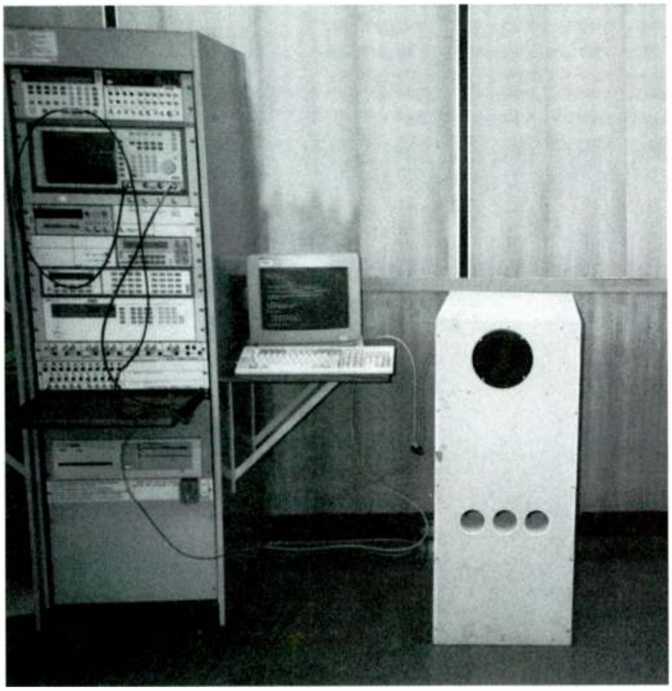

**PHOTO 1:** The enclosure next to the ATE rack.

**PHOTO 2:** The enclosure's internal structure.

completion of this analysis gave 14.6 and 226 ltr for the top and bottom chambers, respectively, with corresponding resonant frequencies of 41 and 28Hz.

## LOUDSPEAKER PARAMETERS

To verify the stated data-sheet Thiele/Small parameters, I tested the Peerless unit using a Hewlett-Packard Automated Test Equipment (ATE) rack. I used a computer to control the testing so as to increase the frequency and measure the electrical parameters from the voltmeter, logging both results to a file. The test produced the following results: $Q_t = 0.376$, $f_s = 46$Hz, and $V_{as} = 24.3$ ltr.

The only result to fall outside a 10% tolerance band was the resonant frequency. A second test provided the reassuring specification of 40.2Hz as the resonant frequency. I obtained the above calculations of enclosure volumes and chamber resonant frequencies from the data-sheet values and left them at that after seeing only minor differences in the measured results.

## LOUDSPEAKER ENCLOSURE DESIGN

Thiele[3] stressed the fact that the 0.8:1.0:1.25 enclosure ratio design was critical for the reduction of standing waves—most important in a design with a volume of nearly 250 ltr. The final enclosure design is shown in *Figs. 2* and *3*. The overall height of the enclosure was 1000mm, and its maximum depth 601mm, both measured internally.

Luckily, the top chamber would be able to break up some of the lower chamber's standing waves by intruding into the cavity space, but the standing-wave issue would still exist. I placed the loudspeaker off center on the front of the cabinet. The vent connecting the chambers and reducing the coupling between them is likewise off-center. *Photo 1* displays the enclosure with its three vents in the lower chamber radiating air into free space. *Photo 2* shows the internal construction of the enclosure; note the white sealant I used on all the internal joints.

## FREQUENCY-RESPONSE SIMULATION

The frequency response of the denominator polynomial aligned to the Chebychev 0.05dB filter coefficients is shown in *Fig. 4*. The slight variation of $Q_{opt}$ from the $Q_t$ of the speaker reduced the $f_o$. The low ripple effect and the flat frequency response above about 30Hz seem quite perfect.

*Figure 5* details the numerator frequency response, with the hyperbolic shape cramped by the logarithmic scale. The dip in

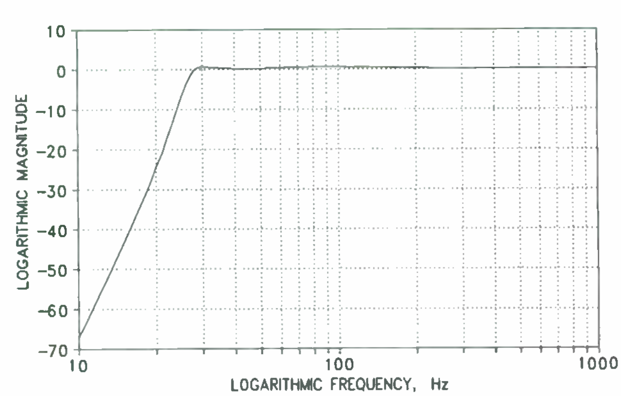


**FIGURE 4:** Denominator frequency response.

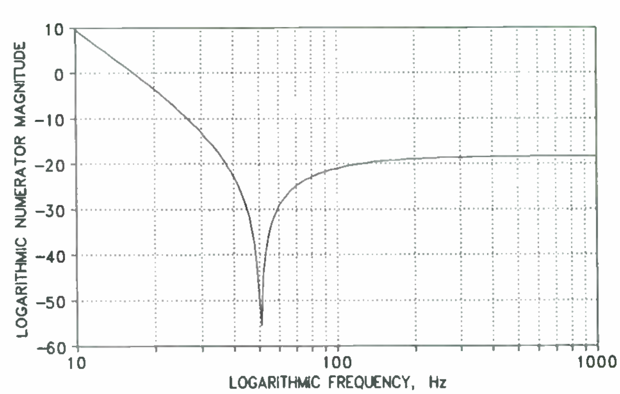


**FIGURE 5:** Numerator frequency response.

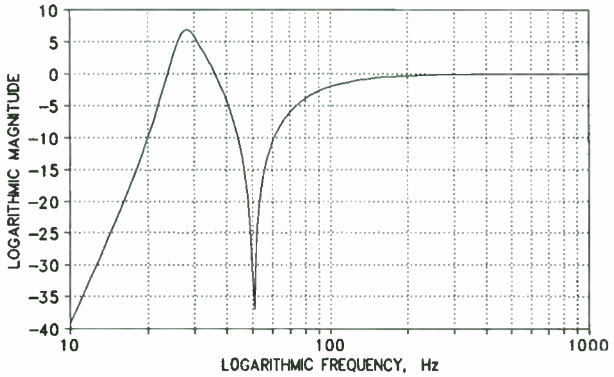


**FIGURE 6:** Transfer-function frequency response.

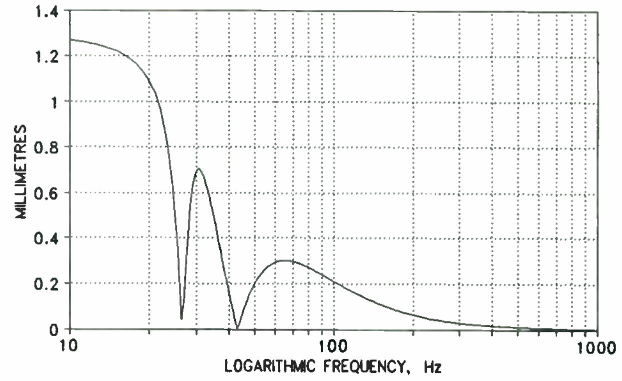


**FIGURE 7:** Loudspeaker cone displacement.

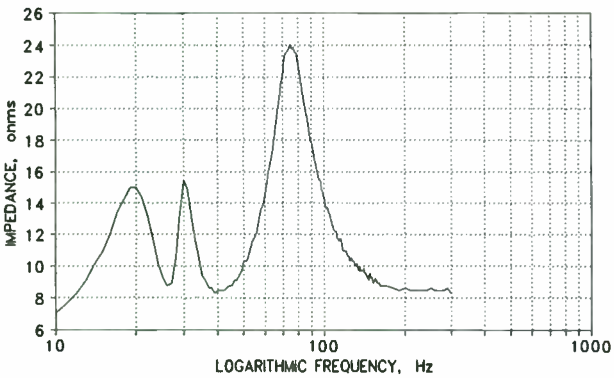


**FIGURE 8:** Measured electrical-impedance magnitude

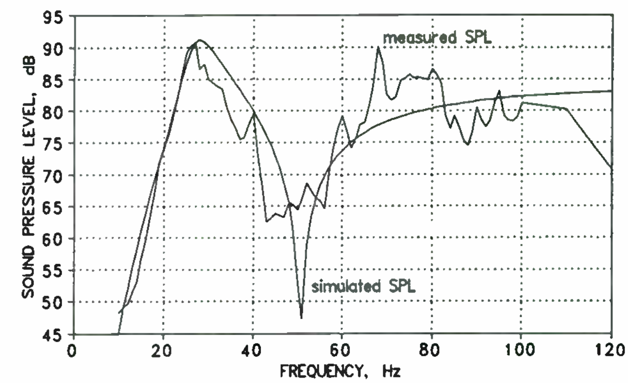


**FIGURE 9:** Measured and simulated frequency-response curves.

the numerator polynomial is a function of both chambers' resonant frequencies and their respective volumes, simulating a minimum at 50.4Hz.

The superposition of the numerator on the denominator produces *Fig. 6*, the transfer-function or overall system's frequency response. The system indicates a high roll-off rate, a low roll-off frequency, and a big dip and hump in the frequency response. The dip dominates from about 29Hz to 81Hz, where it is back at a –3dB point. The initial –3dB point occurs at about 20.5Hz; the hump peaks at +6.5dB at 28Hz and subsides to the second –3dB position at 41Hz.

The simulated results compare favorably to the measurements done by Weems, although the dip of the double reflex enclosure is not so evident in his test results. This could be due to enclosure losses, air mass in vents (especially at the 20–60Hz region), and system-coupling parameters.

## CONE DISPLACEMENT

The loudspeaker cone-displacement simulation was an important factor of the design. Obtaining 20Hz from a 6½″ speaker is great, but it must be within the physical possibilities of the system. The cone-displacement measurements are shown in *Fig. 7*. To measure the cone movement, a sine wave was injected into the system, a lightweight plastic pointer attached to the cone, and a ruler placed under the pointer to verify the cone movement.

The input signal was a 7.87V sine wave from the ATE rack Reference Standard Audio Synthesizer (HP8904A). Cone motion measurements below 30Hz were accurate, but above this the displacement was too small, and the cone was moving too fast. The simulated results included the input signal used in the actual testing of the system.

## IMPEDANCE MEASUREMENTS

The impedance measurement of the system (*Fig. 8*) utilized the ATE rack, allowing me to do other tasks while the system data was recorded and logged. The impedance plot showed no irregularities with the design, two minimum points occurring when the two chambers were at their respective resonant frequencies. The three peaks of the impedance curve correlate with the enclosure's design of multiple chambers and ports.

## MEASURED ACOUSTICAL FREQUENCY RESPONSE

I measured the enclosure's acoustic radiation at a distance of 1m from the loudspeaker's front panel, on-axis vertically with the speaker and midway between the speaker and the second-chamber vents. The frequency response was measured with the enclosure in a bare state, that is, with no damping material inside either chamber, and limited to below 1kHz.

I performed the test manually using a Brüel and Kjaer 2209 SPL meter inside the Arts Theater on the university campus. I chose the theater because its large size and padded seating and walls would attenuate any reflections. (The ATE equipment room was too small and lacked absorptive qualities, so I did not use it for these tests.)


## SPECIAL THANKS

Special thanks to Jim Ball, who was my project supervisor throughout the year, and to Brad Serhan for the loudspeaker and his advice on the project.

The measured and simulated frequency-response curves are shown in *Fig. 9*, highlighting the correlation of results. The graph relates the two curves in the bass region only, where the simulated response was most interesting. As the test frequency was increased, it was evident that the lack of internal damping and bracing was affecting the measured results' smoothness, and some peaks and dips began to appear.

During the testing, the frequency generator and counter were set up on top of the enclosure itself. At 253Hz, the entire assembly began to vibrate, indicating that the internal standing waves of the enclosure peaked at this point.

Unfortunately, I did not have time to brace the enclosure and remeasure the system's frequency response. Moving the internal port between the two chambers (either all in the top or all in the bottom) did not affect the response of the system.

## CONCLUSION

Although I never played any music through the system, the sound produced by the enclosure was effortless, especially at low frequencies. During the impedance measurements through the ATE rack, this was quite evident as the test frequency increased to the 20Hz region and the internal walls of the ATE room began to vibrate. It would have been interesting to build the 400 ltr enclosure to verify the 24Hz resonance from the Peerless drive unit.

The effortless production of 28Hz from such a relatively small enclosure, using a loudspeaker whose resonant frequency was 46Hz, is quite amazing, especially considering the small cone displacement of the speaker throughout the bass-region frequencies. I am sure that if the enclosure were properly braced, built more solidly, and acoustically dampened, that the system's frequency response would be quite devastating.

Further development and design are currently under way, using similar design principles for suitable 4″ and 5″ drive units to provide excellent bass roll-off from a small-volume enclosure. Test results from the new designs should be available in the next few months for comparison with the enclosure this article describes.

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1. Augspurger, G. L., "Double Chamber Speaker Enclosure," *Electronics World*, December 1961, p. 41.

2. Weems, David B., "A Small Double Chamber Reflex," *SB* 4/85, p. 14.

3. Thiele, A.N., "Loudspeakers in Vented Boxes," Sydney, Institution of Radio and Electronic Engineering Convention, 1961.

# AN ISOBARIK TOWER—THE SEQUEL

By Paul L. Kittinger

In the 5/97 issue of *Speaker Builder*, I described an Isobarik tower speaker I designed and built. I was very pleased with the way it turned out, but having become an avid audio enthusiast in recent years, I couldn't leave well enough alone. So, I decided to build another, improving on the design. My objectives for this latest design were:

1. Size: Footprint of ~1ft$^2$; height less than 48";
2. Construction: Less complicated design; easier to build;
3. Tweeter: Fabric dome;
4. Midrange: Increased acoustical power; improved imaging;
5. Bass: An $f_3$ as close to 30Hz as possible; $Q_{tc}$ of 0.7–0.8;
6. Enclosure type: Sealed;
7. Material cost: $1100 or less.

### CHOICES AND COMPROMISES

As in my previous design, I opted to use two 8" woofers in an Isobarik configuration to minimize the cabinet's size and internal volume. I also decided to use two midrange drivers, for increased acoustical output, in a D'Appolito configuration around a dome tweeter for better imaging. To make construction as easy as possible, I'd locate the woofers at the bottom of the cabinet, firing down and then out of slots at the bottom of the cabinet's front and sides.

Primarily, that decision meant designing the system as a two-way with an integral subwoofer, so to speak—rather than as a typical three-way—with the crossover between woofer and midrange occurring at 100Hz or lower to eliminate localization of the woofers' output. Secondly, since the midrange would then need to respond down to 100Hz or lower, its enclosure would also be sealed. Finally, I decided to use third-order Butterworth crossovers to minimize driver-response overlap and because odd-order crossovers tend to favor the D'Appolito configuration.

I expected the crossover from the midrange to the tweeter to be in the 2.4–3.2kHz range, determined by the center-to-center spacing between the midrange drivers and the tweeter. For the midrange drivers, I chose the Morel MW-166 6" units because they sounded so good in my previous design, have a fairly low resonant frequency (48Hz), and respond nicely up to 5kHz. As the dome tweeter, I picked the Morel MDT-40 for its specifications and especially its very small faceplate dimensions that allow short distances between midrange and tweeter centers.

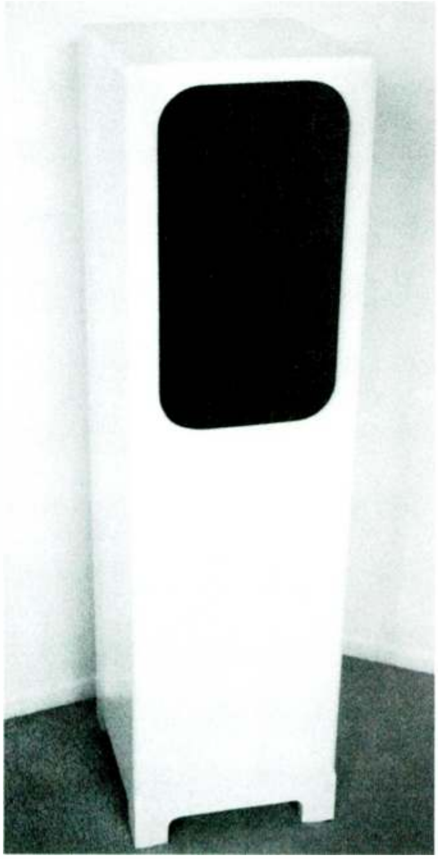

**PHOTO 1:** Front view, with grille.

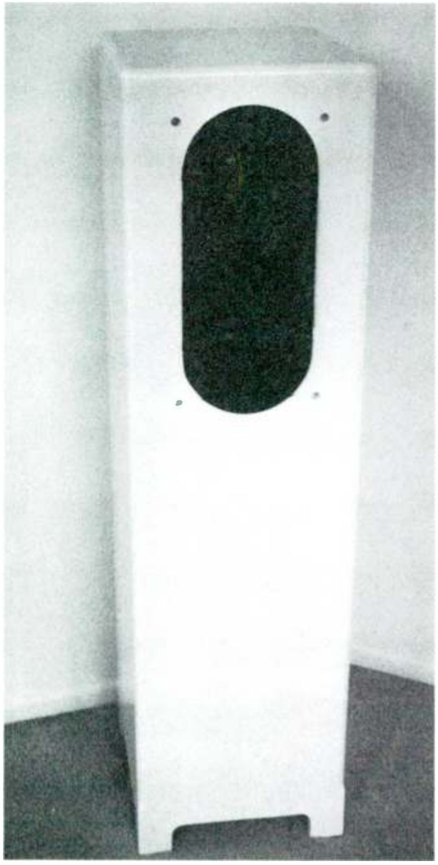

**PHOTO 2:** Front view, without grille.

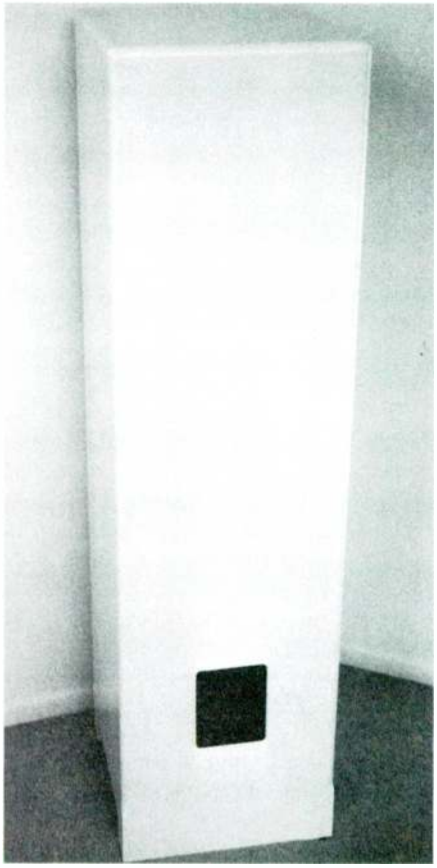

**PHOTO 3:** Rear view.

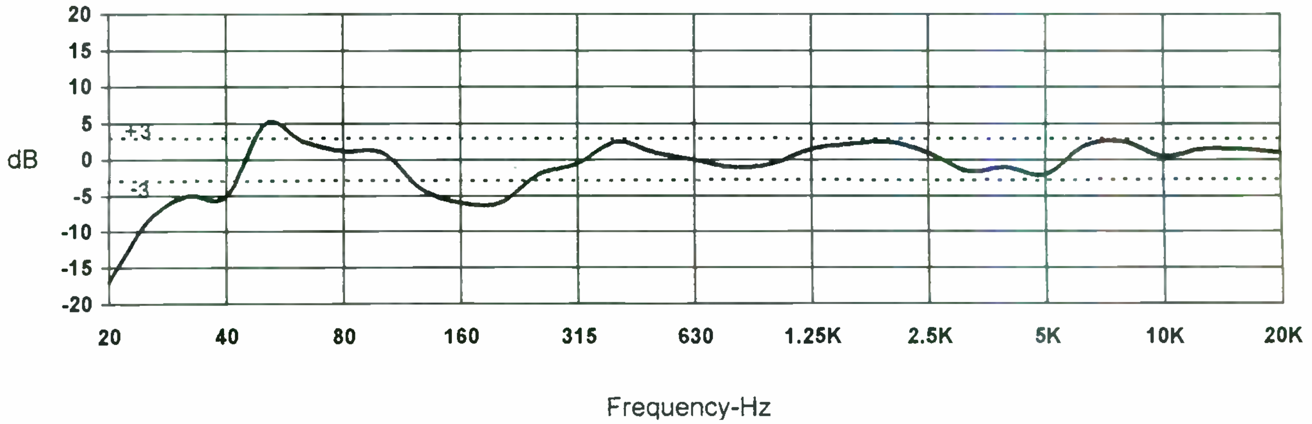


**FIGURE 1:** Frequency-response graph.

Lastly, after much research and calculation, I selected the Morel MW-266 for the woofers because, of all the drivers I considered, they had the best compromise between $V_{as}$, $F_s$, $Q_{ts}$, and $X_{max}$ (there are always compromises). Also, the ratio of $F_s$ to $Q_{es}$ (40) made these woofers suitable for a sealed enclosure.

## ENCLOSURE SIZES

In order to meet my size requirements, the sealed cavities for both midrange and woofers had to be somewhat undersized, but by using the proper type and amount of fill material (foam, fiberglass, polyester fiber, and so on), I expected to achieve my target $Q_{tc}$ and $f_3$. Furthermore, even though the midrange drivers would not reproduce the very lowest frequencies, they would need to respond down to approximately 50Hz in their cavity in order to achieve a smooth transition at the woofers' crossover frequency.

I therefore chose a crossover of 100Hz, so the midrange drivers would have an $f_3$ of approximately 50Hz if their high-pass crossover did not start rolling down at 100Hz. As it turned out, both woofer and midrange drivers in their cavities had calculated $Q_{tc}$s of approximately 0.9 prior to adding fill material.

Based on the test results published in Vance Dickason's excellent book, the *Loudspeaker Design Cookbook*, I decided to use a combination of convoluted foam lining the walls of the cavities and an appropriate amount of Acousta Stuf® filling the remaining volume. This combination of materials theoretically would result in the best compromise (there's that word, again) for lowering both $Q_{tc}$ and $f_3$, with the calculated $Q_{tc}$s of both cavities expected to end up around 0.75, and the woofers' $f_3$ at 34Hz.

Since it worked out so well with my previous speaker effort, I used the same basic design for the cabinet construction: butt joints; nail and glue attachment; ¾″-thick MDF (medium-density fiberboard) for all cabinet walls and braces; and strips of 1½″ wide MDF running top to bottom to form slots for horizontal braces and shelves, to create attachment "runners" for the front and rear panels, and to increase the cabinet's rigidity.

Unlike my previous design, mounting the woofers at the bottom in their Isobarik chamber made unnecessary an access door for installing the inner woofer (you install the woofers from the bottom, one behind the other). This made the cabinet less complicated and easier to assemble, and with ample bracing I expected it would have no bothersome resonances.

Builders almost always recommend using material for the front panel (baffle) that is thicker than the rest of the cabinet. If you're like me, however, you don't want to end up wasting most of a 4′ × 8′ sheet of MDF. That's why I use the same thickness for all panels; but I make sure to use lots of bracing. Also, with this design, I do not mount the woofers on the same panel as the other drivers, so I assume there will be less vibration transferred to the other drivers at low frequencies. It's another compromise, and the designer's choice.

## HOW DID IT WORK OUT?

A finished system is shown in *Photos 1, 2,* and *3*. Its dimensions are 12″ wide, 13″ deep, and 44½″ tall, with the tweeter's center at 35″ from the floor. *Figure 1* shows the overall frequency response of the system. I measured this with my sound-pressure-level (SPL) meter located 6′ from the system at a height of 35″, using tracks 16–18 of *Stereophile*'s Test CD 2 to generate frequencies at 1/3-octave

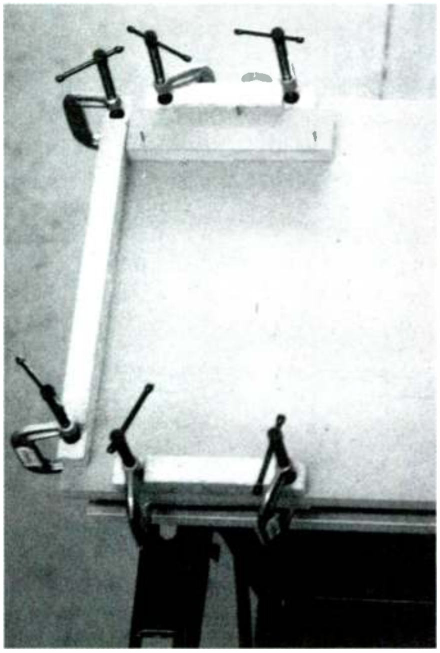

**PHOTO 4:** Side panel clamping detail #1.

**PHOTO 5:** Side panel clamping detail #2.

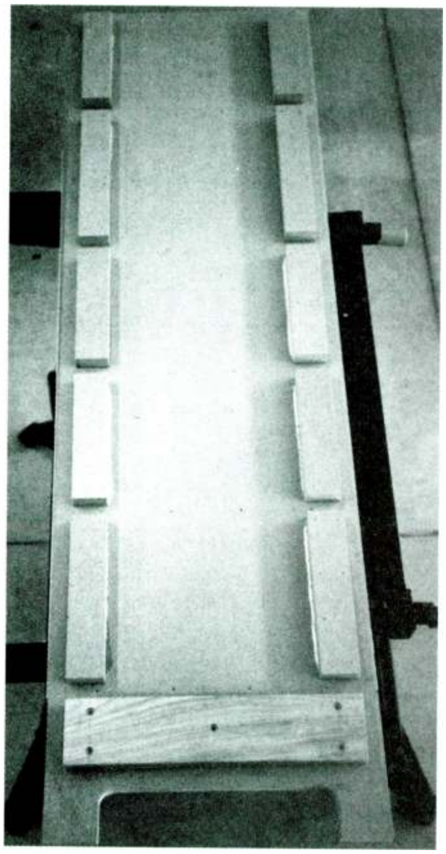

**PHOTO 6:** Completed side panel.

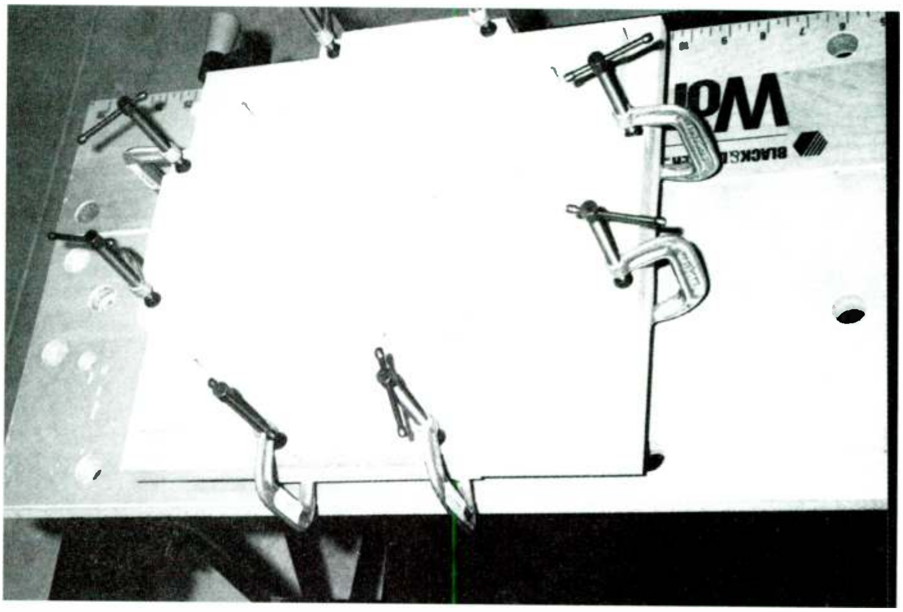

**PHOTO 7:** Top-assembly clamping detail.

intervals. I used a reference SPL of 70dB.

