FOUR/85

U.S. $4.00
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SPEAKER BUILDER

DALINE DESIGN

Good News

BOSTON ACOUSTICS has some new releases with the introduction of two more automotive component speaker systems at CES, the 761 and 793, and the improved A60. BA now offers a complete line of automotive speaker systems designed to fit the four most common factory cutouts in cars. The new 761 is a two-way component system consisting of a 6½-inch woofer, the Varimount™ CFT 1-inch dome tweeter, and a crossover network that is separately housed for installation convenience.

The 793 is a three-way system consisting of a 6 by 9-inch subwoofer, a 4-inch midrange, the Varimount CFT tweeter, and a custom designed crossover.

The A60 Series II, two-way, acoustic suspension speaker system, is an advanced version of the original A60. The same size as its predecessor, the A60 Series II provides power handling and stereo imaging superior to the original.

The A60 has a combination of drivers not presently available in speakers of its price class: a newly designed 8-inch polypropylene woofer and the CFT 3 1-inch dome tweeter, which uses a 1-inch voice coil with ferrofluid cooling, and a Hemispheric Texlite Diaphragm which has excellent inherent damping for a smooth, accurate response.

The A60 has the following specs: frequency response, 52–20kHz, ±3dB; impedance, 8Ω, nominal; power rating, 60W; sensitivity, 90dB/W/m; dimensions are 18¼ by 11¼ by 7¾ inches.

Contact Boston Acoustics, 247 Lynnfield St., Peabody, MA 01960, for more information on their automotive speakers.

Fast Reply #IH336

dbx INC. introduces Soundfield Ten, a lower-priced version of the Soundfield One speaker system, incorporating Soundfield's technology and imaging properties. It comes with an outboard controller that has high and low-frequency compensation controls, and an ambience circuit for adding spaciousness. There is also a new controller feature, a Wall EQ switch. This equalization switch compensates for the effect that against-the-wall placement has on loudspeakers. Music lovers can have truly flat power response, with the speaker either against the wall or out from the wall.

Additional information is available from dbx, Inc., PO Box, 100C, Newton, MA 02195.

Fast Reply #IH85

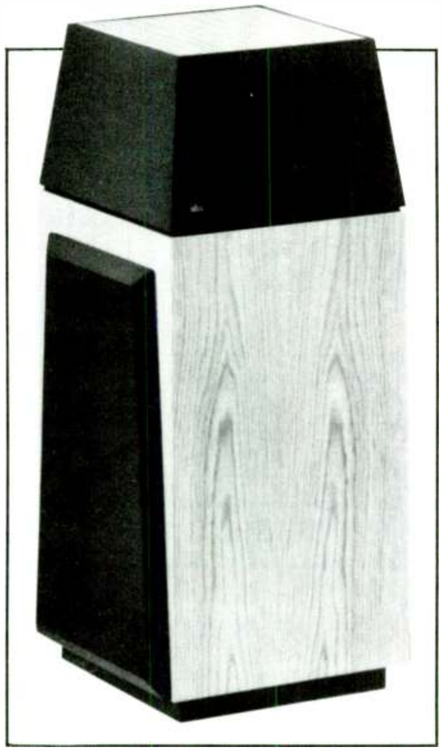
The Dimensions Unheard loudspeaker line was announced recently by **REEL TO REAL DESIGNS** with its *Legacy-1* four-way dynamic speaker system, featuring a Samarium Cobalt leaf tweeter, a 1½-inch European soft dome midrange, 6½-inch inverted roll polypropylene mid-bass driver mounted in an acoustically inert tubular sub-enclosure, and a 10-inch polypropylene subwoofer coupled to a multi-chambered reflex enclosure with a fourth-order Butterworth alignment.

The Legacy-1 uses a phase/amplitude correct hybrid crossover to create a transition between drivers, avoiding the vertical stratification in some other four-way designs. All drivers are sensitivity matched. The system is internally wired with high definition cable and is bi-amp, or bi-wire capable, through multiple gold-plated binding posts. Frequency range is 30Hz to 30kHz.

The extensively braced fibrecore enclosure is covered in select walnut veneers on all exposed surfaces with solid walnut mouldings and tilt base. The Legacy-1 weighs 83 pounds and measures 42½ by 12¼ by 13 inches. The system is also backed by a ten year warranty.