From 250Hz on up, the measured response falls within about a 4–5dB window, which is pretty good performance in a normal room. Below 250Hz, the room characteristics dominate. I believe the large dip between 100–250Hz is typical of partial cancellations from "floor bounce," and the peak at 50Hz followed by the sharp drop at 40Hz is caused by resonances in my room. If I could make these measurements in an anechoic chamber, I would expect a much smoother response.

I made two sets of measurements, one with and one without the grille attached. The differences were virtually negligible, so I've shown only the one with the grille on. Another measurement, which I haven't shown, is that from the close-miked woofer. This peaked at 50Hz as expected, and indicated an $f_3$ of 38Hz with $Q_{tc}$ in the desired range. This $f_3$ is higher than calculated, but I expect it to decrease a bit as the woofers loosen up with use. I'm estimating a sensitivity in the 86–89dB range based on the setting of my preamp's volume control and previous sensitivity measurements of other speakers.

The music these speakers reproduce is quite good and pretty much as expected. With two midrange drivers sharing the load, I'm able to play music at higher levels than I normally use without obvious distortion, and the D'Appolito arrangement has resulted in extremely good imaging, allowing accurate depiction of various instruments' stage positions.

One bit of advice is necessary, however. With the woofers located at the bottom of the cabinet, I found room resonances in the 50–80Hz range to be easily activated with the speakers located close to the wall behind them or to side walls or corners (my room has some really nasty resonances in the 50–65Hz area). I recommend placing the cabinets at least 1½ feet in front of a wall and several feet from side walls and corners. Speaking of resonances, even though I was unable to make any measurements, the cabinet seemed to be essentially free of any.

As far as costs are concerned, I spent just under $1150 to build a pair of these speakers, including sales taxes and shipping costs for mail-order purchases. I certainly would not say these speakers are inexpensive, but anything commercial with comparable performance would cost significantly more—and you would not have the satisfaction of building it yourself. Could these speakers be improved? Certainly, but I'm satisfied with their overall performance, and any possible improvements would be incremental, not major, and probably limited to frequencies below 250Hz.

## DESIGN DETAILS

I used ¾″ MDF throughout, except for the crossover base boards and the grille boards, which I made from 3/8″ particleboard. To ensure adequate strength, I reinforced the Isobarik chamber with strips of 1″ × 3″ birch (which actually measure ¾″ × 2½″). The birch also forms mounting rails for the outer (bottom) woofer panel, which I screwed into the birch strips. I bought the birch in 2′ lengths (you'll need four of these). Be aware that stock wood strips are not always square, so select your pieces carefully, making sure they aren't curved or twisted.

I assembled each of the three crossovers on a separate board. Separate assemblies are supposed to have sonic benefits, but I did this for a more practical reason: the midrange and tweeter crossovers must fit through the midrange driver cutouts for installation, and one board would have been too large. I mounted the crossover assemblies on the side walls of their respective drivers' cavities.

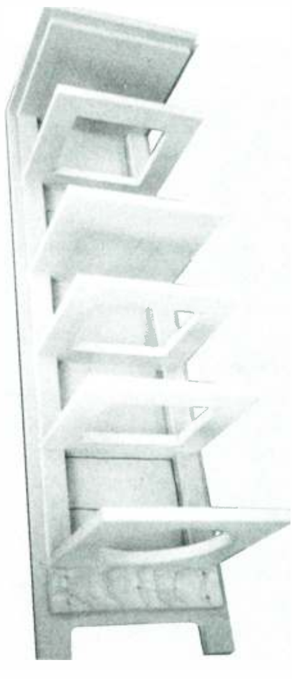

**PHOTO 8:** Side panel with the horizontal pieces and top in place.

# Peerless

MADISOUND SPEAKER COMPONENTS
8608 UNIVERSITY GREEN
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## TWEETERS

| Model | Ω | Fs Hz | Qts | Vas Ltrs | Power | dB | Box Liters | F3 Hz | Price |
|---|---|---|---|---|---|---|---|---|---|
| **801730**: 62CT 13/40 PPb (cone tweeter) | 8 | 1513 | | | 100 | 88.5 | | | $12.40 |
| **811582**:80DT 26/55 SF | 8 | 1075 | | | 90 | 89.0 | | | 15.55 |
| **811546**:100DT 26/72 SF | 8 | 1006 | | | 100 | 92.0 | | | 18.85 |
| **811528**: 94 DT 26/72 SF (Square Flange) | 8 | 980 | | | 100 | 9.15 | | | 18.00 |
| **812687**: 105 DT 26/72 SF (811687) | 8 | 963 | | | 130 | 91.6 | | | 25.75 |
| **811815**: 100 DT 26 72 SF WA (Wide Angle) | 8 | 917 | | | 100 | 93 | | | 20.20 |
| **810665**:115DT 26/72 SF (Used in older Polk Systems) | 8 | 1056 | | | 80 | 91.5 | | | 32.40 |
| **811647**:100HT 26/72 SF (Horn Tweeter) | 8 | 1040 | | | 100 | 99.0 | | | 22.40 |
| We stock voice coils for all the Peerless tweeters, except the 810665. All voice coils are the same price: | | | | | | | | | 7.65 |

## MIDRANGES

| Model | Ω | Fs Hz | Qts | Vas Ltrs | Power | dB | Box Liters | F3 Hz | Price |
|---|---|---|---|---|---|---|---|---|---|
| **821214**:134 DMR 51/100 SF | 8 | 298 | .65 | | 200 | 89 | chambered | | $44.20 |
| **821646**:140 HDM 51/100 SF (Horn Mid) | 8 | 454 | 1.07 | | 200 | 93 | chambered | | 45.75 |
| **821385**:122 MF 26/72 SP (KO40MRF) | 8 | 224 | 1.20 | | 100 | 90 | chambered | | 44.00 |
| **821615**:122 M 26/72 PPB (TO105) | 8 | 530 | .72 | | 180 | 91 | chambered | | 44.00 |

## WOOFERS

| Model | Ω | Fs Hz | Qts | Vas Ltrs | Power | dB | Box Liters | F3 Hz | Price |
|---|---|---|---|---|---|---|---|---|---|
| **832591**:130 WR 26/72 PPB (5" Woofer) | 4 | 51.5 | .41 | 11.5 | 100 | 88.8 | 5.7S/10V | 90/52 | $35.55 |
| **832592**: " " | 8 | 54.9 | .43 | 11 | 100 | 86.9 | 7S/13V | 89/49 | 35.55 |
| **833597**:165 WF 33/100 PPB (6.5" Woofer) | 4 | 45.2 | .28 | 20.1 | 150 | 92.1 | 4S/5V | 115/75 | 36.20 |
| **833429**: " " | 8 | 47.5 | .34 | 20.7 | 150 | 88.7 | 6S/10V | 95/65 | 36.20 |
| **833594**:165 WR 33/100 PPB (6.5" Woofer) | 4 | 40 | .24 | 27.1 | 150 | 92.2 | 3.5S/6V | 120/80 | 39.75 |
| **833599**: " " | 8 | 36.2 | .28 | 32.2 | 150 | 88 | 6.5S/9.5V | 90/60 | 39.75 |
| **831510**:210 WF 26/72 PPB (8" Woofer) | 8 | 37.9 | .82 | 66.6 | 100 | 86.8 | 60+S | 40 | 28.40 |
| **832556**: " " | 8 | 32.3 | .37 | 82.4 | 150 | 89.7 | 34S/55V | 61/38 | 37.75 |

## CC LINE WOOFERS

| Model | Imp. Ω | Fs Hz | Qts | Vas Ltrs | Power Watts | dB | Xmax mm P | Box Liter S/V | F3 Hz | Price Each |
|---|---|---|---|---|---|---|---|---|---|---|
| **832733**:146 MR 26/102 PPB/AL (5" Midrange) | 8 | 59 | .34 | 8.7 | 125 | 88.1 | ±3.5 | 2.7S/4.5V | 122/77 | 44.65 |
| **832757**:180WR 33/102 PPB (7" Woofer) | 4 | 35.2 | .26 | 32.6 | 150 | 90.5 | ±5 | 5S/7V | 97/69 | 51.55 |
| **832732**: " " | 8 | 35.2 | .29 | 32.9 | 150 | 87.9 | ±5.5 | 7S/10V | 86/58 | 51.55 |
| **831758**:220 WR 33/102 PPX/AL (8" Woofer) | 4 | 22.1 | .36 | 109 | 150 | 88.8 | ±5 | 39S/61V | 43/28 | 56.20 |
| **831709**: " " | 8 | 25 | .45 | 86.9 | 150 | 86.9 | ±5.5 | 60S/115V | 39/24 | 56.20 |
| **831858**:220 SWR 39/115 PPX/AL DVC (8" W.) | 8/8 | 22 | .23 | 79.8 | 200 | 90.5 | ±7 | 10S/15V | 65/45 | 68.85 |
| **831759**: 260 SWR 39/115 PPX/4L AL (10" Woofer) | 4 | 22.4 | .27 | 121.9 | 220 | 91.5 | ±7.5 | 22S/32V | 58/40 | 68.85 |
| **831727**: " " | 8 | 22.3 | .34 | 136.2 | 220 | 87.8 | ±9 | 40S/63V | 45/30 | 68.85 |
| **831857**: 315 SWR 39/115 PPX/4L AL (12" W.) | 8 | 24 | .44 | 210 | 220 | 89.3 | ±9.0 | 100S/242V | 39/23 | 91.10 |

## ➡*NEW* CSC LINE WOOFERS - Composite Sandwich Cone

| Model | Imp. Ω | Fs Hz | Qts | Vas Ltrs | Power Watts | dB | Xmax mm P | Box Liter S/V | F3 Hz | Price Each |
|---|---|---|---|---|---|---|---|---|---|---|
| **850100**: 116 WR 26 72 SD (4.5" Woofer) | 8 | 80.7 | .58 | 2.7 | 100 | 85.9 | ±1.5 | 4S | 99 | $31.00 |
| **850106**: 145 WR 26 90 SD (5.5" Woofer) | 8 | 50 | .35 | 11.7 | 110 | 87.8 | ±3.5 | 3.8S/6V | 100/65 | 34.85 |
| **850118**: 176 WR 33 102 SD (7" Woofer) | 8 | 37.2 | .43 | 28.5 | 150 | 87.0 | ±5.5 | 14S/20V | 60/45 | 45.55 |
| **850131**: 217 WR 33 102 SD 4L (8" Woofer) | 4 | 28 | .37 | 77.4 | 150 | 91.4 | ±5.5 | 28S/35V | 53/39 | 50.00 |
| **850138**: 257 WR 33 90 SDX 4L (10" Woofer) | 8 | 26.7 | .52 | 111.1 | 150 | 88.0 | ±4 | 90S | 36 | 62.65 |
| **850141**: 257 WR 33 102 SDX 4L (10" Woofer) | 4 | 25.7 | .48 | 127.9 | 150 | 91.1 | ±5.5 | 90S | 38 | 66.40 |
| **850144**: 257 WR 39 115 SDX (10" Woofer) | 8 | 24.1 | .45 | 137.6 | 200 | 88.0 | ±5 | 80S | 38 | 74.40 |
| **850145**: 257 WR 39 115 SDX (10" Woofer) | 4 | 23 | .35 | 145.9 | 200 | 91.4 | ±5 | 50S/80V | 45/30 | 74.40 |

## ➡*NEW* CSC-X LINE WOOFERS - Composite Sandwich Cone and Short Circuit Ring

| Model | Imp. Ω | Fs Hz | Qts | Vas Ltrs | Power Watts | dB | Xmax mm P | Box Liter S/V | F3 Hz | Price Each |
|---|---|---|---|---|---|---|---|---|---|---|
| **850108**: 145 WR 26 90 SD AL (5.5" Woofer) | 8 | 48 | .34 | 12.5 | 110 | 87.3 | ±4.5 | 4S/6.3V | 96/62 | $39.55 |
| **850122**: 176 WR 33 102 SD AL (7" Woofer) | 8 | 38 | .43 | 27.7 | 150 | 86.6 | ±5.5 | 14S/20V | 59/40 | 51.55 |
| **850136**: 217 WR 33 102 SD 4L AL (8" Woofer) | 8 | 28.2 | .27 | 79.7 | 150 | 89.7 | ±4 | 14S/21V | 70/48 | 59.10 |
| **850146**: 257 SWR 39 115 SDX 4L AL (10" Woofer) | 8 | 22.6 | .35 | 144.4 | 200 | 88.2 | ±9 | 53S/88V | 43/27 | 82.20 |

## ➡*NEW* CDC LINE AUTOSOUND WOOFER - Injection Molded Cone and Surround

| Model | Imp. Ω | Fs Hz | Qts | Vas Ltrs | Power Watts | dB | Xmax mm P | Box Liter S/V | F3 Hz | Price Each |
|---|---|---|---|---|---|---|---|---|---|---|
| **830237**: 100 WR 26 72 CD (4" Woofer) | 4 | 81.2 | .52 | 2.8 | 110 | 89.4 | ±0.5 | 3S | 112 | $24.85 |

I used a terminal cup having two pairs of binding posts, with the woofer's crossover input wired to one pair, and the midrange and tweeter crossovers' inputs wired to the other. This allows the speaker system to be biwired, or driven with separate amplifiers, one for the woofer and the other for midrange and tweeter. You can use a single pair of binding posts instead if you do not desire biwiring or biamplification.

To make the electrical connections in the sealed cavities, I used a pair of 10–32 bolts through the inner woofer-mounting panel and another pair through the bottom panel of the midrange and tweeter cavity. I made the connections from the wires to the bolts with crimp-on ring lugs, secured with lockwashers and nuts. I placed a bit of silicone sealant in the holes for the pass-through bolts to prevent leaks.

I used 14-gauge stranded wire between the lower pair of input posts and the woofers' crossover, between that crossover's output and its pass-through bolts, and between the upper pair of input posts and the pass-through bolts for midrange and tweeter. All other interconnecting wire is stranded 16-gauge.

I soldered the connections to the input posts, but made all other connections with crimp-on solderless connectors. Using soldered connections is often preferred, but it's difficult to make changes later, and most driver warranties won't be honored, I believe, if their terminals have been soldered. I twisted together the leads in each pair. The woofers' coils are wired in parallel, positive to positive, and negative to negative, as are the coils of the midrange drivers.

## CROSSOVER DESIGN

Since this full-range system is really a two-way with an integral subwoofer, the crossovers are a bit nonstandard. Using published equations for a two-way, third-order Butterworth, I calculated values for inductors and capacitors of the 3kHz low-pass and high-pass sections for midrange and tweeter (I used 3kHz because the center-to-center spacing between each midrange driver and the tweeter is equal to one wavelength at that frequency).

I used the same low-pass equation for the woofer crossover components as for the midrange. Then, to figure the value of the capacitor needed in series with the midrange crossover input, I first calculated the input impedance at 100Hz for the total midrange crossover with drivers connected. Not surprisingly, this came out to 4Ω,

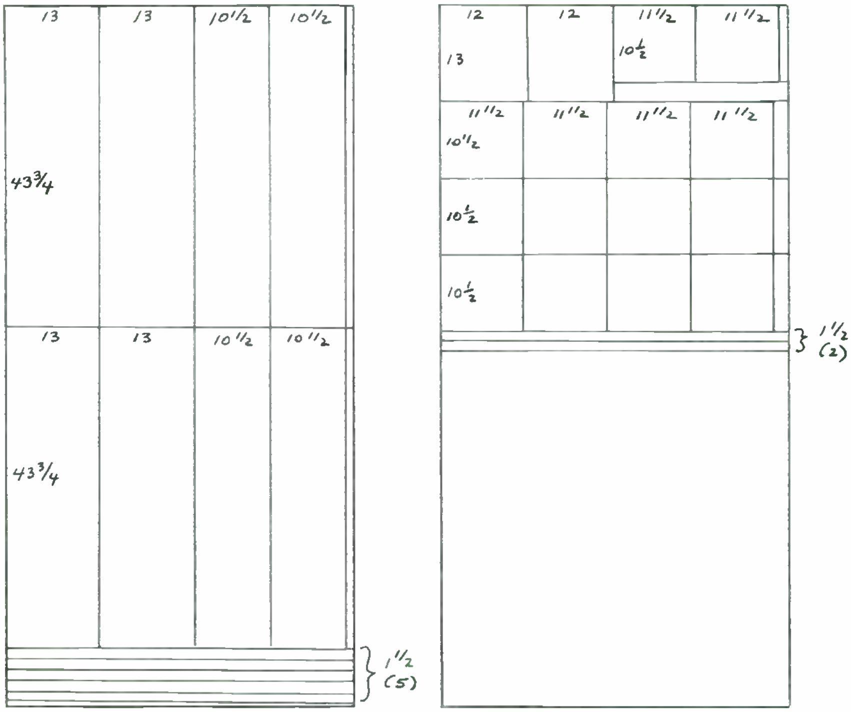


**FIGURE 2:** Cutting guide for MDF sheets.

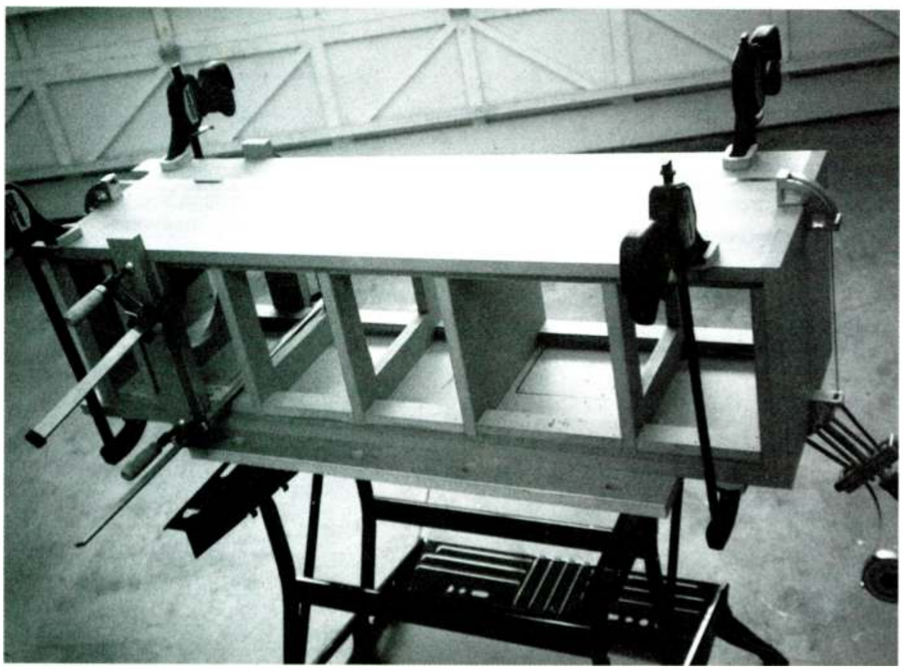

**PHOTO 9:** Clamped side panels.

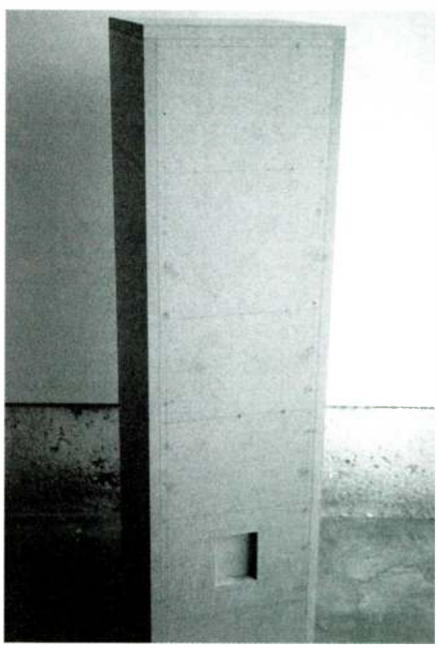

**PHOTO 10:** Rear panel installed on side panels.

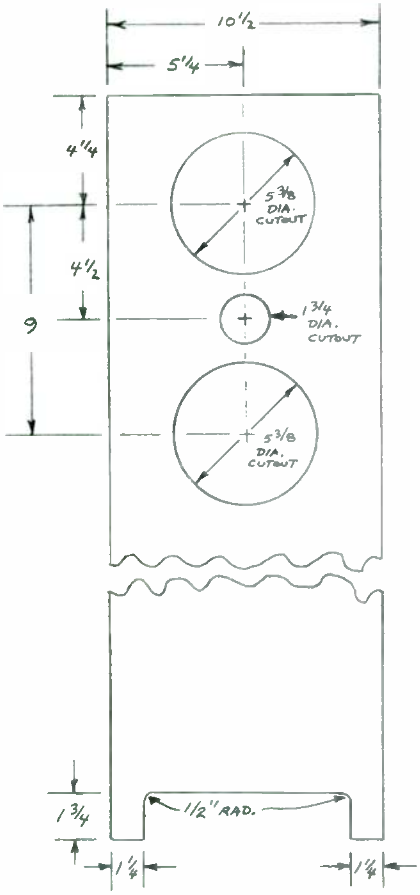


**FIGURE 3:** Front panel.

which I used for the value of the capacitive reactance to calculate that a capacitance of 390µF would be required.

The primary purpose of this capacitor is to keep the very low frequencies out of the midrange drivers and avoid any distortion that would otherwise occur. The secondary purpose is to form a third-order rolloff by combining the natural second-order rolloff of the sealed midrange cavity with the first-order rolloff created by the capacitor.

Thus, the midrange response should be 3dB down at 100Hz, rolloff at 6dB/octave to approximately 50Hz, then rolloff at 18dB/octave below 50Hz. My initial tests of the midrange response, however, showed an $f_3$ of about 60Hz, so I decreased the input capacitor's value experimentally until $f_3$ was close to 100Hz.

For all three crossovers, I calculated sensitivity losses caused by coil resistances of any series inductors. I also calculated the natural frequency-dependent insertion losses of the crossovers with drivers connected at the corner frequencies, at one-half and one-quarter the corner frequencies for the

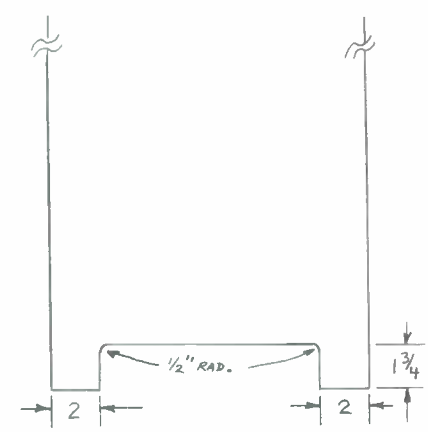


**FIGURE 4:** Side-panel bottom.

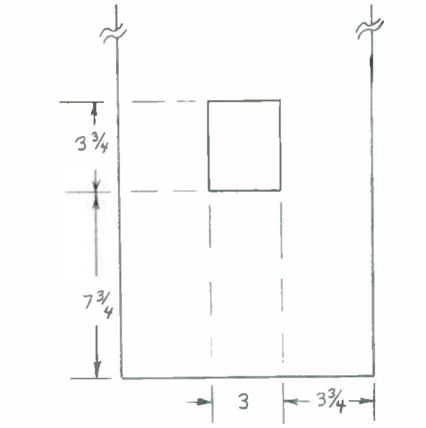


**FIGURE 5:** Rear-panel bottom.

**PHOTO 11:** Foam and wiring installed in cabinet.

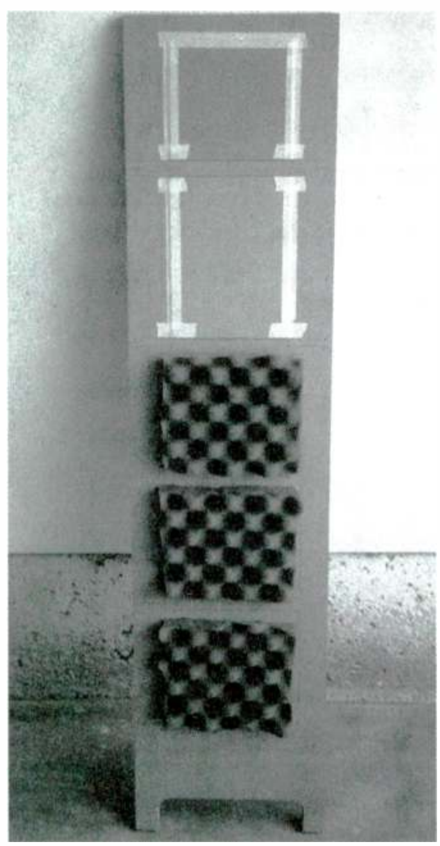

**PHOTO 12:** Foam installed inside front panel.

**PHOTO 13:** Cabinet with front panel installed.





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low-pass sections, and at twice and four times the corner frequencies for the tweeter high-pass section. This should have resulted in fairly accurate calculations of relative sensitivities of the three driver sections when combined with their crossovers.

From these calculations, I determined that the midranges' overall sensitivity should be only a few tenths of a dB higher than that of the woofers', not requiring any attenuation of the midrange section to match it to the woofer section. The tweeter section, however, theoretically needed 1.2dB of attenuation. Final testing showed I was wrong on both counts. The midrange actually needed 5dB of attenuation and the tweeter needed no attenuation. All three crossover sections have Zobel networks in parallel with the driver coils to counter the rising impedance of the drivers with rising frequency.

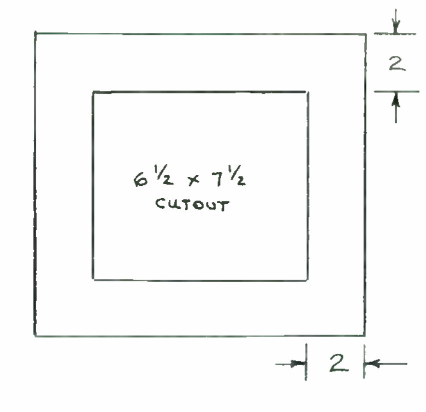


**FIGURE 6:** Shelf brace.

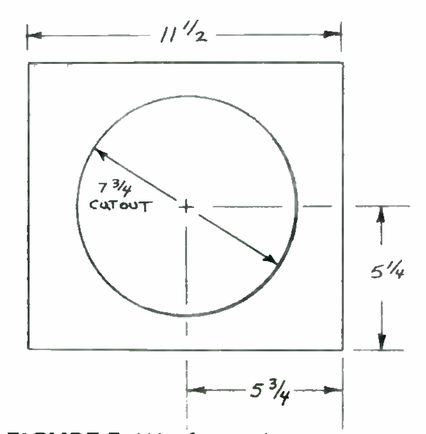


**FIGURE 7:** Woofer panels.

## CROSSOVER COMPONENT VALUES

All the component values used in the crossovers are standard "off the shelf" values that are closest to the values calculated from published equations. After first calculating inductor and capacitance values from the equations, I chose the closest standard values for the inductors, then recalculated the capacitance values while maintaining the initial "L × C" product and, therefore, the desired crossover frequency.

This affects the crossover response only slightly, and because inductors and capacitors are available in a wide range of values, this results in actual crossover frequencies within a few percent of those desired, not including the effects of component accuracies. Capacitor voltage ratings should be at least 100V, with accuracies of 5% for metallized polypropylene and 10% for nonpolarized electrolytics.

The inductors I used had advertised accuracies of 1%, and I took their DC resistances into account when I calculated over-all sensitivities. If you use inductors with significantly different resistances, sensitivity mismatches between driver sections will likely result, and the system $Q_{tc}$ will probably be different.

For some of the capacitor values, I paralleled multiple units to get combined labeled values as close as possible to those I calculated. Except for two of the Zobel networks, all nonpolarized electrolytics are paralleled with a polypropylene capacitor. I made no attempt to measure and select crossover components to achieve exact values.

Similarly, I used the manufacturer's specified values for driver parameters, even though it is usually recommended to measure at least some of them because they do vary from those specified. I suspect that most hobbyists cannot make such measurements, but those of you who have both the equipment and expertise may want to make the measurements and selections.

## MATERIAL AND SUPPLIERS

Other than common hardware and materials such as nails, screws, glue, paint, wood, and so on, I purchased all the components from Madisound or Parts Express. In the parts list (*Table 1*), I've identifed one of these suppliers (with catalog numbers where available) for those parts I believe are either important to be duplicated for purposes of performance or fit, or which you may not be able to find elsewhere.

The drivers are available from several suppliers, so base your purchases on the best price. I would advise against using cheap inductors or capacitors, since the small amount you may save, compared to the total cost and your labor, won't be worth the potential loss in performance. On the other hand, you can spend really big bucks on exotic wire and crossover components, but it's arguable whether they would make much difference in performance.

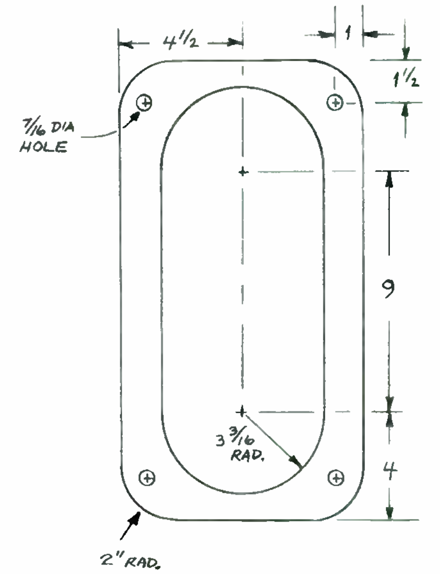


**FIGURE 8:** Grille board.

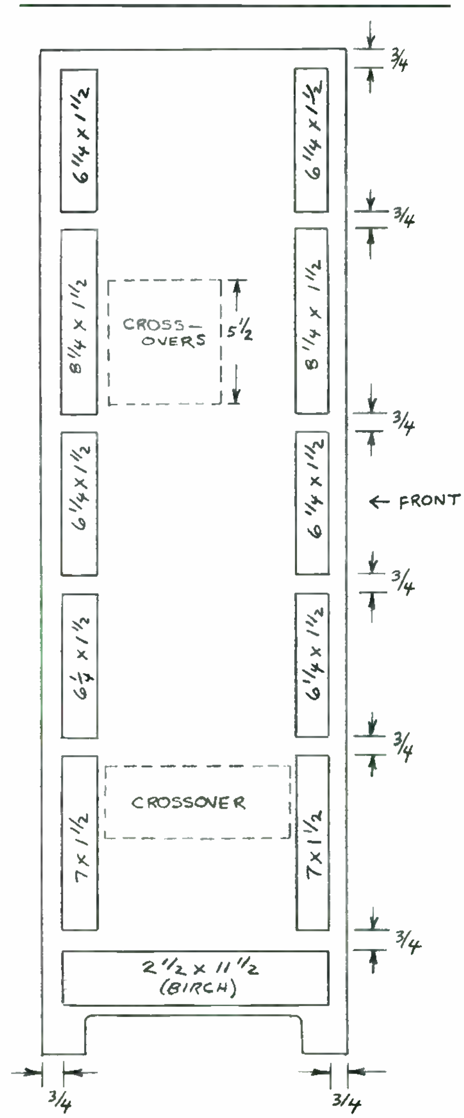


**FIGURE 9:** Side-panel assembly.

## CUTTING AND DRILLING

Start your construction by cutting all the pieces from the MDF and particleboard on a bench saw, making sure your cuts are square and accurate. It will require about 1½ sheets of the ¾-inch MDF to build two cabinets. *Figure 2* is a cutting guide for the MDF.

I laid out the cuts on two sheets so that you can cut all pieces of the same dimensions in sequence before changing to the next dimension, jockeying back and forth between the two sheets as necessary. This ensures that even if your cutting dimensions are *slightly* off, the various parts will fit together properly, but don't construe this to mean you can get by with sloppy measuring or cutting.

Then, with a jig saw, cut out all the circular holes, rectangular holes, and woofer exit slots in the side and front panels (see *Figs. 3–8* for details on these holes and slots). It would be best, at this time, to check the fit of all the drivers in their cutouts and make any necessary adjustments with sandpaper or a file.

To aid assembly, mark nail locations on side, front, and rear panels. These will be on the center lines of the internal horizontal shelves and braces, as well as the center lines of the vertical runners for attaching the front and rear panels.



Use nails approximately every two to three inches (closer spacing is okay, but don't get carried away—that's what the glue is for). I used 2″, 6d finishing nails to attach sides, front, and back together. Holes for all these nails should be predrilled in these four panels, slightly smaller than the nail diameter.

At this time, you should drill holes through the grille boards and into the front panel for the grille fasteners. The fasteners I used are a plastic "mushroom" type that come in pairs—a male part (mushroom) and a female part (socket)—but I used only the male part. On the front panel, draw the outline of the grille boards centered around the midrange drivers, and set in the drivers. Place the grille boards around the drivers, ensuring that they clear the drivers and are square on the panel; then clamp the grille boards into place.

Mark the locations of the driver-mounting holes, then remove the drivers. With a 7/16″-diameter bit, drill four holes through the corners of the grille boards to a depth of ½″ into the front panel (*Fig. 8*). If you do this accurately, either grille board should fit either cabinet.

## PREASSEMBLY

Begin assembly by attaching all the 1½″-wide MDF runners to the side panels. You must space these runners exactly ¾″ from the front and back edges, from the top, and between them. To do this, use narrow strips of the ¾″ MDF, approximately 6″ and 13″ long, as guides, clamped onto the side panel at the top, front and rear edges, and between the ends of the runners. You may be tempted to draw guide lines on the inner surfaces of the side panels, lay the runners along the lines, and then attach them. That would probably be quicker, but it isn't as accurate.

Attach the runners with glue, and hold them in place for drying with 1¼″, 3d finishing nails. When nailing the runners, use a pair of nails on opposite sides about every 2″ or 3″, and make sure you nail the runners squarely against the clamped-on guides. Starting at the top of the side panel, attach the top two runners, remove the clamped guides, clamp the guides for the next pair of runners to be nailed, and so on, working your way down the side panel to the bottom (*Photos 4* and *5* show how to place the clamped guides).

As you move along, wipe off any excess glue from the runners where they will later join with other pieces (also, wipe off any glue that may get on the clamping guides). At the bottoms of the side panels, attach the 2½″ × 11½″ pieces of birch with countersunk 1¼″ particleboard screws instead of nails. Use two screws at each end of the birch strip and one in the center, plus glue (*Fig. 9* and *Photo 6* show the side-panel assembly).

**TABLE 1**

**PARTS LIST** (quantities shown are for two systems; dimensions are in inches)

| Qty. | Dimensions | Description |
|---|---|---|
| **¾″ MDF:** | | |
| 2 | 12 × 13 | Top (outside) |
| 14 | 10½ × 11½ | Top (inside), shelves/braces, woofer panels |
| 4 | 13 × 43¾ | Side panel |
| 4 | 10½ × 43¾ | Front and rear panels |
| 24 | 1½ × 6¼ | Brace |
| 8 | 1½ × 7 | Brace |
| 8 | 1½ × 8¼ | Brace |
| **3/8″ particleboard:** | | |
| 2 | 3½ × 8 | Woofer crossover base |
| 4 | 5 × 5½ | Midrange/tweeter-crossover base |
| 2 | 9 × 17 | Grille board |
| **1″ × 3″ birch:** | | |
| 4 | 2½ × 11½ | Woofer chamber brace |
| 4 | 2½ × 9 | Woofer chamber brace |
| **Miscellaneous:** | | |
| 50′ | 1/8 × ½ | Foam adhesive tape (Madisound) |
| 1′ | 1/8 × 32 | Adhesive-backed felt (Madisound) |
| 2 sheets | 24 × 36 | Convoluted foam (Parts Express 260-316) |
| 2 | | Terminal cup (Parts Express 260-304) |
| 4 lb. | | Acousta Stuf® |
| 1 pkg. | | Grille fasteners (Parts Express 260-367) |
| 1 yd. | | Grille cloth |
| As needed | | Nails, screws, glue, paint, wire, crimp-on connectors, bolts, nuts, sealant |
| **Drivers:** | | |
| 4 | Morel MW-266, 8Ω | Woofer |
| 4 | Morel MW-166, 8Ω | Midrange |
| 2 | Morel MDT-40, 8Ω | Tweeter |
| **Crossover Components** | | |
| 2 | L1—10.0mH, 0.43Ω, ferrite bobbin (Madisound Sledgehammer) | |
| 2 | L2—3.3mH, 0.21Ω, ferrite bobbin (Madisound Sledgehammer) | |
| 4 | L3, L5—0.30mH, 0.16Ω, air core (Madisound Sidewinder) | |
| 2 | L4—0.10mH, 0.10Ω, air core (Madisound Sidewinder) | |
| 4 | C1A, C1B—250µF/100V, bipolar electrolytic | |
| 2 | C1C—6.8µF/100V, metalized polypropylene | |
| 4 | C2, C5—22µF/100V, bipolar electrolytic | |
| 2 | C3A—140µF/100V, bipolar electrolytic | |
| 2 | C3B—1.0µF/100V, metalized polypropylene | |
| 2 | C4A—16µF/100V, metalized polypropylene | |
| 2 | C4B—2.7µF/100V, metalized polypropylene | |
| 2 | C6—4.7µF/100V, metalized polypropylene | |
| 2 | C7A—12µF/100V, metalized polypropylene | |
| 2 | C7B—2.2µF/100V, metalized polypropylene | |
| 2 | C8—1.0µF, mylar | |
| 4 | R1, R2—4.0Ω, 15W, wirewound | |
| 2 | R3—2.0Ω, 15W, wirewound | |
| 2 | R4—8.2Ω, 15W, wirewound | |
| 2 | R5—6.5Ω, 15W, wirewound | |
| 6 | Barrier strip | |

# Swans M1 kit

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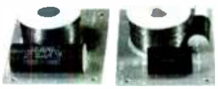

Filter

The Swans M1 minimonitors open a new line of affordable high-end loudspeakers featuring several technological achievements and sound quality distinctions.

The speaker system is a two-way bass-reflex design. The front baffle is very narrow with rounded edges to reduce cabinet diffraction for better clarity and imaging. The internal panel and corner reinforcement substantially reduce unwanted cabinet vibrations. A flared port is mounted on the rear baffle for smooth transition from the port to cabinet boundaries. This provides linear bass performance and absence of port noise. The heavy-duty gold plated binding posts are mounted directly on the rear panel to enable easy cable connection.

The drivers used in the M1 represent a new high performance design from Hi-Vi Research. The 5-inch paper/Kevlar cone woofer has a rubber surround, cast aluminum frame and a magnetically shielded motor system. This driver utilizes a central phase plug to avoid air compression, improving frequency response and dispersion. The extremely rigid cone is hand coated with a special dampening compound to further maximize its performance. The cone is then coupled to a selected grade rubber surround that provides break-up free operation and very low distortion even at high power levels. These key features greatly contribute to the M1's clear transparent sound and effortless dynamic performance.

The tweeter is a high-tech planar isodynamic design that employs Neodymium magnets and extremely light Kapton® film, with flat aluminum conductors.

The vibrating element of the tweeter is almost weightless in comparison to a conventional dome driver. This unit provides an immediate and precise response to any transients in original signal, and gives the M1 an exceptional ability to reveal the true dynamics of instruments with a complex high frequency spectrum.

The crossover is a second order Linkwitz-Riley type resulting in an in-phase connection of the drive units. The crossover frequency between the two drivers is 3.3 kHz and only high quality polypropylene capacitors are used. Each filter has it's own dedicated board mounted on a special rubber interface to reduce vibrations and microphonic phenomenon. The filter boards are spaced inside the loudspeaker with the inductors positioned at right angles to minimize the interaction.

M1 provide very even acoustic power dispersion. The important horizontal early reflections that create spatial impression and add to the overall presentation have the same even spectral balance as the direct sound, these are crucial features of a good loudspeaker.

On the contrary, the M1's vertical dispersion is well controlled in the high frequency domain in a 15° arc symmetrically to the reference axis. While 15 create adequate room for adjusting a listening position, the floor and ceiling reflections are well down in amplitude. This feature greatly contributes to the clarity of sound and imaging of the M1.

Swans M1 kit includes:
- 2x F5 paper/Kevlar bass-midrange drivers,
- 2x RT1C isodynamic tweeters with sealing gaskets,
- 2x dedicated tweeter crossovers,
- 2x dedicated bass-midrange crossovers,
- two flared ports and two swans logos,
- two pairs of heavy duty gold plated terminals.

The drawings of the cabinet shown here represent general dimensions required for optimum bass performance. Rounded corners are advisory as they improve imaging and clarity. Actual finish and appearance is a matter of personal taste.

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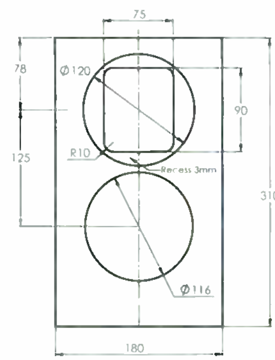
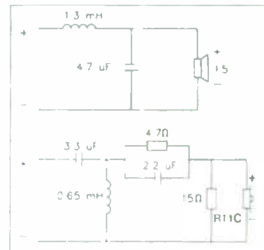
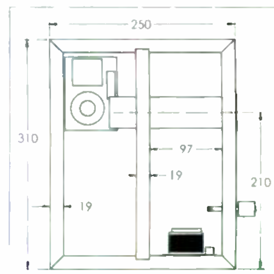
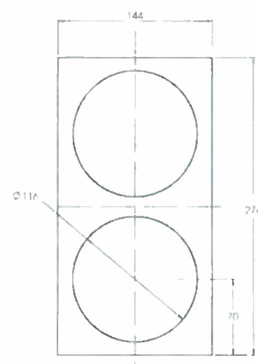



Front view

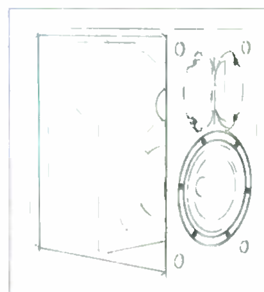



Right view of the cabinet with accessories(right side panel removed)




Internal panel



## SPECIFICATIONS

| | |
|---|---|
| Frequency response (1m,half space) | 53Hz-40kHz,±2dB |
| Sensitivity,1W/1m (100Hz-8kHz averaged) | 85 dB |
| Nominal impedance (7.2 ohms minimum at 250 Hz) | 8 ohms |
| Harmonic distortion At 90dB SPL, 100Hz-10kHz, 1m | THD less than 1% |
| Power handling | 50W nominal, 90W music |
| Dimensions,HxWxD | 310x180x250 mm |
| Net weight | 7.8 kg(17 lb.) each |
| Amplifier requirements: 30W recommended minimum. | |

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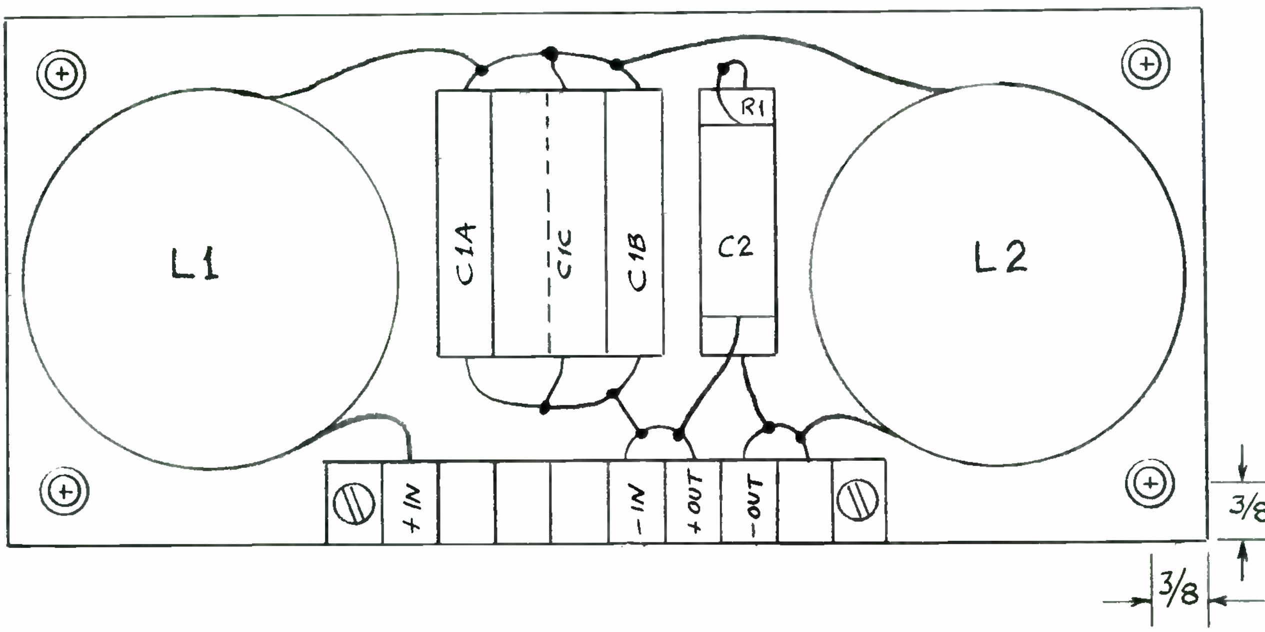


**FIGURE 10:** Woofer crossover-component layout.

Next, assemble the top of the cabinet by gluing and nailing together a 10½″ × 11½″ piece of MDF to the 12″ × 13″ piece. Use the clamping guides on all four edges of the larger piece to ensure the smaller one is located squarely in the exact center of the larger. *Photo 7* shows how to place the clamped guides. You'll need to use more nails than the five shown to firmly seat the two pieces together while the glue dries. You can use particleboard screws instead of nails, or, if you have the tools, these two pieces can simply be clamped together while the glue sets.

## DRILLING BOLT HOLES

Before actually assembling the cabinet with the side panels, locate and drill holes in the midrange cavity's bottom shelf and the inner woofer-mounting panel for the pairs of 10-32 pass-through bolts. You should space the holes for each pair an inch or more apart to allow clearance for the wires and lugs to be attached to them. Also, go ahead and drill bolt holes for mounting all of the drivers—four per driver for midranges and tweeter, and eight per woofer.

I highly recommend using T-nuts and bolts rather than wood screws to mount the drivers: 8-32 for woofers and midrange; 6-32 for the tweeter. Make sure to use a drill-bit diameter appropriate for the body of the T-nuts. Since the cabinet must be airtight, seal the inside seams of the 1½″ strips on the side panels with silicone sealant.

Finally, on the insides of the side panels, mark the locations of the crossovers' mounting holes and drill pilot holes for the ¾″ or 1″ particleboard screws you'll use to mount the crossover assemblies. The woofer crossover is mounted centrally on one side panel near the top of the cavity where you mount the inner woofer.

The midrange and tweeter crossovers are mounted on opposite side panels in the bottom portion of the midrange cavity, about 2¾″ from the back edge of the side panel. If you've already cut out the crossover boards from the 3/8″ particleboard, you should mark their outlines on the side panels to help guide you later when attaching the convoluted foam (see *Fig. 9* for crossover locations).

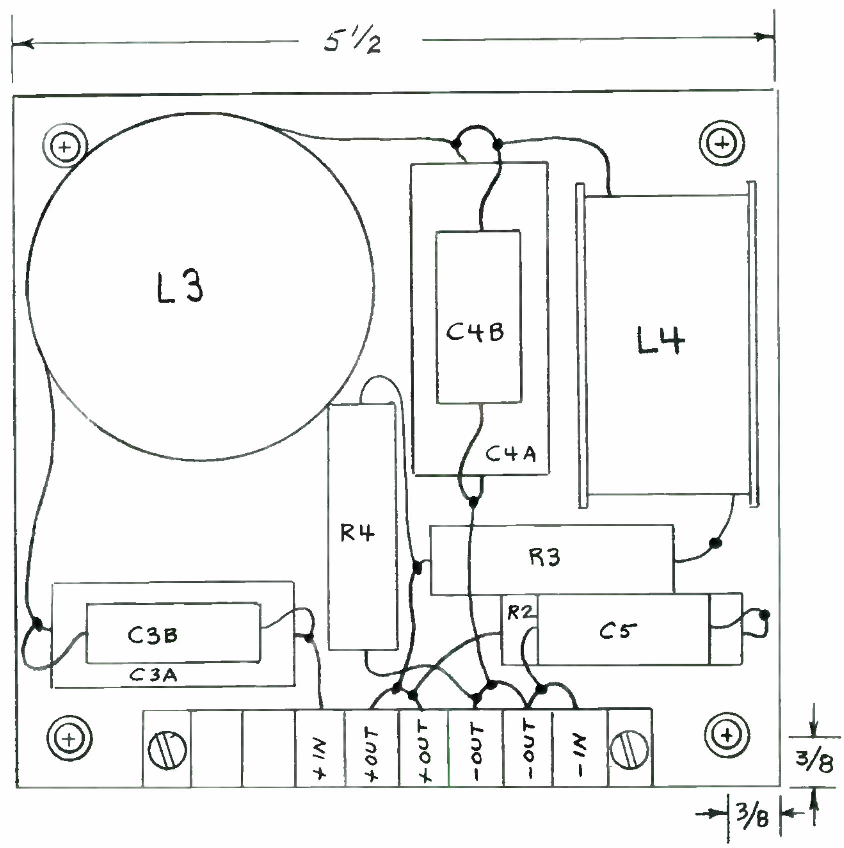


**FIGURE 11:** Midrange crossover-component layout.

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19 years after the publication of the first edition, the latest version of the loudspeaker "bible" is more popular than ever. The new fifth edition adds special chapters on the current trends toward home theater and more advanced, serious car audio accompanied by updated chapters from previous editions. 1995, 165pp., 8-1/2" × 11", softbound, ISBN 1-8825-8010-9. Shipping wt: 2 lbs.

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### Electrostatic Loudspeaker Design and Construction
by Ronald Wagner

This classic, once produced by TAB Books, is now published by Audio Amateur Press. Both a "how-to" book and an informative text on electrostatic speakers, this publication provides a step-by-step sequence for building full-range electrostatic speakers, and acquaints the reader with their basic operating principles. Appendix with construction information, index and bibliography included. 1987, 1993, 243pp., 7" × 9-5/8", softbound, ISBN 0-9624-1916-8. Shipping wt: 1 lb.

**BKAA39 $19.95**

### Bullock on Boxes
by Robert M. Bullock III, with Robert White

Since 1980, readers of *Speaker Builder* magazine have delighted in the scope and clarity of Mr. Bullock's explanations of vented-box loudspeaker systems. Now these articles have been collected into a single volume—*Bullock on Boxes*. This book is an easy-to-read guide to designing and building vented-box systems based on Thiele/Small models. In addition to the background theory and descriptions of the models, *Bullock on Boxes* covers a variety of related information drawn from numerous resources. Also included with the book is a reprint of the *Speaker Builder* 1/82 article by Dr. Bullock on the subject of sixth-order alignments. Index, glossary, bibliography, and over 100 illustrations. 1991, 72pp., 8-1/2" × 11", softbound, ISBN 0-9624-1915-X. Shipping wt: 1 lb.

**BKAA8 $10.95**

### Loudspeaker Recipes: Book One
by Vance Dickason

Taking advantage of the latest techniques for computer-aided design, Dickason lays a firm groundwork, both theoretical and practical, for successfully building a variety of two-way loudspeaker systems. Design is demonstrated by four two-way systems. Valuable insight even if you don't use CAD. 1994, 112pp., 8-1/2" × 11", softbound, ISBN-8825-8004-4. Shipping wt: 1 lb.

**BKAA30 $24.95**

### Ultimate Auto Sound: Your Guide to Heaven on Wheels
by Daniel Ferguson

Improved, upgraded version of *Killer Car Stereo* contains double the material, including updated information on system architecture, cabinet construction, crossovers, and installation, plus a new chapter on vans. 1995, 100pp., 8-1/2" × 11", softbound, ISBN 1-8825-8009-5. Shipping wt: 1 lb.