For more information contact Dimensions Unheard, Dept. SR, 3021 Sangamon Ave., Springfield, IL 62702.

Fast Reply #IH1060



The model X65 Servospeaker, has been introduced by **MARCHAND ELECTRONICS**. The system combines three power amplifiers, electronic crossover network and control circuits with the loudspeaker drivers in the same box. The Servospeaker features a motional feedback system on the 6½-inch woofer that extends the frequency range down to 40Hz, and considerably reduces the distortion at the low frequencies. The loudspeaker produces a clean and powerful sound without coloration from the lowest to the highest frequencies.

Also available are the models X80, X100 and X120 Servospeakers. These speakers have the same features as model X65, but have larger woofers and allow higher sound levels at the low frequencies.

Marchand will gladly do custom modifications, and the speakers come with a one year limited warranty on parts and labor.

Contact Marchand Electronics, Inc., 1334 Robin Hood Lane, Webster, NY 14580, for further information.

Fast Reply #IH1068

SPEAKER BUILDER
MAGAZINE

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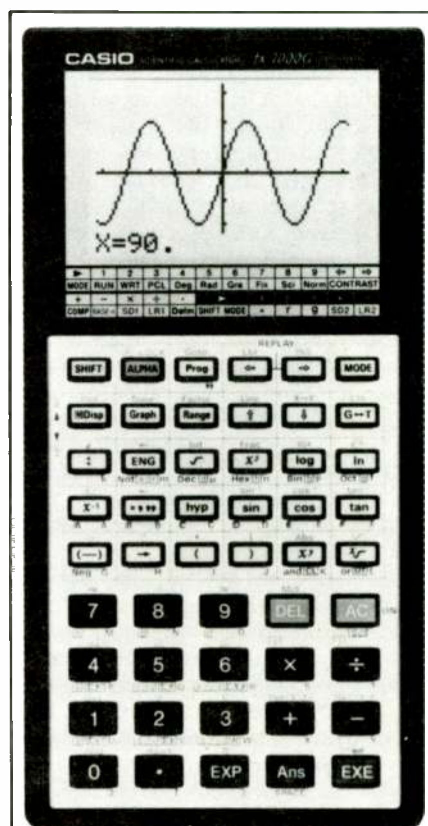
CASIO, INC. of Fairfield, NJ, has developed a new scientific calculator, the model FX7000G, that is capable of displaying numerical equations as graphs upon the touch of a key. It has a large 2.17 by 1½-inch liquid crystal panel (96 by 64 dots), and it measures 3.3 by 6½ by ½ inches, and weighs about 5.5 ounces.

The new Casio's features include: changes in the numerical value itself are shown as continuous graphic fluctuations; two or more function equations can be simultaneously displayed as a graph; several equations can be mixed together to formulate a combined graph; and other features can be seen by a simple operation of the keyboard. The Casio calculator is like a miniature computer with speeds four times faster than conventional calculators.

Fast Reply #IH1069



Good News

DESIGN ACOUSTICS, a division of Audio-Technica, has recently added two new speaker systems to their product list: a new three-way, 8-inch loudspeaker system, the PS • 8a; and a video speaker system, the PS • 6V.

The drivers utilized in the PS • 8a are: an 8-inch, down-firing, mass-loaded woofer, a 4-inch mid-woofer, and a ¾-inch soft-dome tweeter. An Optimized Decade Crossover keeps bass frequencies well below, the high frequencies well above, the critical midrange.

The frequency response of the PS • 8a is 55–21kHz, and impedance is 8Ω. The system is recommended for use with amplifiers rated from 15 to 200W per channel. The PS • 8a is finished in walnut-grained vinyl with a brown grille.

The PS • 6V is a two-way loudspeaker system for use with video monitors. Its magnetic shielding prevents stray flux from the speakers' magnets from interfering with the CRT in adjacent video monitors. This system features a 6-inch long-throw bass driver that crosses over at 3kHz into a ¾-inch soft dome tweeter. It's finished in tough, mar-resistant black with a gray grille, and may be used with amplifiers rated at 10–100W per channel.

Speaker stands are available for each.

For more information contact Design Acoustics, 1221 Commerce Dr., Stow, OH 44224.