**BKAA37 $29.95**

**Old Colony Sound Laboratory, PO Box 876, Peterborough, NH 03458-0876**
Phone: 603-924-6371 • Fax: 603-924-9467 • E-mail: custserv@audioxpress.com

**TABLE 2**

**WIRING & ENDS TERMINATIONS LIST**

(each connection is one or more pairs of twisted leads; Ends Terminations refer to "From"/"To")

| From | To | Gauge | Ends Terminations |
|---|---|---|---|
| Upper input posts | Upper pass-thru bolts | 14 | Soldered/ring lugs |
| Upper pass-thru bolts | Midrange crossover input | 16 | Ring lugs/slip-ons |
| Upper pass-thru bolts | Tweeter crossover input | 16 | Ring lugs/slip-ons |
| Midrange crossover out | Midrange drivers | 16 (2 pr) | Slip-ons/slip-ons |
| Tweeter crossover out | Tweeter | 16 | Slip-ons/slip-ons |
| Lower input posts | Woofer crossover input | 14 | Soldered/slip-ons |
| Woofer crossover out | Lower pass-thru bolts | 14 | Slip-ons/ring lugs |
| Lower pass-thru bolts | Woofers | 16 (2 pr) | Ring lugs/slip-ons |

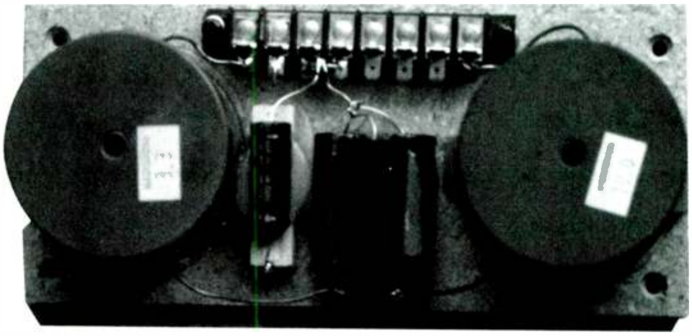


**PHOTO 14:** Woofer crossover assembly.

## ASSEMBLING THE CABINET

After allowing the glue to dry on the side-panel assemblies for 24 hours, you're ready to assemble the cabinet. Lay one side panel with its outer side down on a sturdy work bench. Liberally apply glue all across the "slots" for the five horizontal pieces—midrange-cavity brace and bottom shelf, two woofer-cavity braces, and inner woofer-mounting panel. Set those five pieces in their slots and center them, front to back on the side panel.

Apply glue to the top inside edge of the side panel and set in the double-thick top, having a helper hold that in place (*Photo 8* shows these six pieces sitting in a side panel). Now, apply glue to the upper edges of these six pieces and set the other side panel on them in the opposite slots. Use clamps to squeeze everything together.

I used bar clamps, a picture-frame strapping clamp, and quick-release clamps combined with wood brackets and blocks to make the cabinet go together squarely (see *Photo 9*). Before tightening the clamps, make sure everything is square and that top, shelves, and braces are exactly centered front to back.

From the upper side panel, hammer in about half the nails, some into each of the horizontal members. Then turn the assembly over and hammer in all the nails necessary for that side. Now turn it over once again and finish nailing the first side. Make sure everything is square before you start nailing.

Leave the assembly clamped for an hour or two, and allow the glue to dry for 24 hours. Proper preassembly of the 1½" runners on the side panels will result in a fit that's reasonably tight, yet that still has enough "give" to allow squaring everything together with the clamps.

## REAR AND FRONT PANELS

Attach the rear panel to the cabinet by applying glue liberally along the vertical runners and across the horizontal pieces and nailing (*Photo 10* shows the rear panel after attachment to the side panels). Allow the glue to dry for 24 hours.

Apply silicone sealant to the inside rear panel where it joins with the rest of the cabinet, to the top piece where it joins the cabinet sides, on the inside seams of the inner woofer-mounting panel, and on all the seams inside the midrange cavity. To the rear panel, using five screws and glue at the bottom, attach a 2½" × 9" birch strip against the bottom of the inner woofer panel and aligned with the birch pieces on the side panels.

Before attaching the front panel, you'll need to cut the convoluted foam into appropriately sized rectangles and glue them onto the inside of the cabinet. This works best if you apply spray-on adhesive to the backs of the foam pieces, then stick them on. Do the rear panel first, then underneath both the top and the midrange shelf, finishing up with the sides.

The crossover outlines you previously made will guide you when gluing foam in those areas. Also, cut out and glue on foam pieces inside the front panel, but only in the three woofer cavities, not in the midrange cavity. You don't have to cover every last inch of the inside of the cabinet with foam, so you can get by with two of the 24" × 36" sheets.

Although you can do it later, it would be easier now to install the pair of pass-through bolts and the three pairs of wire leads that attach to them in the midrange cavity. *Table 2* lists the required wiring. Attach the 14-gauge pair underneath the midrange cavity shelf, and two pairs of 16-gauge on the top of this shelf.

To avoid confusion later, it would be

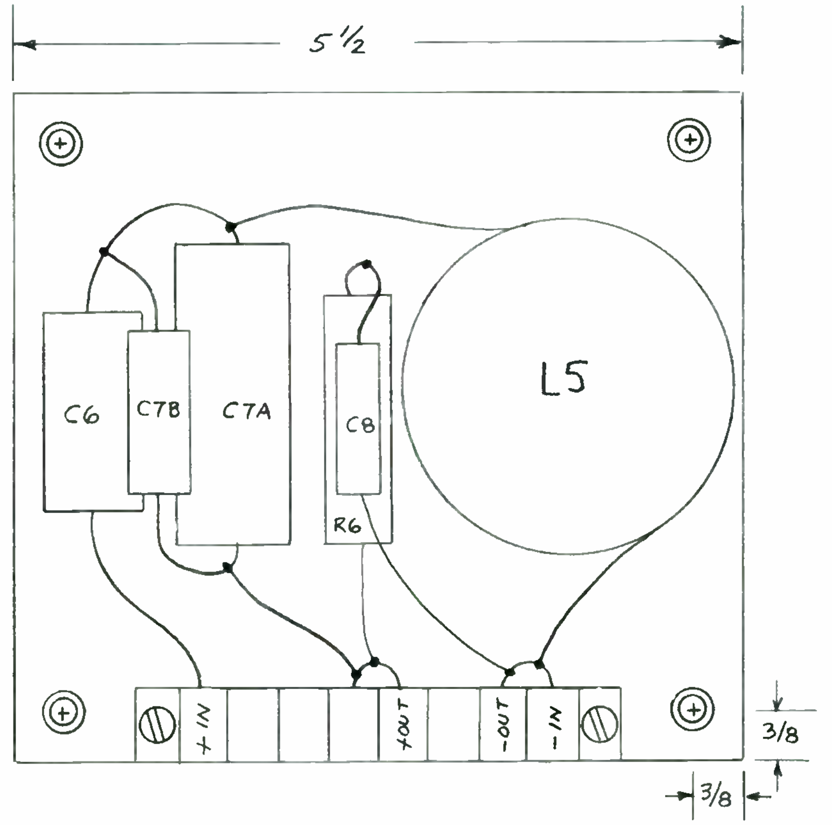



**FIGURE 12:** Tweeter crossover-component layout.

best to color-code the wiring, using black wires for all of the negative connections and a different color for the positive connections for the three driver sections. *Photo 11* shows foam and wiring installed in the cabinet, and *Photo 12* the foam attached to the back of the front panel.

## DUST BARRIERS

Before attaching the front panel, tape cardboard on the inside of the driver cutouts to keep sanding dust and other debris out of the cabinet when you are sanding the outside for final finishing. Do the same on the outside of the inner woofer-mounting panel, over its driver cutout, and inside the terminal-cup cutout.

Now attach the front panel with glue and nails as you did the back panel, and allow it to dry for 24 hours (*Photo 13* shows the front panel attached to the cabinet). Later, you can apply silicone sealant around the inside seams of the front panel in the midrange cavity by reaching through the midrange driver cutouts. You won't, however, find it easy to apply silicone sealant in the woofer cavities, so use lots of glue when you attach the front panel.

Attach the remaining strip of 2½″ × 9″ birch to the inside of the front panel at the bottom, just as you did with the rear panel. After the glue has dried, you'll need to apply silicone sealant to the inside seams of the Isobarik chamber. As you nail the cabinet's outside pieces together, you should countersink all nails before the glue has set.

If you notice warping of some of the long MDF pieces that you cut from the sheets, you may be able to use this bowing to your advantage. For example, when I laid out the side-panel assemblies and front and rear panels, I oriented the outsides of all four panels so they bowed up and away at the ends. As a result, when I clamped or nailed the ends of these panels, their middle sections pulled tightly together.

## SANDING AND FINISHING

With the cabinet assembled and the glue thoroughly dried, fill all the nail-head holes and any seams with wood filler. After this has dried, sand the excess filler off smoothly to the MDF surface. With a ½″-radius router bit, round off the four vertical edges of the cabinet and the four edges of the top. As a small artistic touch, I stopped routing the four vertical edges about 3″ from the bottom.

Sand the entire exterior surface of the cabinet, especially the rounded edges. Vacuum off the sanding dust and wipe down with a tack cloth. Apply a coat of primer/sealer with a brush. Use a primer that is specially formulated for adhering to slick or shiny surfaces. Allow it to dry, and apply a second coat.

With the primer coats applied, it will be easy for you to notice any seams or holes that need additional wood filler. You'll also want to prime the bottom edges of the cabinet and the inside of the outer panels that will show through the bottom slots. Sand the cabinet with fine sandpaper after the second primer coat, and make sure you completely remove any sanding dust.

As I did on my previous speakers, I finished these cabinets by applying three coats of semigloss, white, 100% acrylic paint with a stippling roller to achieve a textured finish. You should allow 24 hours drying time between finish coats—longer if the humidity is high.

Since I did not recess the midranges and tweeters in the front panel, for diffraction control I rounded the inside edges of the cutouts in the grille boards with a ¼″-radius router bit. For appearances and to make the grille cloth easier to wrap around the edges without wrinkles, I also rounded the outside edges (see *Fig. 8* for routing details).

The grille boards need to be sanded, primed, and painted black. Before attaching the grille cloth, install the four fasteners in the back of each grille board by hammering them in. Since the bases of these fasteners are longer than the thickness of the grille board, you must cut off about 1/16″ of each base.

I installed these fasteners in the backs of the grille boards instead of in the front panel so that if the systems performed better with the grilles off, there would be four fewer protrusions on the front panel to cause reflections. I wrapped and stretched the grille cloths around the grille boards, affixing them in place with contact cement on the backs of the boards.

### ASSEMBLING THE CROSSOVERS

I assembled the crossovers by attaching all the components to their particleboard bases with silicone sealant (*Photo 14* shows the completed woofer crossover as an example, and *Figs. 10–13* show all three crossover component layouts and schematics). Be sure to use enough of the sealant to securely hold the heavy inductors. I used eight-place barrier strips with two end terminals already commoned that accept slip-on solderless connectors for I/O connections. You may prefer other techniques, such as screw-type barrier strips or direct soldering. To minimize mutual coupling, the inductors on the woofer crossover are spaced about 6″ apart, and the inductors on the midrange crossover are oriented at 90° to one another.

### FINAL ASSEMBLY AND DRIVER MOUNTING

Using spray-on adhesive to attach it, I lined the inside walls of the Isobarik chamber with 3/8″-thick foam (you could also use ¼″-thick felt or ½″ foam). Drill 16 countersunk clearance holes, four per side, in the outer woofer panel to mount it to the birch frame of the Isobarik chamber. Use this drilled panel to locate and drill pilot holes in the birch frame for 1½″ #8 wood screws.

Remove the cardboard from the cutouts in the cabinet panels and install the crossovers. Be sure to vacuum out any dust that may have entered the cabinet around the seams of the cutouts' covers, and don't forget to apply silicone sealant inside the midrange cavity on the front-panel seams.

On the inner woofer panel, install the pass-through bolts for the woofer section and the three pairs of leads that are attached to them. Note that one pair of woofer leads on these bolts is attached to the inside of the inner woofer panel, and the other pair to the outside of this panel.

Connect the woofer-crossover output to the pass-through bolts, and connect one end of the input post's leads to the woofer-crossover input. In the midrange cavity, connect one pair of the leads from the pass-through bolts to the midrange-crossover input, and the other pair to the tweeter-crossover input.

Then, for eventual connection to midranges and tweeter, connect two pairs of leads to the midrange-crossover outputs and one pair to the tweeter-crossover output. The midranges and tweeters are wired in phase with each other and out of phase with the woofers (see *Table 2* for wiring details).

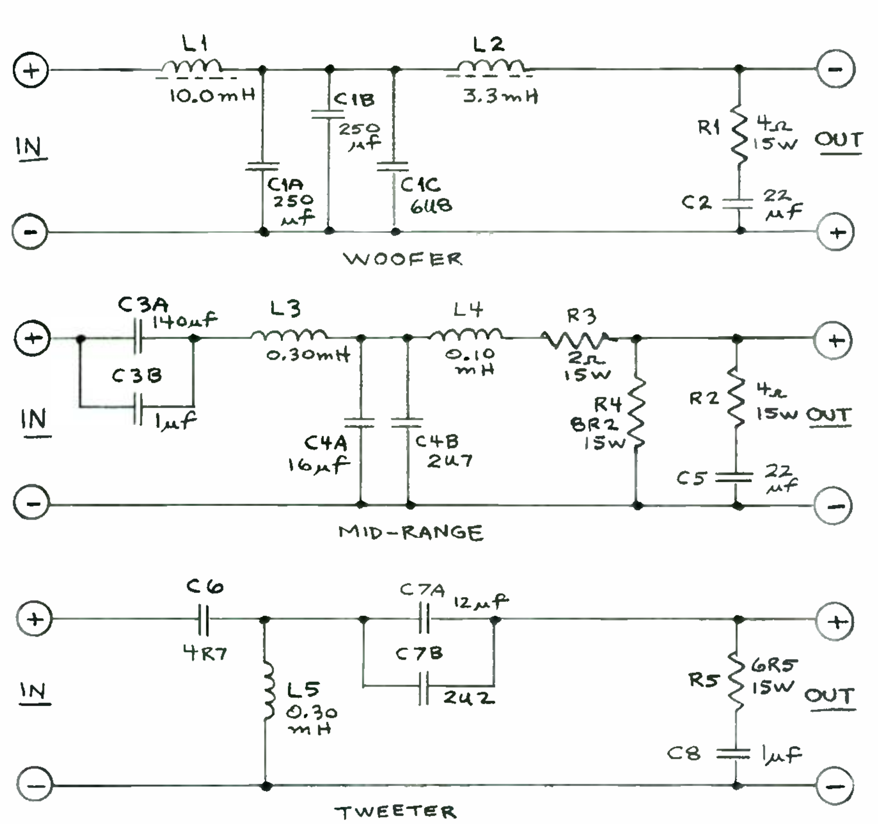



**FIGURE 13:** Crossover schematics.

### T-NUTS AND STUFFING

If you've not already done so, install all the T-nuts for mounting the drivers. I put a bit of silicone sealant inside the pointed flanges of the T-nuts for better sealing, but was careful *not* to get any in the T-nuts' internal threads. Because the midrange-cavity brace is in the way, I had to cut off about 1/3 of the flanges from the top two tweeter T-nuts.

Before mounting the drivers, lay down a strip of foam adhesive tape (1/8″ thick, ½″ wide) completely around the perimeter of each driver cutout. You will also need foam tape on the bottom edge of the birch frame to complete the sealing of the Isobarik chamber when the outer woofer panel is mounted, and around the cutout for the input terminal cup.

Place 16 oz of Acousta Stuf® in the midrange cavity, fluffed-up and more or less equally distributed. Place another 16 oz in the bottom of the cabinet, again equally distributed in the available cavities, but not letting it lie directly against the back of the inner woofer. You can use the internal wiring as a block between the fiber and the inner woofer.

As you install this fiber, fish out the various leads through the cutouts for drivers and the terminal cup. Solder the two pairs of 14-gauge leads to the lugs on the terminal cup, observing correct polarities, with the midrange/tweeter pair connected to the top pair of input posts, and the woofer pair connected to the bottom pair. Attach the terminal cup to the cabinet back with four 6-32 wood screws, making sure to tighten them enough to seal the cup against the foam tape.

As further assurance against leaks, I disassembled the binding posts from the terminal cup before attaching it, and put some silicone sealant on the posts' bases where they pass through the cup holes. Then I reassembled the binding posts.

### DRIVER INSTALLATION

In the woofer section, connect the inner pair of leads to the inner woofer's terminals, then mount the inner woofer. Attach the outer woofer's mounting panel to the birch frame with the 16 wood screws. Now, connect the outer pair of leads to the outer woofer and mount it. Mount both woofers with their cones facing down.

Finish installing the drivers by connecting leads to midranges and tweeter and mounting the drivers with the bolts. You should have a leak-free cabinet, but be careful not to overtighten the driver-mounting bolts.

To allow the grille board to fit properly around the drivers, you may need to trim off excess foam tape that protrudes beyond the mounting flanges of the top half of the upper midrange driver and the bottom half of the lower midrange. For additional diffraction control, I covered the area around the tweeter and between the midrange drivers with two layers of adhesive-backed, 1/8″-thick felt just wide enough to be flush with the inside edges of the cutout in the grille board.

If you don't use the felt, you'll need to paint this area black so it won't be visible through the grille cloth. Similarly, the bolt heads for midranges and tweeter should be black or "painted" with a black felt marker. Snap the grille assembly on, and you're ready to enjoy listening to what you've built!

## FINAL COMMENTS

As I've mentioned several times, there are always compromises that you must make in speaker-system design. And, you'll probably make some mistakes (I certainly did in calculating expected sensitivities). It's impossible to have every characteristic come out perfectly or exactly as you would like.

I made choices and was prepared to live with the results, doing whatever I could to achieve an overall balanced performance with no serious problems. If you undertake a similar project, you must make similar choices.

## SOURCES

**Madisound**
PO Box 44283, Madison, WI 53744-4283
(608) 831-3433

**Morel**
414 Harvard St., Brookline, MA 02146
(617) 277-6663, FAX (617) 277-2415
E-mail morelusa@gis.net

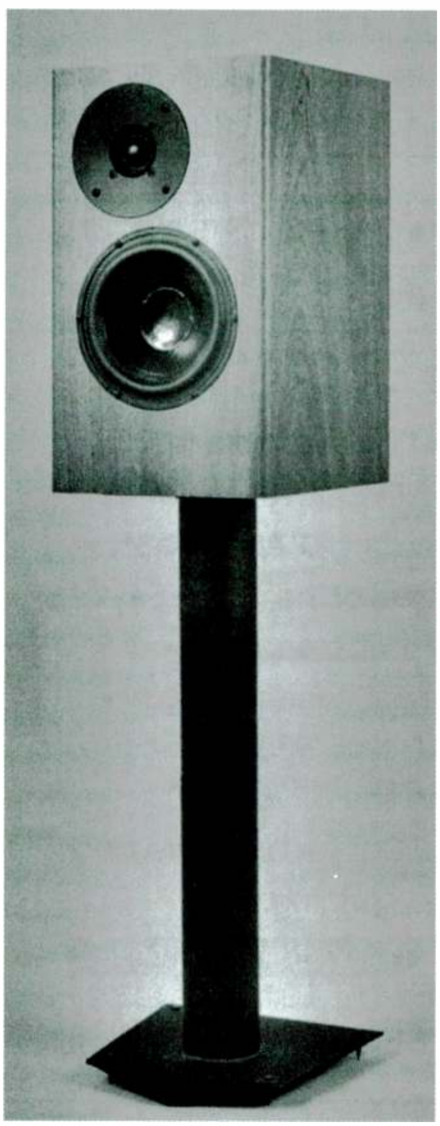
**Parts Express**
725 Pleasant Valley Dr., Springboro, OH 45066-1158
(800) 338-0531

# REFERENCE MONITOR

*(Reprinted from* **HiFi Luidsprekers** *and translated by the editors of* **Elektuur** *magazine, the Netherlands)*

Scan-Speak is a small Danish loudspeaker firm that designs and produces top-class units. Many of its products are made partly by hand and assembled with great accuracy. Inevitably, such work carries a high price.

The Revelator (D2905/9900) is claimed to be the best tweeter in the world, which is, of course, difficult to prove or disprove. It is used in the Reference Monitor in combination with a first-class woofer: a Scan-Speak 18W8546/01.



## THE DRIVERS

The Revelator is the result of a lengthy development during which many technical improvements were incorporated. The magnet system is optimized mechanically as well as electrically. The shape of the chamber behind the dome and that of the conical aperture in the pole piece minimize resonances and reflections. The voice coil has been refined, too: the inductance of the winding has been reduced to only 9μH.

At first glance, the dome looks like an ordinary soft dome, but somehow Scan-Speak has managed to achieve progressive damping that peaks in the suspension. At the same time, its mass has been reduced: the total moving mass, including the air, is only 0.35 grams, which, of course, benefits the dynamic behavior. All these aspects result in a unit that has a resonance frequency of 500Hz, which enables it to take over from a woofer or mid-range driver at an early stage.

The mounting flange is large and heavy and shaped somewhat like a cup. This shape makes it imperative that the tweeter is flush-mounted. If this is not done, its frequency response will have a few dips (that disappear when it is flush-mounted).

There is another tweeter in the Scan-Speak range that is almost identical to the Revelator, but has a different mounting flange. It is type-coded D2905/9700, but is not called Revelator. Its specification is virtually the same as that of the Revelator, but it produces a small phase shift, which

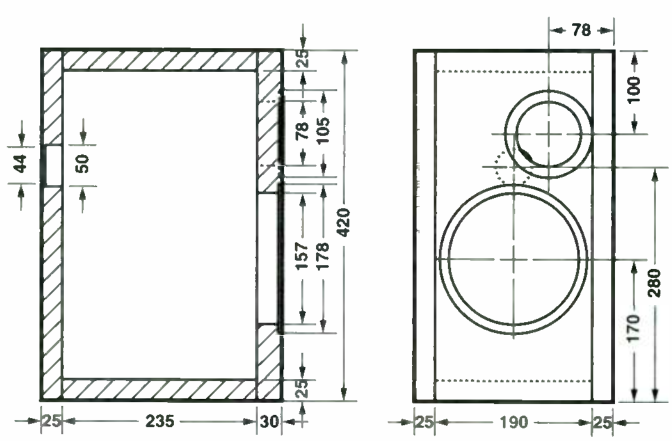



**FIGURE 1:** The construction plan of the Reference Monitor shows that it is easy to build, but mind the thickness of the MDF (or high-density chipboard).

the Revelator does not. The woofer used in combination with the Revelator is a Scan-Speak 18W8546/01, which is an 18cm unit with a black-coated Kevlar® cone.

## CONSTRUCTION

The Reference Monitor is a fairly small loudspeaker (*Fig. 1*) which is, however, very heavy. This is caused partly by the thick MDF and partly by the layer of bituminous felt with which the interior is clad.

Building the cabinet is straightforward, but to obtain good results, great accuracy is needed, which is particularly true of the recessing of the apertures for the drivers.

The bass reflex port is rather unusual. It consists of a 150mm (5.90″) long PVC pipe of 50mm (2″) diameter that is fitted into a recessed hole at the inside of the cabinet. The pipe is filled entirely with straws shortened to 150mm (5.90″). Do not use flexible straws, since these become too thick at the point where you have to shorten them. The straws form a multiple bass reflex port, which can be shorter than a single one and produces fewer interfering spurious sounds.

As mentioned earlier, the internal walls are clad first with bituminous felt and then with Dacron™ wadding.

## CROSSOVER NETWORK

The crossover of the Reference Monitor is a second-order filter whose circuit diagram is shown in *Fig. 2*. It does not contain networks for phase or impedance correction, since these were found unnecessary. All that is required additionally are two resistors to match the level of the tweeter to that of the woofer. Note, however, that the component values are given for use with the D2905/9700. If the Revelator is used, the values of C2 and L2 must be 3.9μF and 820μH, respectively.

Since the drivers used are expensive units, it stands to reason that good-quality components (polyester or polycarbonate capacitors and air-cored inductors) must be used in the crossover. Note in *Fig. 3* that the inductors are placed so that they affect one another as little as possible. (It is often seen that the magnetic field of one inductor overlaps with that of another, and this is, of course, not the intention.) Note also the large connectors to enable heavy-duty loudspeaker cable to be used.

## PHASE AND DISTORTION

The design of the Reference Monitor aims at minimum distortion and phase shift, since these contribute to a good frequency response. The curves showing the (measured) phase shift (Revelator as well as D2905/9700) and the distortion are shown in *Fig. 4*. The distortion is outstandingly low, even at low frequencies.

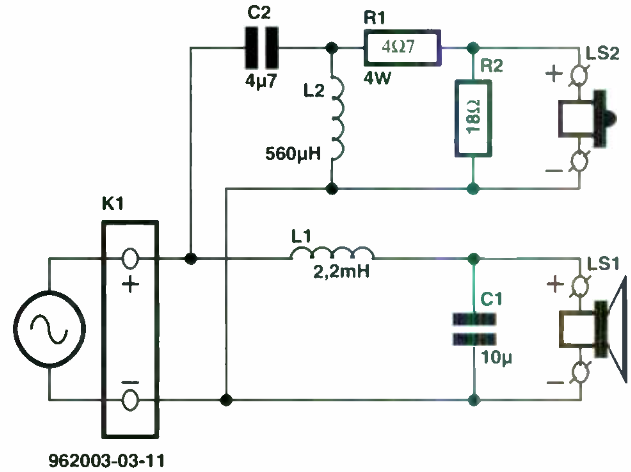



**FIGURE 2:** Circuit diagram of the crossover network.

The sloping phase shift curves are caused by the acoustic center of the woofer being further back at high frequencies than at low frequencies (this means that in the case of a cone driver, the curve is never horizontal). If the cabinet is phase-linear, the sloping curve will have a constant fall-off. Phase errors cause humps and dips: a deep dip or a high hump indicates a large phase jump. Since the curves in *Fig. 4* are reasonably straight, it can be assumed that the cabinet, even without a special front panel or special correction networks in the filter, is nearly phase-linear. Note the differences between the curves of the Revelator and the 9700, however.

Bear in mind also that the illustration must be seen as cylindrical, that is, +180°

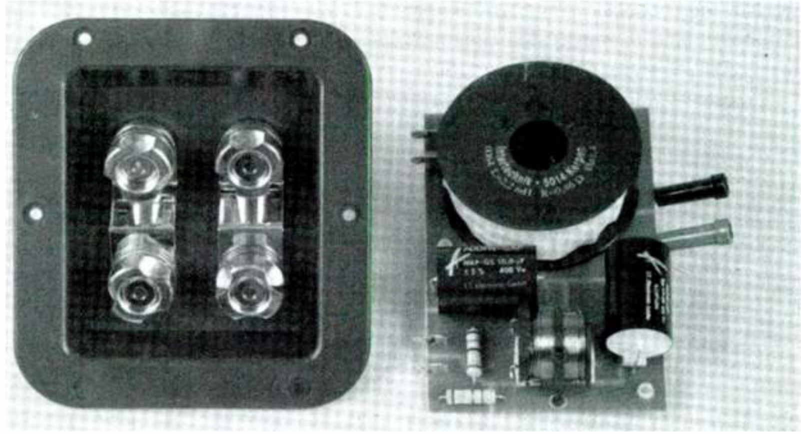


**FIGURE 3:** The completed crossover: note the location of the two inductors.

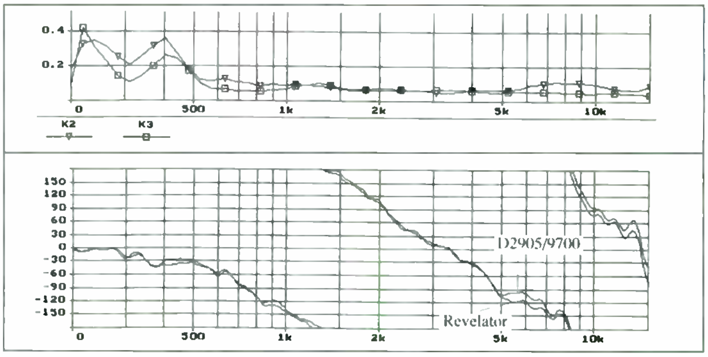



**FIGURE 4:** Distortion (top) and phase shift characteristics.



is the same as -180°. This means that the shifts at 1.5kHz and 8kHz are not phase jumps but are caused by the fact that the illustration only covers 360°.

## PERFORMANCE

Evidently, the Reference Monitor is a loudspeaker full of promise, and during listening tests these promises are more than fulfilled. Once you are listening to a pair of these units, it is difficult to get away from them. After you have listened for only a few minutes, you start trying different CDs, popular, jazz, classical: how do they sound? In all cases, excellent. Concentrating on, say, the cellos or the oboes is fairly easy during a live performance, but certainly not always with recorded sound. Many loudspeakers lack the depth in the stereo imaging necessary to recognize individual instruments or sections of an orchestra. The Reference Monitor passes these tests handsomely; it is a loudspeaker that reproduces the original music with uncanny precision: it is as if you are present at the recording studio.

The overall reproduction remains taut and controlled down to very low frequencies thanks to the Kevlar (an aramid fiber, which is a very tough plastic) woofer. It must be said, however, that if the volume is turned up high (much higher than can be tolerated in the average living room) the sound quality is not so good. This is because the cone is able to produce very large deflections during which the non-linearity of the magnetic field becomes evident. On the other hand, compression does not take place because the movement is damped by the cone suspension. So, the Reference Monitor is honest about this aspect, which is not noticed in many other brands because in these the non-linearity is hidden in the cone suspension.

## MEASUREMENTS

Distortion and phase shift have already been discussed, and now it is time to look at the frequency response, the waterfall plot, and the impedance characteristic, shown in *Fig. 5*. There is not much to be said about these: they are as good as attainable with modern technology. The only comment would be that it is clear that the crossover does not have an impedance correction network. This creates no difficulties at all, however, because almost all output amplifiers can cope with the impedance variations.

## CONCLUSION

In the Reference Monitor it is absolutely clear that the Scan-Speak promises in regard to the Revelator are more than fulfilled. Together with the excellent woofer, the tweeter forms a loudspeaker that belongs to the top units available.

### Parameters

**Design**
Rolph Smulders (Audio Components)
2-way vented

**Woofer**
Scan-Speak Type 1828546/01

**Tweeter**
Scan-Speak D2905/9900 or D2905/9700

**Bass reflex port**
PVC pipe 150mm (5.90″) long, 50mm (2″) diameter filled with straws

**Crossover**
12dB/octave

**Dimensions**
420 x 240 x 290mm (16.53″ x 9.45″ x 11.42″)

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Brogaards Vej 18, Videbaek DK-6920, Denmark
(+45) 97-173-600

**Scan-Speak USA**
2920 Wolff St., Racine, WI 53404
414-635-3099, FAX 414-632-5393
http://www.vifa-usa.com

**Distributors**
Madisound Speaker Components
608-831-3433

Meniscus
616-534-9121

Solen, Inc.
514-656-2759

Speaker City USA
818-846-9921

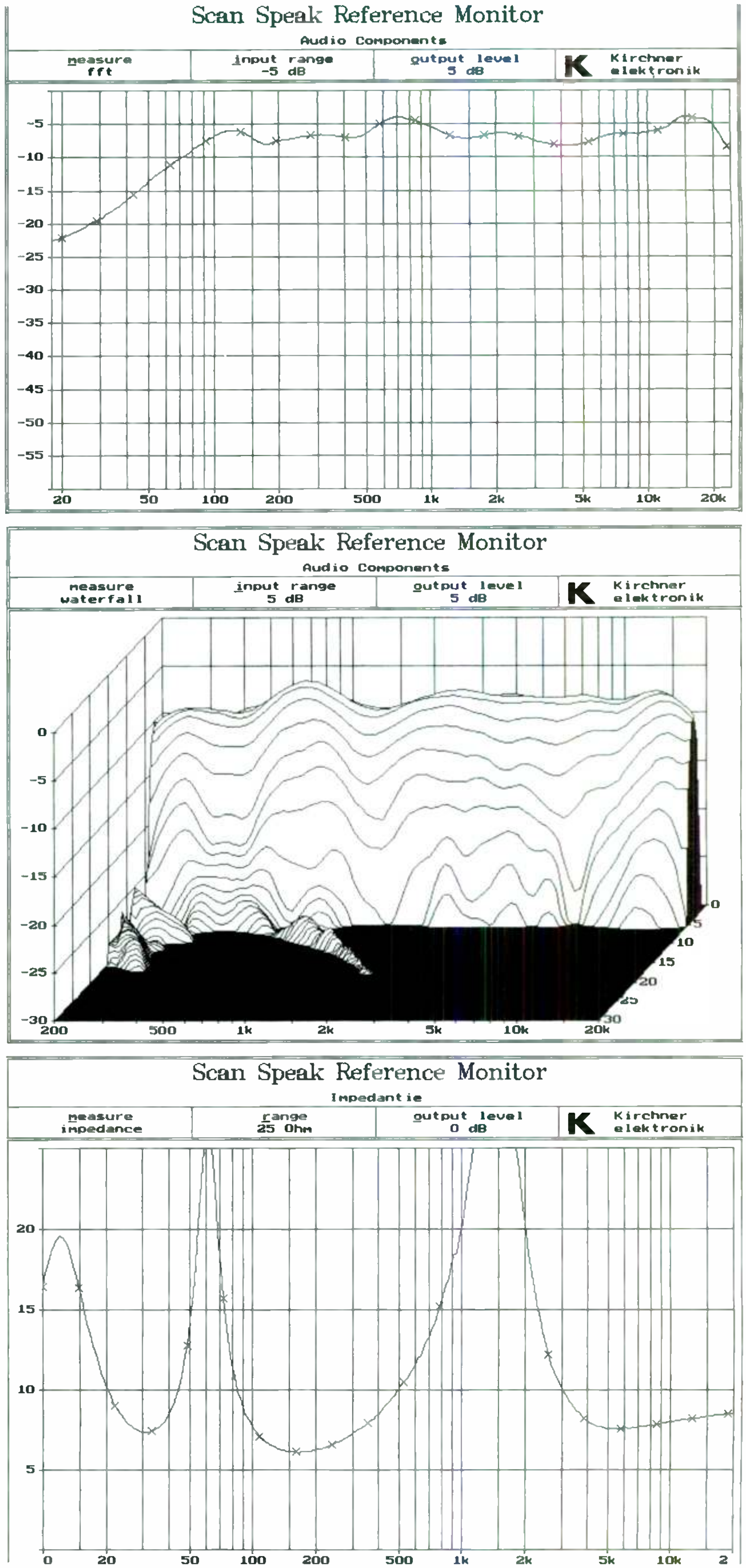


**FIGURE 5:** Frequency response curve, waterfall plot and impedance characteristic of the Reference Monitor.

# REBUILDING THE AR-3*a*, PART 5

By Tom Yeago

In this part, de- and reconstruction of the dome drivers continues.

## MIDRANGE IRON AND MAGNET

Now it's time to separate the magnet from the rest of the steel. In the first go-around, I just soaked the parts in a pot of acetone for a week or so, and then split the magnet from the steel by hammering a steak knife into the joint. This isn't entirely satisfactory, because if AR had done a good glue job, there's a fair chance you'd fracture the magnet. I was lucky.

Then I read Matt Honnert's letter ("Tools, Tips & Techniques," *SB* 6/90, p. 94) that advised heating the motor in an oven at 350° to soften the cyanoacrylate glues used (for obvious reasons) to hold the motor together. There is, so far as I can discover, no solvent that's really effective on these instant glues. Heat works, but it also saps the vigor of ceramic magnets, which I found out the hard way before reading about it in a magnet catalog.

So keep your magnets out of the oven, hope your drivers were built before AR discovered instant glues, and take your chances with mechanical separation. I am back to acetone (in a metal paint bucket), and I use a big vise to hold the steel, and a strap wrench around the magnet to twist it free. Mark the magnet as to which end is up, and scrape off the old epoxy.

The gap has a 1mm span, a 12.5cm circumference, and a stock height of 0.15″. When I took my little iron probe to this structure, I measured it as stock, fitted dry—that is, I cleaned off all the glue and put the assembly back together as stock, keeping the gap by shimming with layers of tape—and a complete modified magnet structure (gap 0.2″ tall instead of 0.15″), pole bored out, and with a backing magnet.

The stock assemblies varied from 350g for one structure with the magnet badly off-center, to 450g. For the dry fitted structure, I had approximately 550g on the balance before the probe pulled free, and my full modified structure held 530g. It may interest you to know that the stock dry structure held just over 710g with a backing magnet stuck to it.

I blame the underachieving performance of the assembly—as AR put it together—on too much glue. I think I mentioned that glued-up assemblies were typically 0.01″ taller than the same pieces put together dry.

For modifications, I drilled and chamfered a 3/8″ hole in the central pole, and drilled three ¼″-diameter holes, ¼″ from the pole piece, in the back plate. These holes enable all the air volumes under the dome to communicate. I checked the mating surface of the bottom plate for flatness, then sent the assembly off to be plated, which added a couple of mils of brass on top of the steel.

you need shims to hold the top plate away from the pole piece during glue-up. Four thicknesses of playing cards will probably do the trick, adding layers of masking tape as needed. Now fit your shims for thickness, since you can slide the top plate over the pole piece without a magnet causing trouble by pulling the two together.

Another immediate job is to wind a couple of turns of thick copper wire around the base of the center pole, solder them together, and violà—you have a Faraday ring in addition to the brass plating.

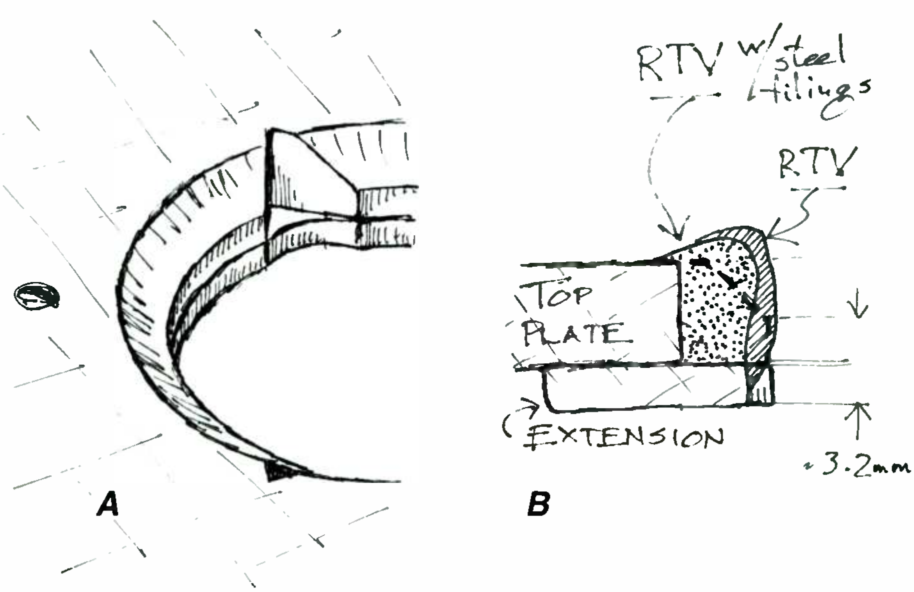


**FIGURE 12:** Treble top-plate details. ***A*** shows the gap-extension treatment at the notch. The 2-56 tapped hole is at the left. ***B*** shows a sectional view of the RTV silicone blob in the notch.

My plater couldn't be bothered to plate just the pole piece, so he plated the whole thing. I filed the brass off the mating surface, but that's probably academic. For those of you keeping track, my plating bill for this project came to $30.

To couple the air under the surround with the air under the top plate, I drilled four ⅛″ holes in the top plate, ¼″ away from the gap. Chamfer both ends of these holes.

## FINAL ASSEMBLY PREPARATIONS

You're now ready for assembly, but first

Time to glue! Spread a very thin layer of epoxy on both the bottom plate and magnet (everything's spotless, yes?) and mate them. Get the magnet nice and concentric, twisting it around on the bottom plate to seat it closely. Then get it truly concentric with spacers between the inside of the magnet and the side of the center pole. It's an odd dimension. Break a pencil into pieces and wind masking tape around them until they fit. Clamp. Wooden clamps are easier to work with, but C-clamps are fine, too. Just screw them down evenly, without applying too much pressure. After ten minutes, retighten. Let it set for 24 hours.

At this point, add a little stuffing under the top plate, something that won't move up toward the gap. Circles of felt, fibrous carpet padding (if dust-free), or wads of polyester batting work well. Fill the cavity about half full without packing it tightly, and secure it with a little DAP smeared inside. This'll also hold the Faraday ring in place.

## GLUING THE TOP PLATE

Now glue the top plate. Arrange your shims so the hole in the top plate will find them evenly distributed when you drop it in position. Glue on both the magnet and top plate. Thread the four 8-32 screws that hold on the flange all the way in, so that they poke out the bottom. Now lower the top plate into position. The four screws will keep it from bottoming. Lower it onto the magnet by unscrewing the screws. Ease it into position, with all the shims in place. Once it's down, twist it around to spread out the glue, clamp it, and retighten your clamps after ten minutes. Let it set 24 hours. Then you can pull out the shims and mask over the gap.

For backing magnets, I chose more of those I used to back the woofer: 10cm outer diameter, 7cm inner diameter, and 2cm tall. A good fit. I was determined to have some fluff under the dome to help soak up the evil back wave, so I pulled a tuft of it through the hole in the bore, and shaped it with scissors and a soldering iron so it was not only well fitted to the dome profile, but, more importantly, was a good ¼″ or so away from the gap. I made sure it stayed in place by smearing a little DAP around the inside of the bore before I pulled it through, and I vacuumed any stray fibers out of the shaped tuft on the front.

Now unmask the gap, dribble in $0.35cm^3$ of magnetic fluid, and lower the flange and dome assembly into position. Tighten the 8-32 screws evenly, pressing on the dome to make sure it isn't rubbing. Put a small dab of DAP on the screws to keep them tight.

## ADJUSTING BOX VOLUME

Consulting the midrange dome's $V_{as}$ (about $160cm^3$), you'll see that the so-called box volume should be about $50cm^3$, given that it's stuffed, to double the final resonance to approximately 400Hz and qualify this as an air-suspension system. Fine. Make all the assorted connected volumes a total of $35cm^3$. You can easily enough adjust the volume inside the backing magnet to 12 to $15cm^3$.

To make this adjustment, I cut some rough chunks of ¼″ masonite to fill about half the exposed back of the bottom plate and support the 7cm-diameter plug I intended to glue on the back. The plug is ¼″ away from the back plate, enclosing a volume of $38cm^2 \times 0.63cm$, or $24cm^3$, except that half of that volume is taken up by my odd-shaped chunks of masonite; hence it is $12cm^3$.

I threw in a little felt for good measure, without covering up any of the holes I'd drilled. I made my 7cm plug out of sheetrock, and glued it down with DAP. It's plenty sturdy, and if I need to get inside, I can just hack away at it and make another.

Now stuff what steel you can between the exposed magnet face and the top and bottom plates. The midranges are easier to do than the woofers in this respect. But mind the input connections. In fact, whack those silly little tabs off and tape over the rivets before you wind steel wire in the joints (not forgetting the DAP to hold things together). After you've done that, you can solder some 1′ lengths of color-coded wire in the eyelets and make your connections to those.

The only steps left are cosmetic. In the matter of the expanded-metal grille and the stuffing between it and the dome, I opted to go for the stock look. I kept the little pupil-and-iris pieces and, instead of AR's disk of fiberglass, I trimmed down a disk of poly batting to about ¼″ thick, dyed it yellow by daubing it with Radio Shack's P.C.B. etchant, and stretched it to follow the grille's contours—and it stayed put when I glued the grille back in place (DAP, of course).

## THE COMPLETED DOME MIDRANGE

The data tells you the warmed-over midrange is about 2dB more efficient than the stock unit, but its higher impedance makes it a toss-up regarding sensitivity. Stock units vary significantly because of the variations in flux density (B), which puts those level set pots in a new light. My impedance curve tops out at about 9Ω at 400Hz. No surprise there. It's down to 6.2Ω at 1kHz and bottoms out at about 5.5Ω at 2kHz. It must be padded down, which will smooth things out as far as impedance is concerned, so I have no qualms about treating it as a simple resistive load and using a textbook crossover solution.

The aluminum former and ferrofluid should give plenty of power-handling. At the low end, you have $X_{max} = \pm 1mm$, which is plenty for a midrange dome. I see modern units (usually 2″) advertised with less than half that, but this 30-year-old design can still beat 'em here, as modified. It kicks really well, considering it's such an old geezer.

For the record, motor-coil inductance is calculated at about 0.09mH, a figure I have no hesitation using, because the steel adjacent to the coil is much further toward saturation here than in the woofer. If all that steel was irrelevant to woofer coil L, I figure it's less so for the midrange motor coil, despite the fact that the gap's span here is 1mm instead of 2mm. I might also mention that the ferrofluid plays a role in mechanically stabilizing the motor former, thus discouraging rocking.

Incidentally, one of my midrange motors decided to start rubbing the top plate a month or so after I buttoned it up—things sounded distinctively wrong. Of course, I hadn't taken quite as much care in assembly as I'm preaching to you here. A little doctoring of the countersinks fixed it.

## THE TREBLE UNIT

This unit was the most frustrating of the three. From my reading, I expected it to be down in output (re the woofer) by 5dB or so, or even—it depended on the source. After dissecting my treble units, I began to understand this spotty reputation. The top plate was typically dished; the voice coil, obviously wound by hand, wasn't done as neatly or compactly as it might have been. The suspension for the dome, three small blobs of foam squirted between the dome and notches in the top plate, was mystifying, unique, and a carryover from the AR-3 dome units.

I was determined to get the output up,

maybe in the ballpark with the midranges so I could use the AR level-set pots (as part of a larger pad circuit). I had a laundry list of changes to accomplish, including a lower resonance, a 6Ω impedance to simplify the crossover, and increased power-handling.

Ferrofluid in the gap was a foregone conclusion, and I would rewind the voice coil to get more wire in the gap. I wished to enlarge the gap itself, like the midrange dome, if it didn't compromise flux density too much. There would be a backing magnet, a vented pole, a grille to protect the dome from inquisitive fingers, and a more substantial mounting flange.

After some noodling on paper, I wasn't satisfied until I hit on the notion of increasing $S_d$ (piston area) by gluing a little diaphragm to the dome, held taut at its perimeter. It would seal the magnetic gap from dust, yet be small enough that it wouldn't (or shouldn't, since this is seat-of-the-pants engineering) resonate too aggressively in the mid-treble. I should add that I stole this idea from Roy Allison, who used this "inverted cone" arrangement in his drivers starting way back in the mid 1970s.

I planned to control the diaphragm extension by securing its perimeter with a glue that wasn't very hard, so the boundary at the perimeter wouldn't be distinct. I also intended to use a material that was decently self-damping, so it wouldn't support much resonant activity. I'd need to fabricate some flexible leads for the dome, too, and a way to attach them.

All of which I'll get to directly; first, I need to clear up some details on how to get this treble unit apart.

## TREBLE-UNIT DECONSTRUCTION

First, cut around the paper dome between the foam-rubber blobs with your X-acto knife. AR used a clear, flexible cement here to keep out dust. Then cut the foam clear from the top plate. Break up your blade into a shape that will reach down and cut the dome free. You've cut the leads to the dome, too, somewhere along the line. No matter; lift the dome free and notice how fragile the little Nomex® former is. Put it in a safe place, like a film container.

Now peel off the circle of vinyl stuck to the front and go to work with a hammer and chisel, whacking off all that black plastic. Get it all. No sense muddying up good acetone with plastic. Scrape off all the glue exposed around the joints, too. Then plop the assembly into the acetone.

There's little more you can do until you get the magnetic structure apart, so take some time to make the flange. For this, I used some 1/8″ fiberglass composite I had on hand. I cut out the disk, drilled three holes to mount the unit in the box, and six more for 6-32 screws on a 6cm-diameter circle. I drilled these with a 3/32″ bit so I could use it later as a template for drilling the top plate. Then I drilled a 1½″ hole in the center for the dome, used a sanding disk to dish the front, and sanded the sharp edge off the hole on the magnet side.

To make the grilles, I laid a 4″ × 8″ piece of Al windowscreen over two 1½″ holes drilled in some scrap, and beat on it with the rounded end of a handle and a golf ball until I had two nice dome contours in the screen. I smeared some epoxy on these, working it into the wires' interstices, while keeping the mesh open, and let it dry. The domes kept their shape nicely, thanks to the glue. Then I cut them out, leaving a ¼″ flange to hold them in place, and painted the screens and the fiberglass flange plate black. I was impressed with the dome grilles' strength. To dent them, you would need to press extremely hard.

Then I gouged two grooves in the back of the flange plate for the wire leads. These are 180° apart, running from the 1½″ cutout between the holes for the 6-32 hardware and stopping ½″ from the edge. The grooves are about 1/8″ wide and half as deep. They don't need to be pretty—just big enough to hold 24-gauge or similar insulated wire.

## MAGNETIC ASSEMBLY

Assuming you've been busy with other things and the treble magnetic assemblies have been sitting in acetone for 10 to 14 days, it's time to pull them out and separate the magnets from the steel.

Next, scrape off all the glue. Then bore a ¼″ hole down the center of the pole piece and three 3/16″ holes through the bottom plate, spaced evenly around the base of the pole piece. These holes will come in handy when you need to shim the treble dome into position during the assembly phase. Dress the magnet-mating surface of the bottom plate flat with a big file, and send these pieces out to get a heavy plate job (again, copper is preferable, but brass is fine).

Now for the top plate. Using the front flange as a template, drill and then tap the top plate for the screws that will hold it and the front flange together. I used 6-32 hardware here. Then slightly chamfer the threaded holes on the magnet side to make sure no displaced steel keeps the top plate from settling flat against the magnet. For the same reason, check the top plate for flatness and file down the dished area until it's respectably flat. You don't need to take this all the way to the gap, since the magnet has a 3.3cm hole in it. Just true up the area that mates with the magnet.

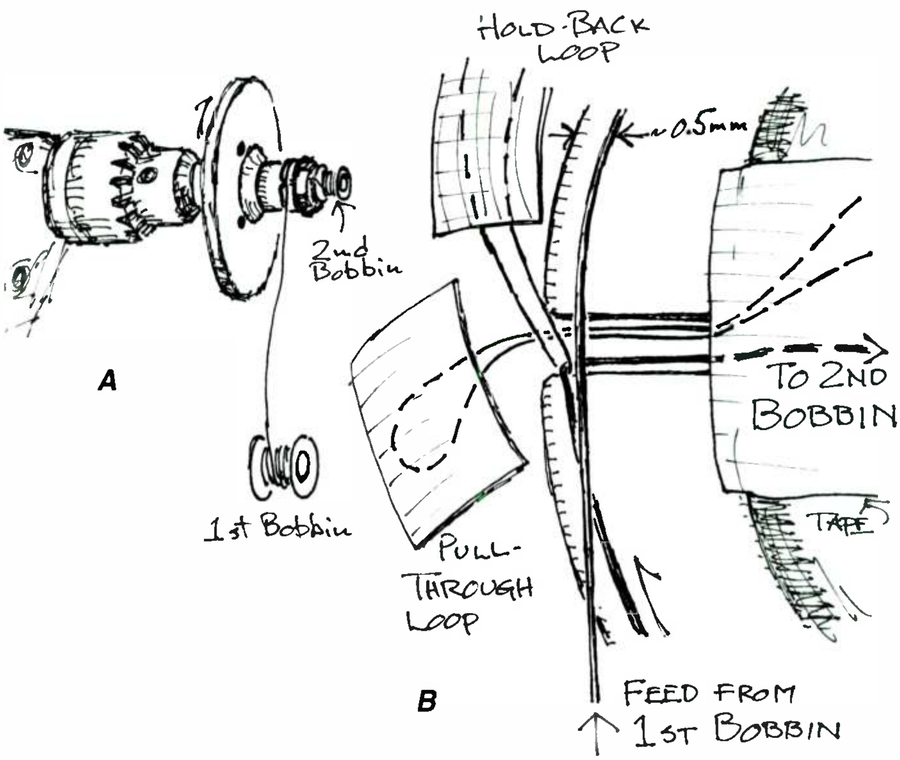


**FIGURE 13a:** Laying wire onto the treble motor former. ***A*** shows the general layout. Note the second bobbin taped to the top of the dome. ***B*** shows the first turn wound on. The hold-back loop gives a good bend, and the pull-through loop is needed at the finish of the second layer.

# THE OVID BELL PRESS, *Inc.*

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Dear Subscriber,

You find enclosed a reprinted version of *Speaker Builder* 2/98. Please replace it with your original copy.

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Sincerely,

Paula LeSeure,
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Enclosure

Supplement to *Speaker Builder* 2/98.

Now, using a 1¼″ fender washer, increase the gap's height to about 3mm by screwing the washer to the top plate and drilling and filing it to bring it to the same diameter as the stock gap. (Just as you did with the 1.5″ domes.) The only trick is what hardware to use. I used three 2-56 screws. Tap and die sets don't usually run this small. I got mine at a hobby store that carries supplies for RC model aircraft—$5.50 for the tap and a 1/16″ drill for the hole. Go very carefully when you're tapping for 2-56 threads. And make sure your washer is mounted concentrically; there's only 1mm or so of clearance between it and the magnet.