Fast Reply #IH345

About This Issue

This first ever 64-page *Speaker Builder* issue is decidedly a builder's delight. **Thomas Cox** offers his all purpose, exploratory transmission line enclosure (p. 9) and three possible TL systems he tested with the five-port rig. We welcome **David Weems** to these pages who follows up on work by **George Augspurger** and **Dick Marsh** (see *SB* 3/80, p. 7) in a tiny double-chamber enclosure vented with plastic pipe (p. 14).

L.A. White goes to the nether end of the cabinet rigidity parameter and builds enclosures with near-rubber walls. His well researched thesis will stir a lot of reaction, no doubt.

Carlos Bauza saw a Robert Fris design in a British publication and decided to build an enhanced version of it. His fine report on the decoupled antiresonance line married to the famous LS3/5A drivers begins on page 25. **Bob Killingsworth's** and **Dave Tryon's** work graces our *Tools, Tips & Techniques* section (pp. 42-45) with good ideas on cabinetry design and execution. The *Letters* interchanges this time are vital and extensive.

If this is the final issue in your subscription, be sure you renew right away, **Bob Bullock's** crossover series continues next time, along with a tiny transmission line, pentagonal cabinetry, and a line driver design.

SPEAKER BUILDER

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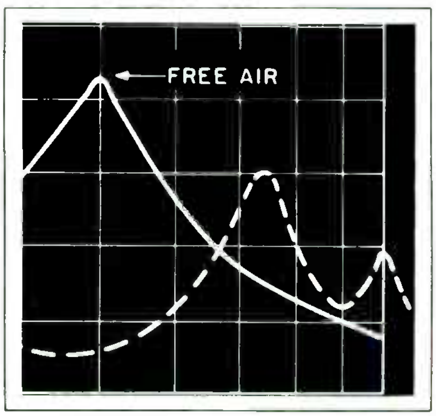

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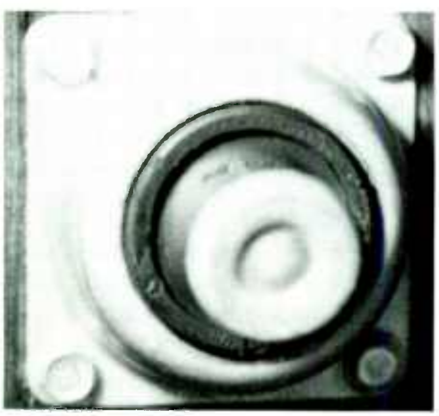

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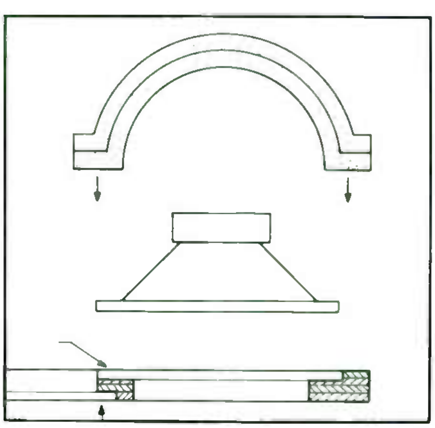

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FEATURES

DEPARTMENTS

Editorial

New Year, New Game

It is probably no secret to you and other *SB* readers that loudspeaker technology has been "in flux" in the last four years. By that I mean that the complexities of enclosure, driver and crossover design are finally coming to be more fully understood and explored and just at a time when new manufacturing materials and exploration tools are multiplying the options.

As you scan this issue you will doubtless notice offerings from a number of driver manufacturers and dealers. The business is booming. But you will also notice the manufacturers are almost all Europeans. The Danes, Norwegians, Germans, French and also the Israelis have spent the R & D money and are seeking a new U.S. market which our local, generally fat (and lazy) U.S. manufacturers scorn. The U.S. is a large market and the high profits and easy success of fully manufactured consumer and professional loudspeaker projects makes the home builder's need look puny by comparison. This attitude has also infected some British manufacturers, apparently, since we can buy few fine drivers from Britain here in the U.S. but our British cousins are eagerly encouraged to do so in the U.K.

But the situation is more serious than that. A growing number of U.S. speaker manufacturers are buying their R & D "offshore" because it is cheaper and quicker. It follows that their manufacturing will also go overseas as well.

Fortunately for us, as our level of knowledge about driver parameters increases, the necessity to control manufacturing tolerances becomes more obvious and those who are making the newer units are making very serious efforts to improve uniformity. Thus they are responding to more informed end users.

Computers are another large factor fuelling this development. Manufacturing control is now easier and cheaper, as are design and end result analysis. The computer now in 18 of each 100 American homes is another reason why the speaker enthusiast knows so much more about how his system behaves. And the computer gives us a tool to explore all the possible systems we could build—and uncovers some ideal driver characteristics we would like to have.

All of this is also rapidly building a marketing infrastructure which is beginning to serve our needs in an outstanding way. The dealers I talk with across the country are more knowledgeable, responsible and service oriented than almost any area of electronics I can think of. It is true we have had a few casualties and missteps—but that happens in any industry and are always the result of poor management judgement or greed.

But the rich array of hardware choices and the new tools now available (hardware and software) make speaker design and construction an exciting and deeply rewarding avocation.

The other vital ingredient in all this growth and development is the very dedicated, hard work of the authors who make this publication possible. Many of you write to say nice things about *Speaker Builder* and while I appreciate those comments—they should rightly be directed to our hardworking authors whose love of this avocation makes the publication possible. Our staff does a fine job in packaging and shipping the vital information you read here about loudspeakers, but it is our authors and contributing editors who are pushing the frontiers for all of us.

So we welcome a brand new era in hands-on speaker technology. It is time for many more of you to get out of the armchairs and into the sawdust. We're only at the beginning of a new time of improving that last barrier to sound that is closer and closer to the original.—Ed.

AN EXPERIMENTAL TRANSMISSION LINE

BY THOMAS E. COX

How long should a transmission line (TL) be for the best driver match? How short can it be before performance suffers? When TL speaker systems used air as the transmission medium (acoustical labyrinths), the length suggested for best driver match was a quarter wavelength at the driver free-air resonance. In the 1960s, A.R. Bailey began stuffing TLs with various kinds of wool, and the game changed.

Bailey's original article[1] and many that followed[2,3] covered the low-pass filter and reduced sound-velocity effects of line media such as raw wool, fiberglass and polyester batting. Detailed descriptions of methods to determine length for a particular driver and line medium were limited, though.

Since limited information was available and my current project involved the use of small drivers in TLs, I built an experimental line as a design tool. *Figure 1* shows the internal layout and external dimensions of the experimental TL. I used ¾-inch AB-grade fir plywood fastened with liberal amounts of glue and screws. I installed removable opening covers and line stops *(Fig. 2)* so that I could change port location and line length. *Figure 3* shows the enclosure with the 39-inch port opening cover removed.

The line cross-section dimensions are uniform along all lengths at 7½ inches high by 6 inches wide. Port openings are 9 inches long by 5 inches wide. I stapled plastic bird netting (sold in garden supply stores for fruit-bush protection) at 6-inch intervals to support the stuffing materials.

I used two types of stuffing material—long-hair wool (available from J. Ebbert, 431 Old Eagle School Rd., Strafford, PA 19087 for $13.50/lb. including shipping) and a polyester material called Poly-Fil (manufactured by Fairfield Processing Corporation, Danbury, CT). Several different textures of Poly-Fil are available, but I used an open-texture variety called Extra Loft, which I found at a local fabric store in 45-inch-wide rolls. Packing density for the wool and polyester was 8 ounces (½ pound) per cubic foot. I designed a removable driver mounting panel and enclosure top so that I could change stuffing materials and drivers. The mounting panel and top were fastened with screws and sealed with a closed-cell vinyl foam used to seal windows.

DRIVER TESTS. I tested three drivers—the Madisound 6102, the Peerless TP165F and the Speakerlab W618P—all of which I broke in with ten hours of musical input. The tested free-air resonance and manufacturer's specifications for Q_{TS} and V_{AS} are listed in *Table 1.*