I had pieces from four tweeters to play with, and the chamfer AR puts on the front of the gap wasn't strictly consistent, but I managed to come up with two top plates having clean profiles and face heights of about 1/8″. I had no clear idea of what to do about the notches in the top plate. Should I duplicate them in the washer extension? I compromised by filing an indent with a ¼″ round file at the notches. See *Fig. 12*. This left a little shelf at the bottom of the notches, but still followed the lead set by AR of pulling away from the pole piece at this part of the gap. See *Fig. 12* again.

For the dome's suspension, I kept AR's tripod arrangement, but used the same black RTV silicone I used to coat the woofer surround. I filled the notches in the top plate in two stages. In the first, I filled out to a level even with the fender washer's contours with a mix of RTV and steel filings. I reasoned that if I could convey a little more flux to the gap, why not?

I let that cure an hour or so, then filled to approximately the gap curvature with straight RTV. Keep in mind that these RTV blobs will primarily attach to the dome's structure above the motor coil and slightly up on the black pressed-paper dome itself. So you want to build your blobs up a little bit, about even with the face of the top plate. Again, I refer you to *Fig. 12*. It's good practice to get your little RTV blobs fairly similar in size and shape.

I had a terrible time getting the RTV to stick to this steel. I cleaned it and scraped it and did everything I know to give the RTV a good surface to adhere to. I was never really happy with the result, but decided in the end it didn't matter. More on that later.

## DOMEWORK

I had extra parts to work with—a luxury. If you have a punched-in dome, you can either scout around for a cheap pair of 2axs or give dome restoration a shot. Here's what you do. First, you need a fixture to hold the fragile assembly, and nothing works better than the pole piece of the magnet structure. It's back from the plater by now, isn't it? Wrap two tight turns of masking tape around the pole and see if the Nomex former slips firmly over the tape. If it's a little loose, take off the masking tape and try one turn of transparent tape, then two of masking. You must hold the dome firmly, but you should be able to twist it on the fixture without trouble.

Once it fits, take it off and mount a tuft of poly fluff to the top of the pole by pulling part of it through the ¼″ hole. Don't let it hang out over the side. Then carefully slide the dome down onto the fixture, making sure you don't catch any fluff between the Nomex and the side of the pole piece; all the fluff must be between the black-paper dome and the top of the pole piece. Once you have the dome assembly fully seated, lightly wind a turn of masking tape around it to hold it in place.

The fluff might partially push the dent out, but it won't be at all satisfactory. So, with a 1/8″ drill bit or small rod start pushing the fluff through the ¼″ hole. It may be necessary to keep adding fluff and cramming it inside with the back of your drill bit. Go slowly, little tuft of fluff by little tuft.

The dome will eventually assume its cor-

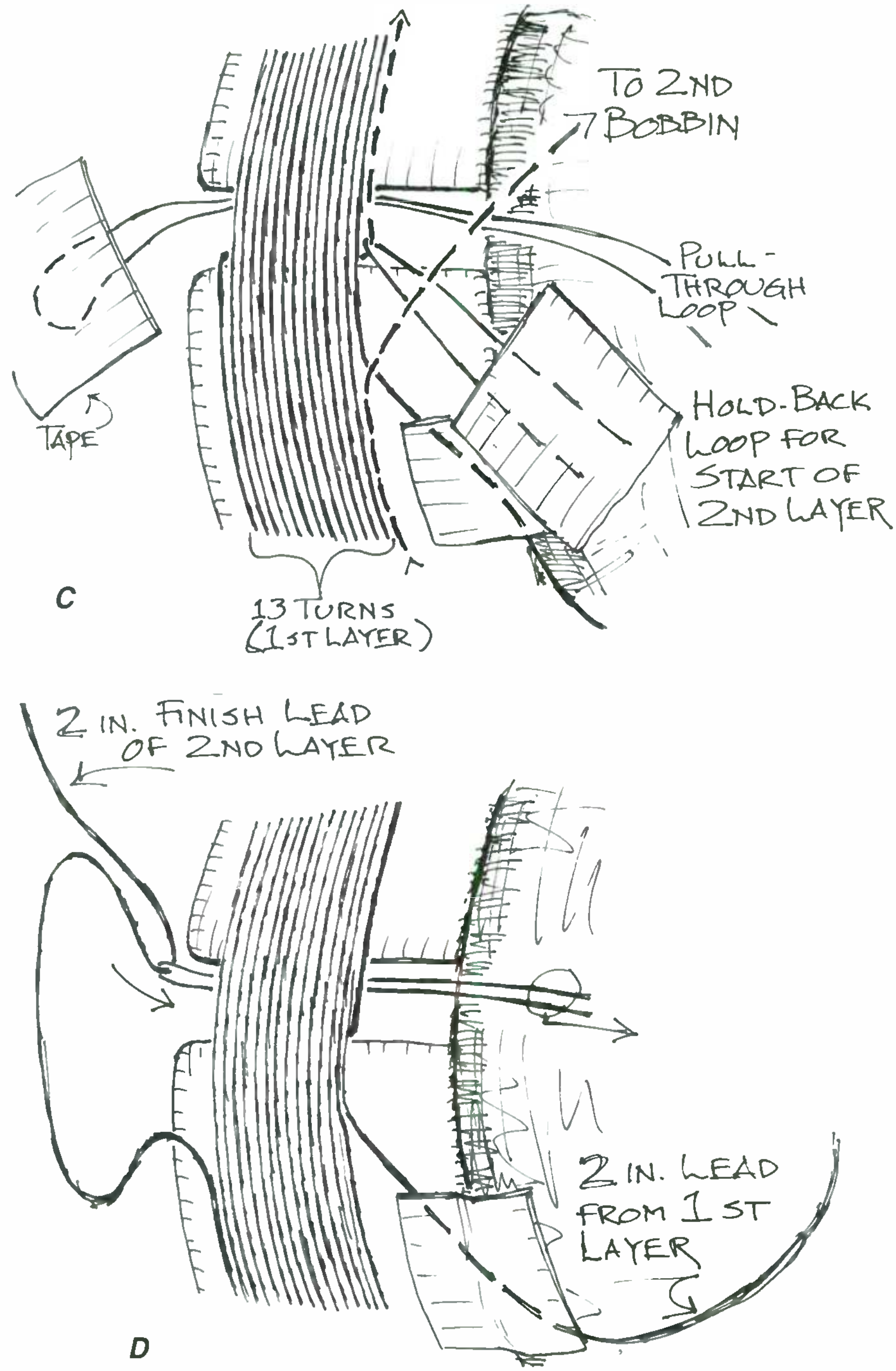


**FIGURE 13b: C** shows the first layer done, and one turn (dashed line) of the second layer down and glued to the former. In the next couple of millimeters, the wire climbs up onto the first layer, into the groove. **D** shows the finish, using the pull-through to bring the finish of the second layer under the coil and forward for dressing and flex-lead attachment.

rect shape. When it does, apply a coat of instant glue, especially at the creases in the paper, or on areas where it was severely bent, if not actually creased. After a couple of hours, it should be hard. Remove the masking tape and take the dome off the fixture by carefully twisting it. A short length of bicycle inner tube is useful here, giving you plenty of grip without applying very much pressure. It would be a shame to crush the little paper dome.

## MORE DOMEWORK

Next, work with the coil. Insert a ¼″ bolt through the hole in the center pole, and screw a nut down tight against the bottom of the back plate so it won't twist. This lets you chuck it in the variable-speed drill.

Now mount the dome on the fixture, and once it's seated, place a turn of masking tape (slit to half its width) right at the bottom of the former, so no glue can get under the former there. Now slowly and carefully take off all of the stock motor coil. You just want the wire; don't peel off any Nomex with it. Once the wire's gone (18 turns, in case you weren't counting) smooth out the former's surface with a needle file or a diamond nail file. Usually there's a lot of glue left. Take off what you can and get the surface smooth and clean.

Now put on a two-layer coil, 27 or 28 turns, using 39-gauge wire. It's best to place 13 turns on the first layer, making up the difference with the second layer. Wind it according to Fig. 1 (Part 1), i.e., nested and with one run of wire, no joints. The only real trick is getting a good start for the first turns you wind; but I'm getting ahead of myself.

You'll need good magnification, strong light, and to keep your mind on what you're doing.

You must wind about four feet of wire onto a second bobbin. Oh, and snap a couple pieces of wire again, to get the feel of it; this stuff is almost delicate. Cut up a dozen or so pieces of masking tape, of various sizes, and have them handy. You'll need three or four short lengths of the 39-gauge wire, 2″ or so, for small loops.

*Figure 13, A–D,* shows the procedure. Note the loops that hold the wire in place when you make sharp bends and pull the finish of the second layer through to the front. If you don't understand the process, experiment with some more twine or heavy thread and a pop can.

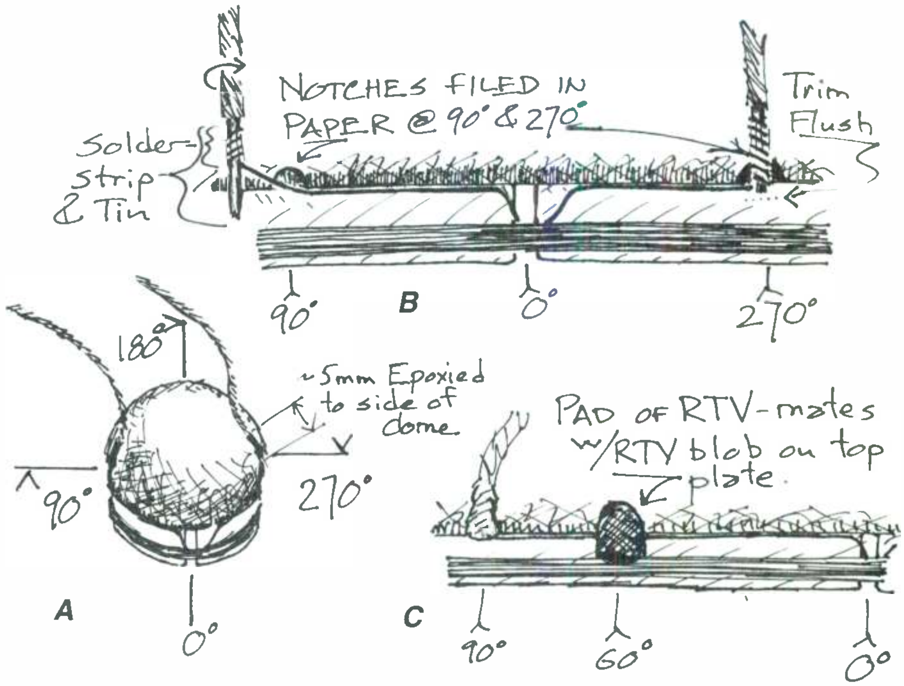


**FIGURE 14:** Dressing the motor-coil leads. **A** shows general layout. **B** shows the leads dressed and epoxied against the paper dome out of the field. Notches are filed into the paper, and the method of connecting the motor leads to the flexible leads is shown. **C** shows the thin patch of RTV on the dome and former that matches the RTV blobs on the top plate.

## WINDING DETAILS

A few points need emphasis. When you mix up the epoxy for the first layer, make sure you don't spread any into the former gap. Wind the first layer, tie it off with masking tape, and take off the hold-back loop at the bottom of the coil. Examine your work closely. If the turns aren't closely packed, you can push them together now with a needle. Be careful to keep everything even and straight. Install a hold-back loop as shown in *C* (*Fig. 13*) and lay down the first turn of the second layer, as shown. Tie off the lead from the second bobbin with a piece of masking tape, and use a small piece of rubber or tape to smooth out any glue on top of the first layer; the grooves need to be distinct.

Now begin testing the epoxy remnant from the batch you mixed for the first layer. When it starts to harden, you know it's safe to start laying down the second layer, meaning that your second layer won't spread the turns of the first as you wind it on.

So mix the epoxy, spread it on, and, working very slowly and counting turns as you go, wind on the second layer. It's very easy to lose the groove, so go slowly and adjust the light and viewing angle so you can see the glossy epoxy. It's difficult to distinguish the first layer from the wire you're laying down. You have plenty of time. Use it.

When the groove runs out, take one more turn against the bottom of the first layer, cut 2″ of lead, and use the pull-through loop to get you back to the front of the coil and give you a nice clean finish at the bottom of the second layer. Inspect your work, and if all is well, give the coil a thin finishing coat of epoxy and let it set for 24 hours.

The tables say you should be able to get 14 or 15 turns of 39-gauge enamel wire into a coil about 1.5mm tall. Mine came in at 1.6mm, giving me a nominal $X_{max}$ of ±0.8mm—remember that I had a 3.2mm gap. Since I intended to increase the surface area ($S_d$) and add ferrofluid, I was in very good shape—way ahead of the stock tweeter.

## HANDLING THE LEADS

For flexible leads, I used 1½″ lengths of Litz wire, the nylon-wrapped stuff used in IF transformers in 60's and 70's vintage radios. First I melted off the nylon by pinning the wire against a board with a soldering iron; this gave me a nice sharp, melted edge. Then I was ready to scrape what enamel I could from the tiny wires. You don't have to get it all. Clamp where the nylon wrap begins with a heatsink (so you don't melt it), twist the wires together tightly, and tin the last ¼″ or so. This will burn any lingering enamel off the wires.

Now look at *Fig. 14*. Use a small triangular file to make two notches in the edge of the black dome paper (at 90° and 270° in the figure). Now dress the two leads from the coil up to the black paper and around to the notches. Epoxy them fast. Scrape the enamel off these leads, starting about ⅛″ past the notches.

Then start wrapping the motor-coil leads around the tinned Litz, as in ***B***. After a few turns, heatsink the nylon wrap again and solder the joint. Then just keep twisting to take up the slack until the Litz flex lead fits into the notch. Glue the flex lead to the paper dome for the first 5mm or so, tape it down flat against the dome profile, and clip the excess of the Litz at the former (*Fig. 14B*). I put a very light coat of epoxy on the black paper—not enough for it to soak in, but just a glaze over the surface to waterproof it and possibly help it structurally. Let it set for 24 hours.

## REMOVING THE DOME ASSEMBLY

Since the next step is to take the dome assembly off the fixture, you can use the time to get ready for that. Take off the masking tape below the former. Examine the coil and former minutely for any trace of epoxy attaching it to the fixture. Be thorough. Pay special attention to the former gap area. You must eradicate any trace of offending epoxy with a needle or a sharp blade.

That done and the epoxy thoroughly cured, cut a 5″–6″ strip of masking tape 4–5mm wide and lightly wind it onto the former coil. Your aim is to reinforce the assembly without squeezing it onto the fixture more tightly, so, I repeat, wind lightly. Keep an edge up on the former-dome joint, and the tape will be thin enough so that the bottom edge will take care of itself.

Now get out your length of bike inner tube, slip it down over the dome assembly, squeeze, and twist. Apply pressure as evenly as you can to the coil former, and twist to and fro, using more force until the assemby begins to slide on the tape-covered fixture. Don't try to pull it off, or you will surely crush the dome. Just get it to twist. Once it's moving on the former, you can carefully twist it free, gently "unscrewing" it.

Now place three little thin pads or patches of RTV silicone on the former and 2–3mm up onto the edge of the dome (*Fig. 14C*). (You will have gently removed the turns of masking tape you wound on it to help get the dome off the fixture.) These pads are at 60°, 180°, and 300°, and will mate with the RTV in the top-plate notches to form the tripod suspension. It's better to apply the RTV to the dome assembly now because you can get it nice and thin, and properly shaped. You'll work a little more RTV between these pads and the blobs when you assemble.

## ADDING FOIL

I wished to have a layer of aluminum foil inside the motor former both to make the assembly slightly stronger and to aid in damping, so I cut a 6.3cm × 0.6cm rectangle of medium foil. Remove a turn of masking tape from the central pole/work fixture and replace it with a turn of thinner tape such as transparent cellophane.

Now mix up a little epoxy and spread a thin layer on the inside of the former and the periphery of the dome's inside, making sure you get a good coat on the tiny patch of motor coil you can see through the former gap. Spread an equally even coat on the dull side of the foil.

Now wait until the epoxy starts to set, becoming good and tacky, before you press the foil in place. Keep testing the unused epoxy, and when it starts to harden, form the foil into a circle and, holding it at the ends with a pair of tweezers, drop it inside the dome assembly. Work the foil into place from the middle of the strip toward the ends, bending the top edge to fit the inside of the dome profile as best you can. A pencil eraser works well.

Using your fingers if they're small enough, press the foil flat against the former. This is important. Let the crease against the dome part fall where it may. Once the former is covered with foil, there will be a little foil extending below the former. Bend this out at about a 90° angle to keep the foil from shifting. If any epoxy shows on the foil inside the assembly, clean it off.

Now slide the assembly carefully down onto the fixture. If there's no glue exposed, it should fit pretty smoothly. After about 20 minutes, twist the assembly carefully off and press the little crimps of foil flat against the inside of the dome with the eraser.

If things go badly awry here, just pull the foil out, scrape and smooth what epoxy you can from the inside and try again. Just be sensible and don't foolishly jeopardize the whole assembly. Trim off the excess foil at the bottom of the former. In the next, final, installment of this series, we complete the assembly and finally get the opportunity to kick back and take a listen to this unit.

# Kit Review

## MARCHAND ELECTRONICS XM9 CROSSOVER

TEST DRIVE

*By Kenneth W. Ketler*

*XM9 Crossover, Marchand Electronics Inc., PO Box 473, Webster, NY 14580, (716) 872-0980, E-mail info@marchandelec.com, Website http://www.marchandelec.com.*

When you go to a place like Big Joe's Pancake House, do you usually order a "Build-Your-Own Breakfast" or do you let Big Joe decide what you'll eat with *his* idea of a meal combo? It's a fact of life: some people can be extremely picky with their food. You and I both know there are people who are picky about audio gear, too. Are you one of them?

Marchand Electronics is an audio company that is definitely willing to let you build your own. It manufactures various high-performance power amplifiers and active crossovers that are available as unassembled kits or fully completed units. Moreover, it pledges to perform custom modifications or even design completely new products to suit the needs of its customers! How could you not love these guys?

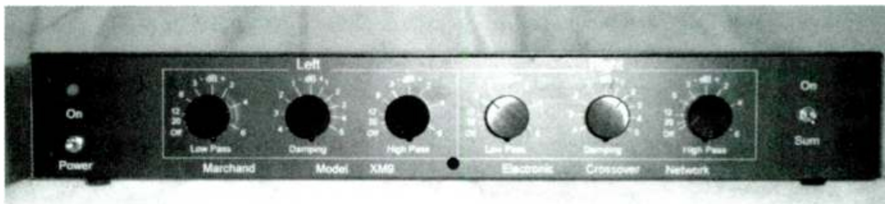


**PHOTO 1:** The completed XM9 crossover system.

Marchand's kits are not simply exercises in square pegs and round holes. If you hunger for knowledge and experience, a lot of information is packed inside the user's manuals. However, if you desire the satisfaction of doing it yourself without getting too technical, you can skip directly to the building instructions and still wind up with a great piece of equipment.

I had the distinct pleasure of assembling the XM9 crossover system, which is available in two-way or three-way versions. The unit I received was a two-way, with a crossover frequency of 100Hz, intended for subwoofer use (*Fig. 1*). The XM9 utilizes fourth-order Linkwitz-Riley filters; however, the assembly manual explains how to modify the unit into a third-, second-, or first-order system. Wheat, white, rye, or pumpernickel...your choice!

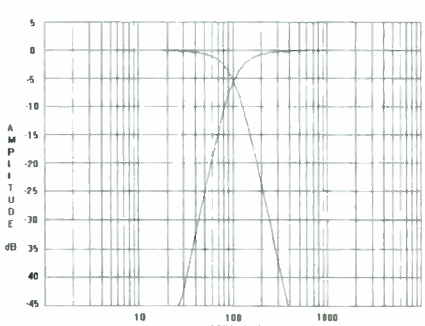


**FIGURE 1:** Two-way version of the XM9 with a crossover frequency of 100Hz.

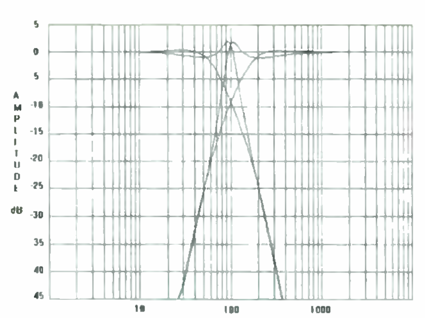


**FIGURE 2:** Graph of the damping control that allows you to vary response at the crosspoint.

### THE MULTIFEATURE CREATURE

The XM9 has several traits that put it in the deluxe category in my book. For starters, it includes a relay that turns the unit on a few seconds after you power it up, eliminating transient thumps that could potentially ruin your speakers or your nervous system. It also has the handy ability to sum its low-pass outputs, which greatly simplifies any single versus dual voice-coil subwoofer choices you may have been forced to make in the past.

Marchand also makes changing crossover frequencies a snap. For each crosspoint, there is an 8-pin dual in-line package (DIP) housing four resistors that determine the frequency in question. These crossover modules are available for $1.95 (unassembled) or $3.95 (completed). The frequencies in stock are 20, 30, 40, 50, 60, 70, 80, 90, 100, 125, 200, 250, 500, 1kHz, 2kHz, and 5kHz, but the company will create modules for any frequency you specify.

Although swapping DIPs on the circuit boards isn't the best way to perform AB tests, it's still a very quick way to completely change the character of your music system. Sure, it may not be a drive-through, but at least the lines aren't long.

Each stereo channel has three separate potentiometers. The left and rightmost controls vary the levels of the low-pass (LP) and high-pass (HP) outputs, respectively. Each has a range from OFF to +6dB of gain. The middle knob varies the damping of the LP and HP filters simultaneously, which helps achieve a perfect hand-off between satellites and subwoofer.

Since the sats and the sub are putting out equal levels at 100Hz (in this case), their acoustic interaction can cause a peak or a dip according to differing room locations and

### MANUFACTURER'S SPECS

- Frequency response: DC to 100kHz
- Crossover frequency: 20Hz–5kHz
- Insertion gain: 6dB with level controls at maximum
- Filter slope: 24dB/octave
- Harmonic distortion @ 1kHz: less than 0.001%
- Signal-to-noise ratio: better than 110dB
- Input impedance: 25kΩ
- Output impedance: 50Ω, typical
- Output load capability: 2kΩ, minimum
- Maximum input voltage: 4V RMS
- Power supply: dual regulated ±15V @ 50mA, typical
- XM9 in cabinet: 110V AC, 0.3A

enclosure topologies. The damping control lets you vary the response within +5dB and –4dB at the crosspoint for a flat acoustic transition (*Fig. 2*).

## SPECIAL DELIVERY

I'll never forget the day when the stork brought the package to my front doorstep. I tore open the cardboard bassinet and plastic bubble-wrap blanket. Like a nervous father, I gently sifted through the zillions of tiny components. It was a bit intimidating at first, but it quickly occurred to me that *this* baby comes with complete instructions!

This kit does come with quite a few parts, but please don't be alarmed. They are all neatly separated and grouped according to their final destinations (power supply, circuit board, and cabinet). I suggest that even the most knowledgeable user should read all the assembly manuals (especially the Parts Substitution list) before unwrapping any parts.

I found that the unit I had received for review (XM9L-KK) was upgraded with higher-performance op amps than the already reputable XM9-KK. Also, some capacitors had been changed since the assembly manuals were printed.

All manuals (crossover board, power sup-

**PHOTO 2:** XM9 kit fresh from the box.

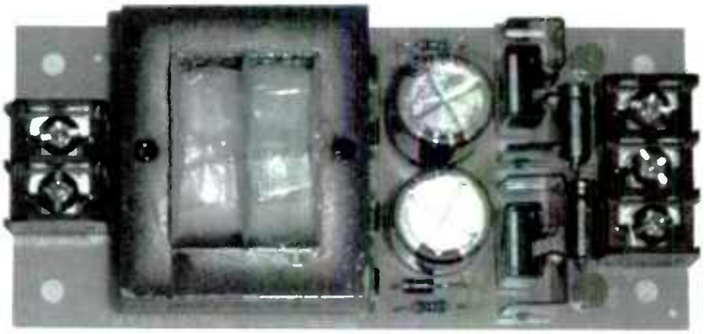

**PHOTO 3:** Assembled power supply. Note LEDs (near 3-terminal block) that indicate proper ±15V operation. This is especially good for builders who have no test equipment.

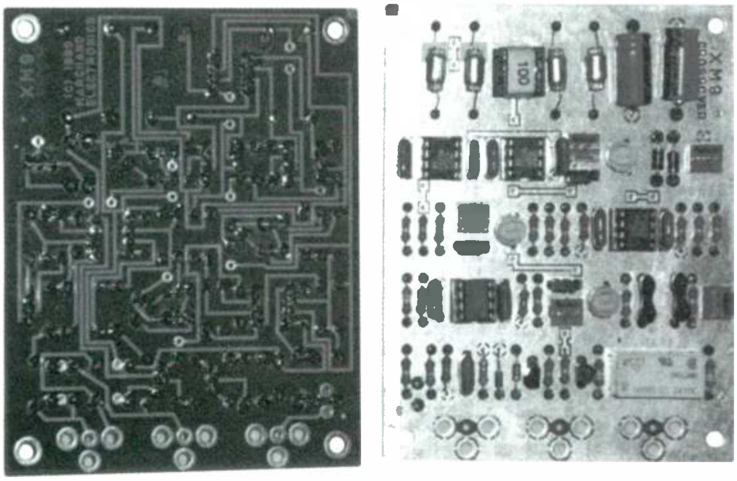

**PHOTO 4:** Completed crossover PC boards (both sides shown). Note the DIP labeled 100; this determines the crossover frequency.

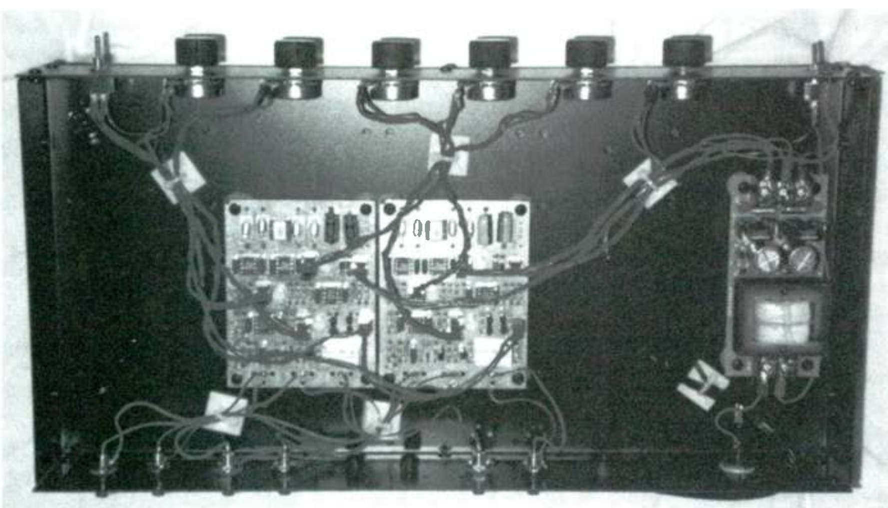

**PHOTO 5:** Innards of the completed system.

ply, and custom cabinet) were very clearly written, with plenty of diagrams and photographs. Each has a well-detailed theory of operation and step-by-step assembly process. Anyone who has ever handled a soldering iron, a screw driver, and a wrench will have no problem putting the XM9 together. I followed Marchand's steps word for word and the darn thing worked perfectly the first time I turned it on. Really!

## THE DOUBLE BLIND TASTE TEST

Once I had calibrated the HP, LP, and damping controls for unity gain, I measured the system clipping level (max level) to be 4.5V RMS at 1kHz. Its frequency response was flat from 5Hz to 40kHz (I did not look any higher than that). Left- and right-channel separation was a decent 73dB at 1kHz, while the signal-to-noise ratio was better than the lowest range of the Fluke 8060A multimeter that I used (better than 90dB).

The manufacturer's specifications claim a harmonic-distortion level of less than 0.001%. Using a Hewlett Packard 339A distortion analyzer, the best I could measure was 0.0035% with a 1kHz, 2.7V RMS input. Although this may seem ominous, I don't really think so. The 339A measures total harmonic distortion plus noise, whereas Marchand's specs may not necessarily include the noise component. Also, the distortion level, like the signal-to-noise, was down into the lowest range possible for this analyzer—very difficult to read.

Although all of the lab equipment on earth might suggest that a piece of gear is going to perform a certain way, the most important measurement tools are, of course, your ears. Due to the complex characteristics of the program material, loudspeakers, and room acoustics involved, it's very difficult to describe the way a crossover sounds. However, I hope a brief note about my listening setup will shed a little light.

My listening room has a volume of 2300ft$^3$ with a fair balance of acoustic reflection and absorption. The satellites I used with the XM9 were a pair of PVC-pipe transmission lines (à la John Cockroft) that I built. I mounted them on 15″ floor stands so that they were at the same height as my listening position on the couch. I found it necessary to sacrifice the optimal acoustic placement of the satellites in favor of a less obtrusive location. I was able to space them 4.5′ apart; however, the listening position was 8′ away, so, needless to say, stereo imaging could have been better.

The sub was a transmission-line enclosure that utilized a Pioneer B20FU20-52D 8″ woofer (available from Parts Express), with both voice coils connected in parallel. Its close-miked low-end response was down 5dB at 40Hz, so this was really more of a bass module than a subwoofer. It fit nicely on the floor, against the front wall, directly behind the left satellite. This placement seemed to give quite a smooth response for various locations in the room, with no particularly troublesome acoustic modes.

## IMPRESSIVE SOUND

As I played many of my favorite CDs (and even some I hate), I was very impressed with how well the satellites and the sub integrated with one another. There didn't appear to be any "holes" at the crossover point, and it wasn't aurally apparent where the sub was located. I varied the damping controls, but my system really sounded best when they were set to their 12 o'clock positions.

Just for fun, I moved the sub to the opposite side of the room. It sounded very detached from the satellites, but I still couldn't accurately locate its position. This was an interesting experiment; however, the sats and sub belonged closer together for pleasing results.

I must say that the XM9 is a wonderful piece of gear, whether you build it as a kit or purchase the finished model. In the throwaway type of society we live in, though, wouldn't it be nice to be able to modify your audio system as your needs change, rather than chuck it? If your crossover ever needed repair, imagine knowing where everything is and how to replace a faulty part yourself because you put it together in the first place.

If your system is already bi- or triamped, I would suggest looking at Marchand Electronics. Besides the XM9, Marchand makes a 24dB/octave tube crossover system and a 48dB/octave solid-state unit, plus a lot more. If you're the kind of person who never tried biamping, or if you swore you'd never buy triamping, you might be shocked at the difference in performance between active and passive crossover filters.

I give the Marchand XM9 an A+, five stars, and two thumbs up. You can visit Marchand's web site at www.marchand-elec.com and decide for yourself.

I would like to thank my good friend Norman S. Stickney for his indispensable help with the graphics.

# Trade Secrets

## MAGNETIC STRUCTURES AND BASKETS

*By Mike Klasco*

*In this series, I take a close look at the speaker components themselves, providing an insider's perspective on how they work and how they can work better. In this second article, I look at magnetic systems and speaker baskets.*

### MAGNETIC SYSTEM

Before World War II, speakers were electromagnetic, using field coils to produce the magnetic field and tapping the radio's power supply to compose an electromagnetic field. But as the first cheap permanent magnets (of aluminum-nickel-cobalt steel, and known as alnico) became available, it was curtains for the field-coil speaker. Throughout the 1950s alnico was king (*Fig. 1*).

During the late 1960s the supply of alnico became scarce and, eventually, the speaker industry switched over to ferrites (*Fig. 2*). While ferrites offered some benefits to alnico, including less vulnerably to demagnetization by heat and physical shock, they resulted in a much bulkier magnetic system. As speakers became heavier, they were also better able to dissipate the heat from the voice coil due to their larger mass and the increased surface area of the magnetic system.

Early ferrite magnets were dry pressed into their final form. A higher performance process, known as wet press, is now widely accepted. Although the tooling costs are greater for magnetic suppliers, wet-pressed magnets offer increased energy for magnets of the same size and weight. Some suppliers of ferrite magnets are General Magnetics, Sumitomo, TDK, Korea Ferrite, and Hitachi.

Many speaker companies resisted switching over to ferrites. When comparing speakers with identical construction, except for the magnetic system, those having alnico always sounded better. JBL introduced symmetrical field geometry techniques that addressed some of the problems. These modifications included an undercut pole piece and an inductance-canceling aluminum ring on the pole piece—techniques often found in the better drivers today. But the speaker industry's use of ferrite was a choice of necessity, not performance. Since alnico used nickel and cobalt, and the countries from which these materials are sourced are politically unstable, the supply is problematic.

### NEODYMIUM INTRODUCED

Neodymium was first introduced to audio almost a decade ago by Electro-Voice in a professional compression horn driver (*Fig. 3*). Key patents for processing neodymium are held by GM Delco and Sumitomo. Quite a few firms make neodymium under license from one of the patent holders, offering many variations of this high-performance magnet material. Many of the early processing patents are expiring about now, but secondary patents, especially covering corrosion resistance and forming material into the final precise shape without damaging magnetic performance, still have a way to go.

Neodymium is a very potent magnetic material (*Fig. 4*) and promises lighter, more efficient, and lower distortion speakers. Early neodymium was extremely expensive and too sensitive to temperature, but all aspects of this material have improved. Today, neodymium is very popular in autosound tweeters since it allows surface mounting to the interior. For audiophile and home-theater applications, the compact magnetic structure is inherently shielded and can be mounted much closer to the woofer—or even co-axially as in the KEF Uni-Q. JBL has introduced woofers for commercial sound applications having neodymium magnets based on a low-distortion push-pull magnetic structure geometry. Neodymium is the future for audiophile speaker design. Aura Systems, an aerospace and magnetics firm, has developed a magnetic geometry with good linearity for loudspeakers (*Fig. 5*).

### CIRCUIT STRUCTURE

But, I am getting ahead of myself—back to conventional magnets. The ferrite magnetic system consists of a steel magnetic flux return circuit. The conventional speaker's magnetic circuit consists of a donut- or washer-shaped top plate, a back plate, and a mag-

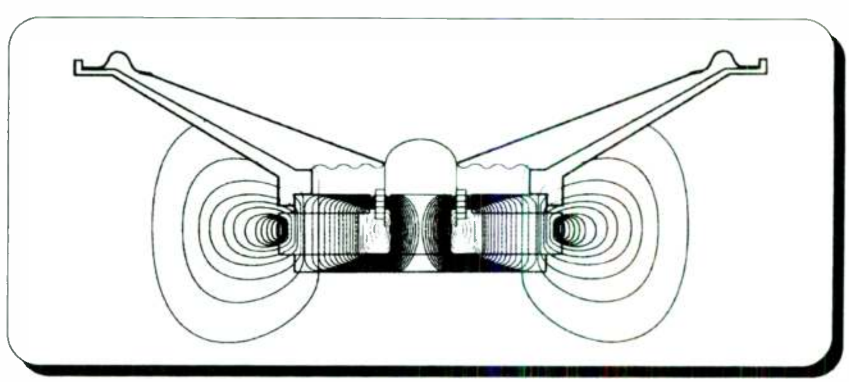

**FIGURE 2:** Conventional ferrite magnet structure including magnetic flux lines.

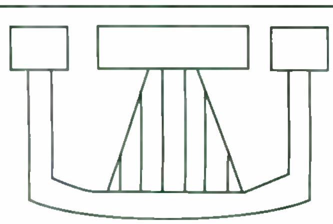

**FIGURE 1:** Cross-section of alnico magnet.

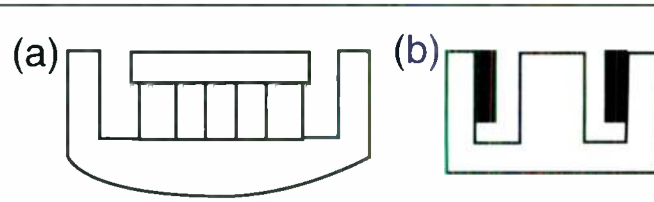


**FIGURE 3:** Axial (a) and radial neodymium (b) magnet cross-sections.

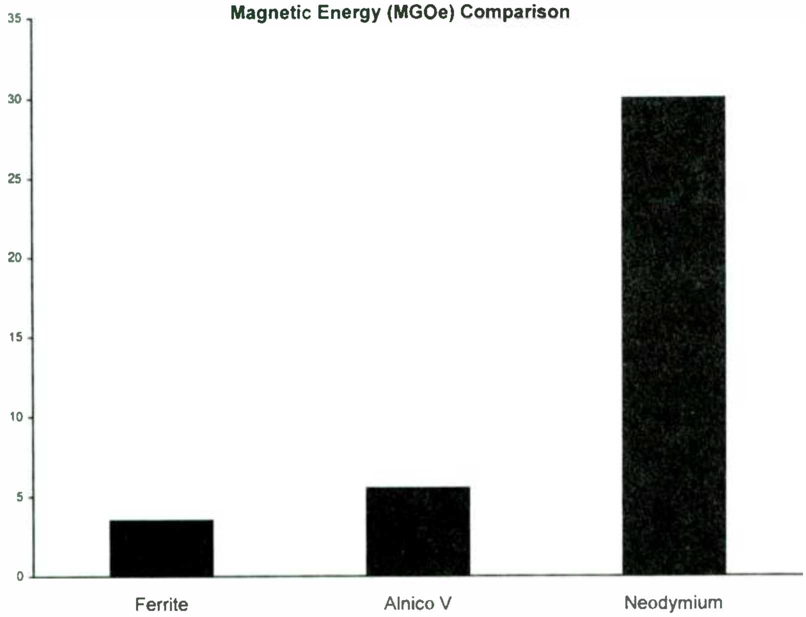


**FIGURE 4:** Magnetic energy comparison of ferrite, alnico, and neodymium magnets.

net ring sandwiched in between. The top plate and back plate are connected by a pole piece, although the pole piece is separated from the top plate by a tiny radial gap. The magnetic force jumps this gap, inside which is an intense magnetic field. This radial gap is the place to locate the voice coil.

Sometimes the back plate and pole piece are cold-forged as a single piece. A large-diameter soft steel (low carbon content) rod is cut into slices. Each slice is placed in a 1,000 ton (!) knuckle press about the size of a large room, but four floors high. The steel disc is then bashed and, by the sheer force of the press, the metal flows and a cold-forged back plate/pole piece is formed.

Top-plate thickness, chamfering of the tips of the top plate, pole piece shape (such as under cutting the pole piece), will all have significant effects on excursion linearity, distortion, power handling, and sensitivity (*Fig. 6*). Ideally, the top plate would be much longer than the voice coil, which is known as underhung geometry (*Fig. 7*). With an underhung coil, the speaker's Thiele/Small parameters, especially the characteristics relating to force (Bl) remain stable with excursion. Bl is the product of the magnetic field and the number of turns of voice coil wire in that magnetic field. But almost all woofers use overhung coils (*Fig. 8*), where the coil is longer than the top plate, and typically, even with just a little excursion, the magnetic characteristics are constantly changing. This intrinsic instability results in all sorts of modulation effects that degrade the clarity and definition at medium to high sound levels.

Why don't speaker engineers use underhung coils? The reason is that a thick top plate (much deeper than the voice coil) is expensive, and would require too much magnet to drive the deep magnetic gap with adequate flux. The previously mentioned "Neo-Radial" magnetic circuit design lends itself to underhung voice coils.

### VENTED POLE PIECE

Back to the back plate/pole piece! Often you will see a hole down the pole piece, known as the vented pole piece (*Fig. 9*). This is for cooling: the dust cap will pump air down the pole piece to reduce its temperature. Yet, the voice-coil temperature really must be dealt with first. (I will take a look at this next issue.) By the way, another benefit of vented pole pieces is the prevention of air cavity pressure build-up. As the cone assembly moves back and forth, air pressure will increase and decrease behind the dust cap. Without an escape path, the dust cap will either be pumped up or drawn inward.

Additionally, the high air velocity being forced through the voice-coil gap will cause whistling noises. The vented pole piece provides a pressure relief path for the air behind the dust cap, thereby reducing the speaker's modulation noise characteristics, sometimes called spectral contamination. (In future articles, I will discuss spectral contamination, how it is measured, and why a driver's signal-to-noise ratio is one of its most important specifications.) The speaker engineer must be careful, because if the vent in the pole piece is too small, then the vent will create turbulent noise, and if it is too large the effi-

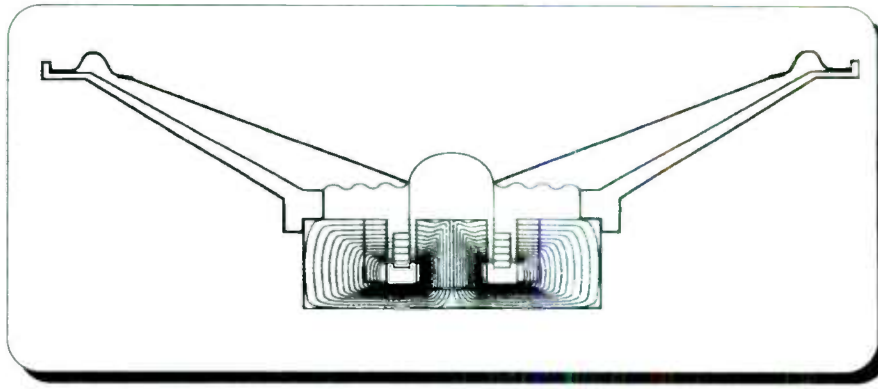

**FIGURE 5:** Aura's Neo-Radial technology magnet.

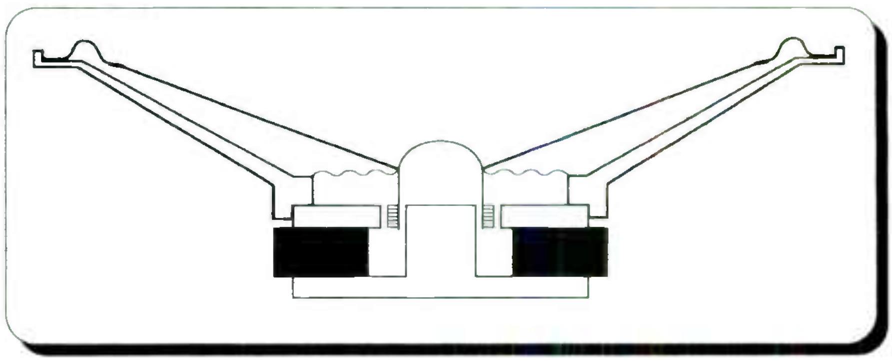

**FIGURE 6:** An equal-hung voice coil design.

ciency of the magnetic circuit will be compromised.

The steel used for magnetic circuits must be soft, that is, have a low carbon content. Japan and Taiwan are big suppliers of low-carbon magnetic circuit steel. The lower the carbon content of the steel, the less loss of magnetic flux occurs. The motley gold finish you sometimes see is the cadmium-zinc plating, while the black finish is black zinc. Aside from looking better, the black offers better heat emissivity (the ability to dump heat) and is a bit more expensive. The gold finish has the best corrosion resistance, while the silver is the best compromise in between.

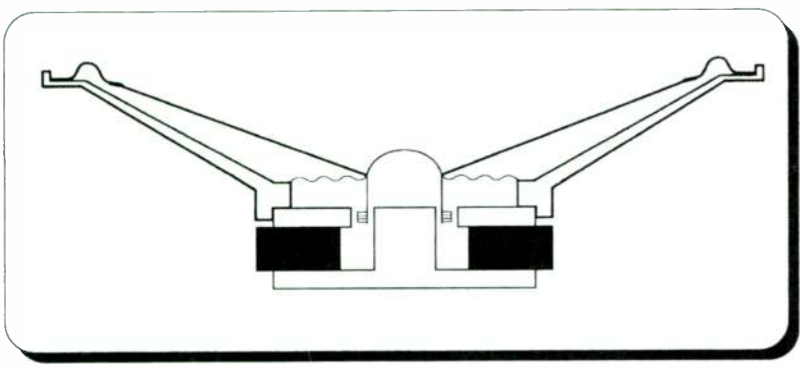

**FIGURE 7:** Underhung voice coil design.

### THE BASKETS

The frame of the speaker is either stamped steel or cast aluminum. Stamped steel is common on all but the most expensive speakers. The appeal of steel frames for speaker manufacturers is that they are readily available. Tru-Die, US Speaker Basket, Sundstrom, Alden, Alpha, and others have tooling readily available to bang out all sorts of sizes and shapes with many options. The gauge of the steel (higher gauge numbers are thinner) is an important factor in the baskets' strength. Cheap 5″ midrange speaker baskets might be only 20 gauge, while a typical 12″ frame is 18 gauge, and a heavy 15″ frame from Sundstrom is 16 gauge.

Aluminum baskets are associated with pro-

## SOURCES

**Ferrofluidics Corp.**
40 Simon St.
Nashua, NH 03061
(603) 883-9800, FAX (603) 883-2308

**General Magnetics**
5252 Investment Dr.
Dallas, TX 75236
(972) 296-4711, FAX (972) 298-4298

**Hitachi Metal America Ltd.**
7800 Neff Rd.
Edmore, MI 48829
(517) 427-5151, FAX (517) 427-5772

**Sumitomo Special Metals**
23326 Hawthorne Blvd.
Ste. 360, Skypark 10
Torrance, CA 90505
(310) 378-7886, FAX (310) 378-0108

**Sundstrom Pressed Steel**
8030 S. Chicago Ave.
Chicago, IL 60617
(773) 721-2237, FAX (773) 721-9534

**Tru-Die, Inc.**
3700 N. Sandra
Franklin Park, IL 60131
(708) 455-0220, FAX (708) 451-9663

**US Speaker Basket Corp.**
108 John St.
North Aurora, IL 60542
(708) 892-3777, FAX (708) 892-3810

fessional speakers. Light, strong, and sexy, a cast aluminum basket can make a speaker look like a precision machine. Another appealing factor is that aluminum, unlike steel, is non-ferrous and does not drain the magnetic force from the magnetic system (maybe 0.5dB of the magnet's energy is lost with steel). Cast aluminum frames also tend to have less resonance than steel. These resonances have a way of finding a path to the sound quality. Very few sources sell raw cast aluminum frames. Most manufacturers that offer cast frame speakers have had to pay for the tooling.

Next time I will explore the heart of the speaker, the voice coil.

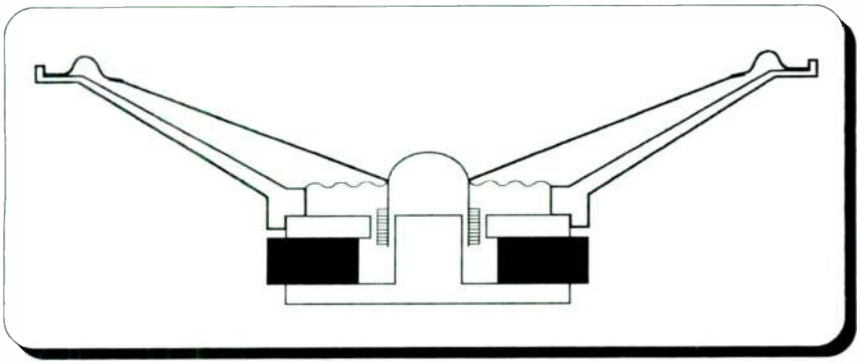

**FIGURE 8:** Overhung woofer design.

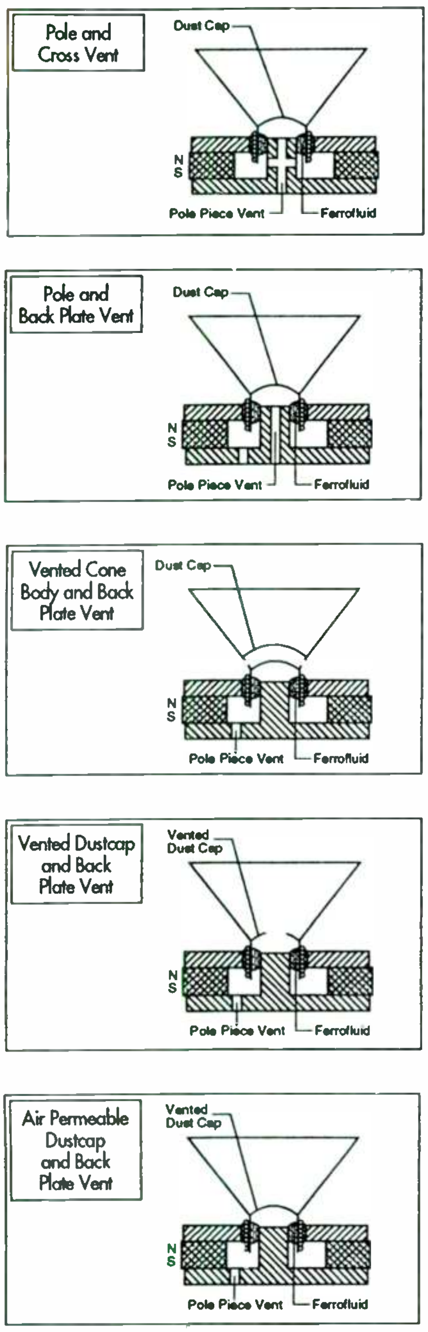


**FIGURE 9:** Venting schemes for woofers.

# Driver Report

## TWEETERS FROM SEAS

*By Vance Dickason*

This month's report focuses on two new drivers: the SEAS 27TAFC-G and 27TAF/G (*Photo 1*) metal-dome tweeters. SEAS has been making high-end aluminum domes for many years and has just released its latest incarnations, the 27TAF/G and 27TAFC-G.

**Features:** Both tweeters use SEAS' high-definition aluminum/magnesium-alloy dome material with a wide soft-fabric surround made from Sonotec®, a proprietary material used by SEAS. Both domes are protected by a screen grille that also houses a small Mylar phase-correction device built into the glass-fiber reinforced mounting flange. Both domes also use aluminum vented voice-coil formers and are damped with low-viscosity magnetic fluid. The 27TAF/G has a damped pole vent and the 27TAFC-G has a complete vent and a reinforced cavity for lower crossover frequencies.

**Measurements:** Tweeter impedances were measured with LMS as shown in *Figs. 1* and *2*. The impedance of the cavity damped version (27TAFC-G) shows a broad dampening of the driver resonance. Both drivers were mounted on an 8″ × 15″ baffle recessed above a recessed 6½″ driver. Response curves, depicted in *Figs. 3* and *4*, are very similar for both drivers, and differ mostly in the low-frequency rolloff of the drivers (the lower "Q" of the cavity version is obvious).

Both drivers exhibit a relatively smooth SPL profile and could likely be made to fit a less than ±2dB window above 2.5kHz with the proper network. The breakup mode for the metal dome material occurs at about 27kHz on both tweeters. On- and off-axis

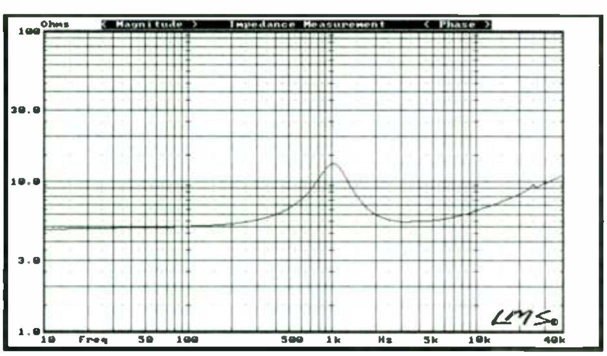


**FIGURE 1:** SEAS 27TAF/G tweeter impedance plot.


**FIGURE 3:** 27TAF/G tweeter on-axis frequency-response curve.

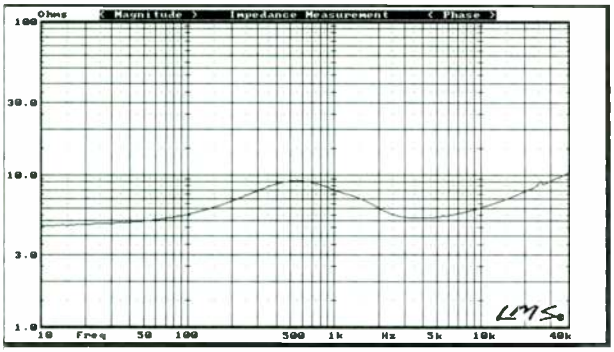


**FIGURE 2:** 27TAFC-G tweeter impedance plot.

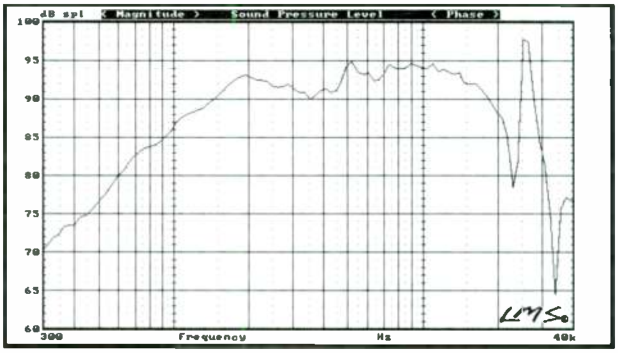


**FIGURE 4:** 27TAFC-G tweeter on-axis frequency-response curve.

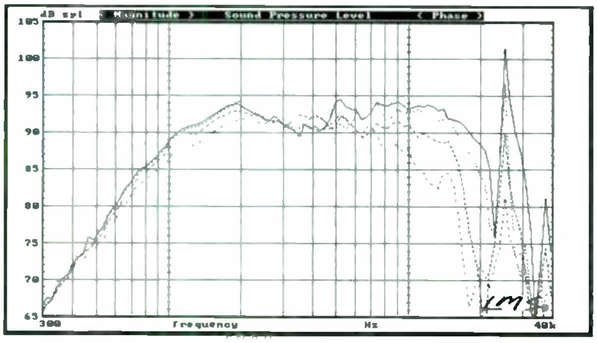


**FIGURE 5:** 27TAF/G tweeter on- and off-axis frequency response (solid = 0°, dot = 15°, dash = 30°, dot/dash = 45°).

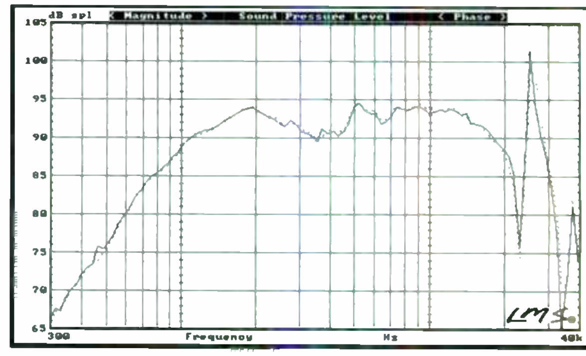


**FIGURE 7:** 27TAF/G tweeter SPL comparison for two samples.

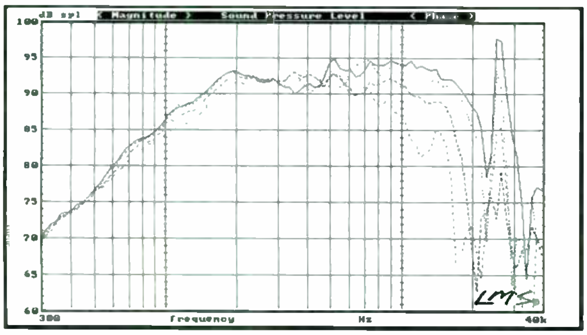


**FIGURE 6:** 27TAFC-G tweeter on- and off-axis frequency response (solid = 0°, dot = 15°, dash = 30°, dot/dash = 45°).

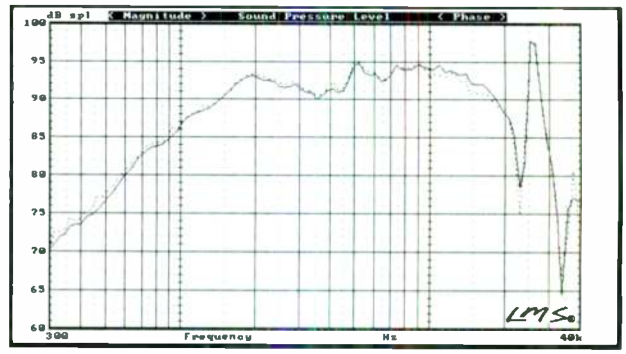


**FIGURE 8:** 27TAFC-G tweeter SPL comparison for two samples.

performance is shown in *Figs. 5* and *6*, and is also nearly identical for both tweeters. *Figures 7* and *8* show the two-sample SPL comparison, again showing the tight quality control exhibited by virtually all of the European driver manufacturers.

For more on these new metal domes, contact SEAS USA, 736 N. Western Ave., Ste. 33, Lake Forest, IL 60045, (847) 735-9255, FAX (847) 735-9256. The 27TAFC-G and 27TAF/G are available to consumers from the following distributors: Madisound Speaker Components, 8608 University Green, Madison, WI 53744-4283, (608) 831-3433, FAX (608) 831-3771, E-mail madisound@itis.com, Website www.itis.com/madisound; Zalytron Industries Corp., 469 Jericho Turnpike, Mineola, NY 11501, (516) 747-3515, FAX (516) 294-1943; and Solen Electronique, 4470 Avenue Thibault, St. Hubert, PQ J3Y 7T9, Canada, (514) 656-2759, FAX (514) 443-4949, E-mail solen@quebec.net, Website www.quebec.net/solen/.

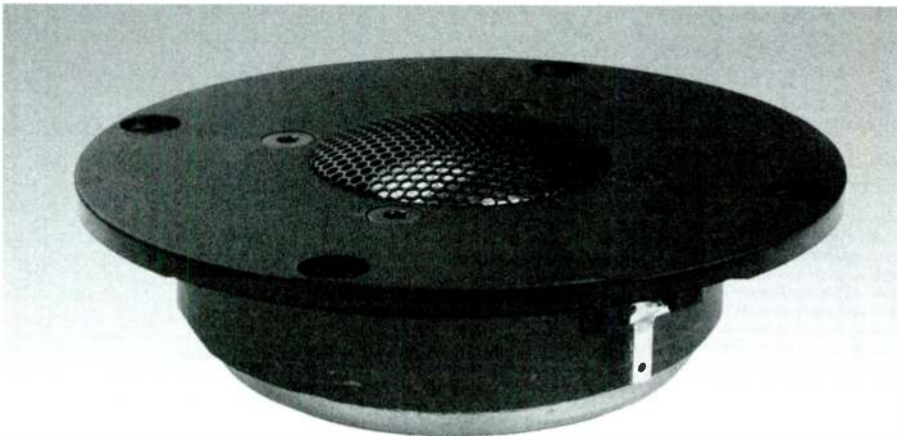

**PHOTO 1:** SEAS' 27TAF/G metal-dome tweeter.

## CROSSOVER CORRECTION

An error has appeared in *Loudspeaker Projects #1*, p. 64, Fig. 2. I have simulated the proposed crossover and it is inadequate. An 18dB series crossover should appear as noted in *Fig 1*.

Patrice Pelletier
Quebec, Canada

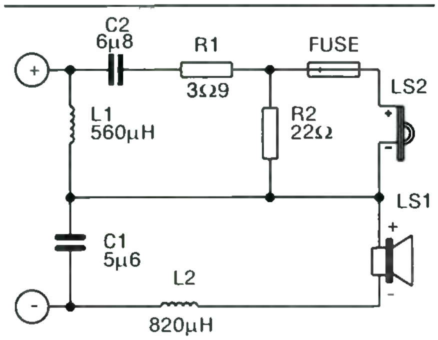


**FIGURE 1:** The corrected crossover.

## EARLY YEARS AT AR

Although writing letters to editors is not one of the items on my agenda, the article "Rebuilding the AR-3*a*, Part 2" (*SB* 7/97), screams for some comments. To start with, the author, Tom Yeago, must have been consuming some of the hallucinogenic mushrooms of *Maria Sabina* (Cantata by Leonardo Balada, Louisville Records) in either his salads or omelets. Either that or he possesses very, very long legs (longer, perhaps, than Fred Astaire's) to be able to jump to some of the inaccurate conclusions which he has reached.

To begin with, the article should have been properly headed "Redesigning the AR-3*a*." Second, there are some comments in the article which require clarification or correction. Although it's really impossible to go through all the statements point by point, I will pick on some particularly salient ones.

1. The free-air resonance of the AR woofer was designed to be 14Hz and was meticulously kept at that frequency. It was also designed to have, and carefully kept at, a peak-to-peak excursion of 5/8-inch. Its resonance in the box was also designed to be, and kept at, 44Hz with a "Q" of 1.

2. It may surprise many people that Acoustic Research invented and applied for a patent covering the dome radiator (dome with poured latex suspension, 1959). When the dome was developed, there were really no suspensions which had been worked out previously, permitting utilization of a dome radiator in a magnetic structure. One must look at the AR-3 and the AR-3*a* domes as

the beginning of a technology which evolved into the current, much-improved suspensions. Remember, the AR-3*a* dates back to the late '50s, making it some 40 years old. The foam suspension used in the AR-3 and AR-3*a* was the simplest and best available manner, at that time, to suspend the dome.

Contrary to Mr. Yeago's statement, there were no "Brits" lurking anywhere. In actuality, the people involved in the design of the AR-3*a*, including the domes, were all Americans. They were primarily of Jewish, Italian, and other extractions. There were many workers at AR, but no British nationals. That came 20 years after this period.

3. At the time of the AR-3*a*'s design, it was much cheaper to buy a big magnet and essentially "throw away" some of its potential than to machine plates for perfect fit. The assembly of the midranges and highranges, nevertheless, was very carefully watched and the torque of the electric screwdrivers used during assembly was checked twice a day to make certain that the correct tension was applied to the top and bottom plates. If incorrect tension was placed on the top plate, the result would be a peak in the response of the highrange, primarily, and would cause a reject during test.

Furthermore, the tweeter was not down in output because of the magnetic structure or any other factor such as mass, voice coil, and so forth. It was actually designed to be down in output. There were many reasons for this design parameter, but the most important was that the AR-3*a* was designed to emulate the spectral energy distribution at an ideal seat in a concert hall such as Symphony Hall in Boston. Records of the day were neither recorded nor cut that way (spare me exceptions, please).

4. I quote one statement on page 19, "...those were hectic days; the company was opening factories right and left." The fact is that AR had only one factory and continued to have one factory for decades. The original was at 24 Thorndike Street in Cambridge, MA, and all the drivers were made in that building. In the very late '50s, AR expanded into a building directly across the street (actually, its entrance was on Otis Street), and this was primarily used for warehousing and shipping. Subsequently, the Test and Final Assembly departments were moved to Otis Street. In the early '60s, the Otis Street facility was expanded to accommodate the AR turntable manufacture and assembly, but it would be hard to say that this was opening another factory. The situation remained as in 1960 until Acoustic Research moved to 10 American Drive in Norwood, MA, in the early '70s.

Oh yes, there was a Final Assembly facility set up in Holland, which subsequently moved to England (Houghton Regis), but the drivers were still manufactured in Cambridge. Only final assembly took place at this other facility. But this did not occur until the very late '60s and early '70s. Primarily the purpose was to try to reduce import duties of US-manufactured loudspeakers sold in Europe. It should be stated quite clearly that there were no other manufacturing facilities producing any of the AR products. This, of course, does not include the Western Electric "tweeter," which was used in the AR-1, nor the Carbonneau tweeters/midranges, which were used in the AR-2 and AR-2a.

5. The "damned stuff" surround used on the AR woofer requires some explanation. The AR woofer was originally designed using Western Electric 728B as a source. This was a highly regarded driver used for monitoring in broadcast studios and for cinema work. The inventor of the acoustic suspension system, Edgar Villchur, used the cone on the 728B and had his wife Rosemary fabricate a surround using the edge ticking of an old mattress. This was used for the prototype of the acoustic suspension woofer, and was chosen because of its excellent cone performance and because it was readily available. The mattress material, of course, was treated to prevent leaks.

When the AR woofer was put into manufacture, the cone material had to be formulated for good damping characteristics, weight, and so forth. Most of the experimentation resulting in the final cone formulation seems to have been done by Henry Kloss[1]. The goal was to produce a cone with a Young's Modulus which would reduce cone breakup and be "lossy" enough to damp out the peaks and other breakup modes which were caused when the cone reached its upper limits (600Hz) and began to behave as several diaphragms rather than one. The surround was fabricated of a linen-like fabric which was saturated with phenolic and then pressed to shape in a mold. To make the annulus air-tight, the material was then painted with butyl rubber and darkened with carbon black.

The procedure was not as simple as it sounds. The impedance of the surround had to be correct so that when the acoustical energy traveled through the cone from the voice coil, particularly at and above cutoff, it would not be reflected back from the adhesive and surround, thereby causing standing waves which would ensure serious cone breakup. The butyl-rubber treatment of the surround was very helpful in the

*to page 59*

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*from page 55*

mechanical performance of the surround. Some early woofers can be seen to have a termination at the junction of the surround and the cone, because, on test, specifications were not met for cone breakup after cutoff.

Unfortunately, the latex lost some of its properties through time and, after a few years, some of the surrounds began to "flap." Also, the manufacturing process of the surround could not be done precisely enough to ensure identical performance from each and every woofer. This latter was a characteristic which was demanded by Ed Villchur and held to very tight tolerances. Indeed, every woofer was thoroughly checked for all kinds of parameters to ensure that the performance of each woofer was as close to the ideal as possible.

Due, in part, to the factors described above, AR was always looking for a better and more uniform material for the annulus. This showed itself in the form of "foam." A lot of other materials were tried, of course. But it proved that this "damn stuff" was the best available to fulfill the requirements of the surround.

The closed-cell foam which was used for the annulus had to go through a forming process (actually pressed in a heated die) much as the original cloth, and there was no evidence, nor did tests reveal, that it would degrade with time. Please note that at this particular point, all loudspeakers used an "accordion" outer suspension and no one used the half-roll surround technique. No other companies were interested in mechanically linear excursion in those days.

As an aside, the mat for the AR turntable was selected to damp not only resonances in the cast, machined turntable platen, but also to damp vinyl resonances (please remember in those days, the "raised edge" and label of vinyl discs made their appearance, leaving the center part of the record, with the modulated grooves, unsupported). The entire industry followed suit and used the foam half-roll surround, and many drivers still use it to this day, with consequent deterioration.

6. The original AR woofer used a voice-coil former made of a copper alloy similar to bronze. Circular perforations were punched on the top of the former, next to the apex of the cone, to relieve pressure behind the dust cap, while the woofer moved forward and backward, and to help cool the voice coil and its former. It was found, however, that the voice coil separated from the former under certain situations, due to heating of the voice coil and the former. The wire used to form the voice coil on the former was very similar to "transformer wire," which was supplied coated with an adhesive activated by heat.

Once the former, with a coat of a similar adhesive, had the voice coil wound on it (on a mandrel), the assembly was "cooked" in specialized ovens to activate and cure the adhesive and bond the voice coil turns to each other and to the former. Interestingly, KLH used DC running through the voice coil to generate heat and accomplish a similar result. In certain applications, particularly when people tried to get levels out of the loudspeaker beyond the capability of the power amplifier, the average power going into the woofer coil, primarily, exceeded the heat dissipation capabilities of the coil, resulting in serious voice-coil overheating. This softened the adhesive on the voice coil and the former, resulting in windings "letting go" and separation from the former.

Nomex® was picked because it was much more resistant to these over-temperature conditions. Using Nomex did not mean that the voice coil and former were made impervious to these circumstances (overdriving and overheating), but it made the assembly much more resistant to abuse. There were many other factors involved, but the length of the explanations preclude inclusion in this letter.

An aside concerning the impedance of the AR woofer and the AR-3*a* is necessary and interesting. The voice coil of the woofer ended up being 4W simply because in the original AR-1, the Western Electric "tweeter" selected for use (then made by Altec Lansing, the 755A) had a 4W impedance. The reason an 8″ tweeter was selected for use was that, at that time, there were very few high-frequency devices available. The 755A was a highly respected, small monitor, full-range speaker used in both broadcast and cinema applications. Other loudspeakers, mainly made by G.E. and others, did not have the necessary uniformity from unit to unit which was demanded by people at AR.

Because the 755A had a nominal impedance of 4W, the woofer ended up being 4W.

There have been a lot of explanations advanced for the AR speaker being 4W, but the actual reason is the one stated above. It had nothing to do with drawing more power from amplifiers, because at the time of the AR-1's design, amplifiers were almost all tube units with output transformers which had 4W taps. Transistor amplifiers did not make their appearance until five years after the design of the AR-1 woofer.

7. I am afraid that Mr. Yeago will find that ferrofluid, even the modern variety, will not remain in the woofer gap. Many, many experiments were run dating back some 25 years, and the result was that the woofer voice coil, moving over a distance of some 5/8-inch would "blow" the ferrofluid from the gap.

8. Concerning the extension of the bottom end of the design to 35Hz or lower, it can only be done at the expense of much higher low-frequency distortion, or a meaningful decrease in the sensitivity (sometimes incorrectly called "efficiency") of the woofer, and thereby the system. The spectral energy distribution of the AR-3*a* would be grossly affected and this would not be a "Rebuilding of the AR-3*a*," but a redesign of the loudspeaker, violating its original premises. My suggestion is that Mr. Yeago look into "Hofmann's Iron Law."

9. Interestingly, as far back as 1960, Acoustic Research had been experimenting with other cone materials. In one instance, we were checking the performance of an expanded polystyrene molded cone. The results were very unsatisfactory in that the peak-to-trough ratio in the response caused by cone breakup exceeded 14dB. In addition, the termination/matching of the surround became very, very critical and unsatisfactory. Mr. Yeago must be very careful when attempting to use aluminum-skinned polystyrene, particularly without extensive testing facilities, to assess the mechanical performance of the devices which he might be using.

The above is by no means intended to cover all statements or points concerning Mr. Yeago's articles. I have tried to cover the most meaningful ones (and not all) without writing a book. Some others will have to go unquestioned and unanswered.

The Quality Control procedures at AR during that time were incomparable and unique in the industry. Every step was checked and tested for important and critical specifications. No other loudspeaker manufacturer approached the thoroughness of this Quality Control. Even today most manufacturers fail to effect these control procedures with specialized test equipment at every step. In most cases, a final test of the finished product is undertaken at differing levels of thoroughness with a rather cavalier attitude toward variations in specific individual parameters. At AR, research was actually undertaken and followed through. AR did not simply stuff drivers made by someone else into a cabinet and call it the "Bopmagilvie Superior."

It is easy to look with disdain at the accomplishments which were effected 40 or more years ago, particularly when these techniques were used as the base for furtherings which progressed to what is now jokingly called "state-of-the-art." Incidentally, how is Mr. Yeago's 1960 automobile working nowadays? How about its door, engine, and hydraulic gaskets?

C. Victor Campos
Framingham, MA

1. "Conversation with Henry Kloss," *Audio Amateur*, 3/71, pp. 3–7, 20.

(Mr. Campos was a member of the early management team at the original AR facility in Cambridge, MA.—Eds.)

*T.D. Yeago responds:*

*A chastening, if not actually irate letter, from C. Victor Campos! What fun! I'll save his first paragraph for last, so let me start by agreeing absolutely that my humble little series ("Rebuilding the AR-3*a*," SB 6/97–3/98, barring catastrophe) would be better titled something other than "Rebuilding..." That's an editorial call. My working title was "AR-3*a* Remake" and sharp readers saw "Remaking..." surviving into the "About This Issue" and table of contents of 6/97, but no further. Any reader who got as far as the second page was warned I was embarking on a major modification, not a simple refurbish. To borrow across cultures from our automotive brethren: anybody can restore, real men chop and channel.*

*Now, let me say I'm very happy to have provoked Mr. C. Victor Campos into writing, because not only am I happy to be corrected, I am pleased that he took the time to give us some valuable background. "Salad Days at Acoustic Research" isn't a title that would jump onto the bestseller lists, but these anecdotes and war stories are catnip for us audio geeks. Now, by the numbers:*

*1. I yield, and gladly. If I wanted to weasel out of this I could suppose my replacement (and modded) surround stiffened the composite suspension enough to bump $f_s$ to 16Hz from the specified 14Hz. But no. I likewise accept correction when it comes to the stock system resonance of 44Hz (versus my calculated 43Hz) and system Q of 1.0 (versus my calculated 0.9).*

*And regarding pk-pk woofer excursion, I think we can agree that the motor coil is 1.04" tall and the top plate 0.5" thick, although it's chamfered to 0.47" or so at the gap.*

*2. I thought the AR-3 showed up in '58, the AR-3a in '68, although I naturally enough don't know when the drivers were designed. And my crack about my suspicion of a Brit lurking, well, that was a joke. I believe it's generally accepted that, for whatever reason, the English have a history of and propensity for arriving at engineering solutions that are startling, eccentric, and even strange. Having said that, I would also add brilliant (sometimes) to the list. I think Peter Walker deserves a knighthood.*

*3. OK, so parts that fit poorly, by modern standards, were incorporated into the engineering. It seems to me that occasionally the pieces would fit, what then? And I'm not certain what Mr. Campos' point about the electric screwdrivers and their torque has to do with this, unless he's saying the clamping fixtures used to squeeze the magnetic structures during glue-up were tightened with screws, whose torque was closely controlled. Even so, the units I've played with showed considerable variation in flux density, remembering I'm not using the most sophisticated methods.*

*I'm glad to learn, at last, from an authoritative source that the treble unit was designed to be down on output (re: the woofer). Why did the AR ads of the time show the (spliced) response curves as predominately flat, eh?*

*4. I stand corrected. My remark about AR opening up factories was speculation arising from a remembered remark by Henry Kloss in some interview or other. He commented that one of the reasons he and his band left to start KLH was that things were hectic, factories had to be started up, decisions had to be made, and because of AR's inert organization, nothing got done. I misremembered.*

*5. I thank Mr. Campos for telling us the tale of AR's woofer surrounds, culminating with the accursed foam. I hope he doesn't think I'm faulting AR for failing to see into the future and divining the dreaded foam rot (Y. Berra: Predictions are tough, especially about the future). But I am confident I speak for, well, hundreds when I say I hate it. Oh, and does anyone know if our present foam will suffer similarly?*

*6. Again, thanks to Mr. Campos for the skinny on the woofer's nominal 4W impedance.*

*7. Yeah, ferrofluid in a woofer. I haven't been inside to check, so Mr. Campos may be right. I wouldn't be surprised. In my reading I've come across only two instances of liquid-cooled woofers—one in a '70s era system, the other in an aluminum-coned woofer in one of the catalogs. But I figured it was worth a shot, considering that I took steps to keep the ferrofluid in place (see Part 4, SB 1/98). I figure between the vent down the center pole, smooth surfaces (pole face and former surface), increased flux density, and filling the space only half full, I have a decent chance.*

*8. I never claimed to extend the bottom end to 35Hz. A speaker with a system resonance at 35Hz and system Q of 0.5 is very different from one with system resonance of 45Hz and system Q of 1.0. And yes, I'm familiar with mass/motor/efficiency-sensitivity tradeoffs; give me a little credit.*

*9. OK, about this cone; I was obviously aiming for a nice rigid (within the band) piston. Styrene foam with an aluminum skin glued to AR's woofer seemed like a good idea, since I was determined to add mass anyway. Just how good an idea we'll all find out when Mr. D'Appolito puts one of my units through the wringer, er, test regime. (When he wrote me telling of his decision to publish, Mr. Dell offered to have Mr. D'Appolito subject one of my units and a stock 3a to the usual tortures, which offer I eagerly accepted, as he's paying shipping.) It will be interesting to see how my seat-of-the-pants approach fares under duress, but I'm also curious to see how well the stock unit does.*

*I have tried to be careful not to characterize my efforts as authoritative or this loudspeaker as exceptional. I simply indulged myself to see what I could do with this unit. I hope readers have found my little project interesting. I half suspect Mr. Campos thinks I was mocking Acoustic Research and all who labored there. Not at all. I would never have given the time and effort to this little project (let alone write it up) if I didn't think these were worthy units to start with, which might be improved. One cannot make a silk purse from a sow's ear, or didn't I make all that clear in Part 1? At any rate, what exactly my labors have accomplished will be learned soon enough when Mr. D'Appolito goes to work.*

*In fact, the car I drive misses the '60s by only a few years, and although it needs regular attention, its doors (?), engine, and hydraulic systems function well enough. I have friends who have much older cars, and know of a few people with Model A Fords, Packards, and other similar cars, all in excellent order. I appreciate them in context, naturally. I don't confuse them for modern, or I should say contemporary, cars.*

*Lastly, I am curious to know: what's the provenance of the word "Bopmagilvie?" And, in fact I am confident that, while not* *"very, very long," my legs are longer than the late Mr. Astaire's. And if Mr. Campos will write or phone me and set me straight on my too-numerous-enumerate mistakes, I will cheerfully compile them for SB readers. And I say again: I'm glad I provoked Mr. Campos into writing. Let's have more tales from the formative years.*

## STICKY SOLUTION

With regard to Tom Yeago's request for more information on high-temperature adhesives ("Rebuilding the AR-3*a*, Part 3," *SB* 8/97), the following companies may be helpful.

Masterbond Adhesives
154 Hobart St.
Hackensack, NJ, 07601

Cotronics Corporation
3379 Shore Pkwy
Brooklyn, NY 11235-3693
718-646-7996,
FAX 718-646-3028

Cotronics manufactures 3000°F ceramics and 700°F epoxies, adhesives, sealants, and coatings.

Michael Machnica
West Seneca, NY

## PEERLESS PARAMETERS

Vance Dickason's "Driver Report" covering the Peerless CSX 257H woofer (*SB* 1/97, p. 53) inadvertently included the incorrect table. The LEAP measurements of the CSX 257H compared to the factory specifications are as shown in *Table 1*.

**TABLE 1**

**PEERLESS CSX 257H PARAMETER COMPARISON**

| | SAMPLE A | SAMPLE B | FACTORY |
|---|---|---|---|
| $F_S$ | 25.6Hz | 25.7Hz | 24.5Hz |
| $R_{EVC}$ | 5.82 | 5.81 | 5.9 |
| $Q_{MS}$ | 4.05 | 5.50 | 4.32 |
| $Q_{ES}$ | 0.41 | 0.40 | 0.38 |
| $Q_{TS}$ | 0.37 | 0.37 | 0.35 |
| $V_{AS}$ | 125.3 ltr | 122.8 ltr | 139.5 ltr |
| Sens. | 89.75dB | 89.86dB | 88.9dB |
| $X_{MAX}$ | 4mm | 4mm | 4mm |

## HELP WANTED

I have a pair of old Bose 601 series II speakers, and would like to rebuild them. Does anyone have any info or advice to make them better with updated crossovers and drivers?

Shawn Baker
Classic Stereo
3714 S. Reed Rd.
Kokomo, IN 48092
FAX 765-453-4534

*Readers with information about this topic are encouraged to respond directly to the letter writer at the address provided.—Eds.*

## LETTERS/INQUIRIES

*Speaker Builder* encourages reader feedback in the form of letters, queries, and comments. Send correspondence to:

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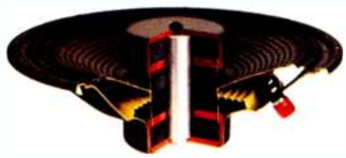

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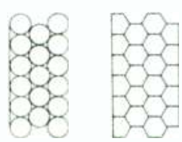

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