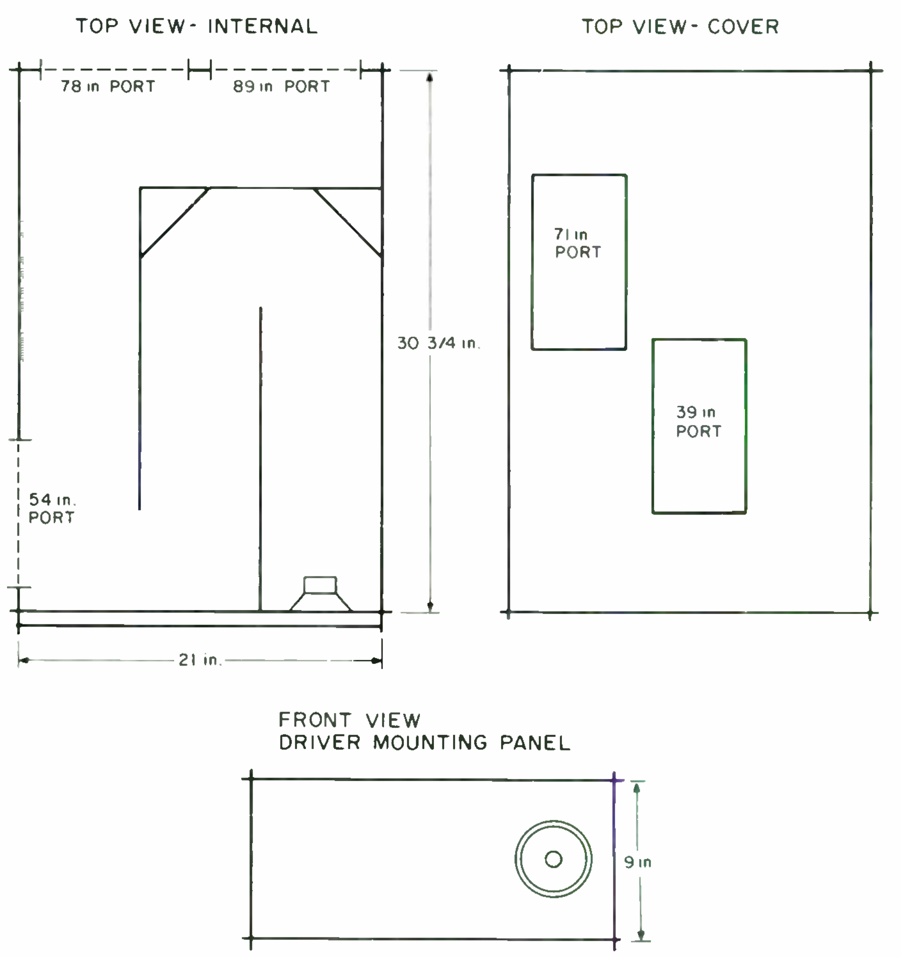

FIGURE 1: Internal layout and external dimensions of the experimental TL.

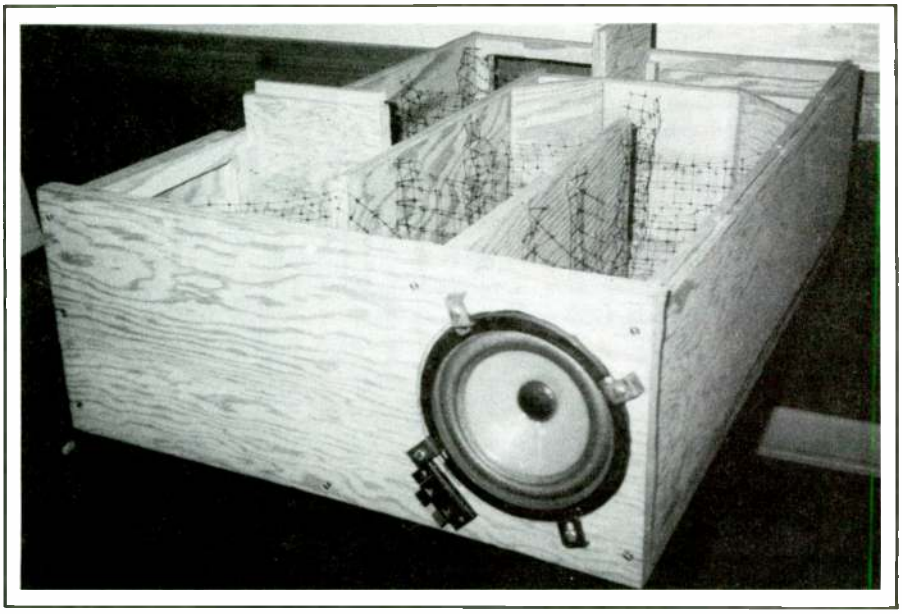

FIGURE 2: The author installed removable covers and line stops so that he could change port location and line length. Two line stops have been partially removed to show their locations.

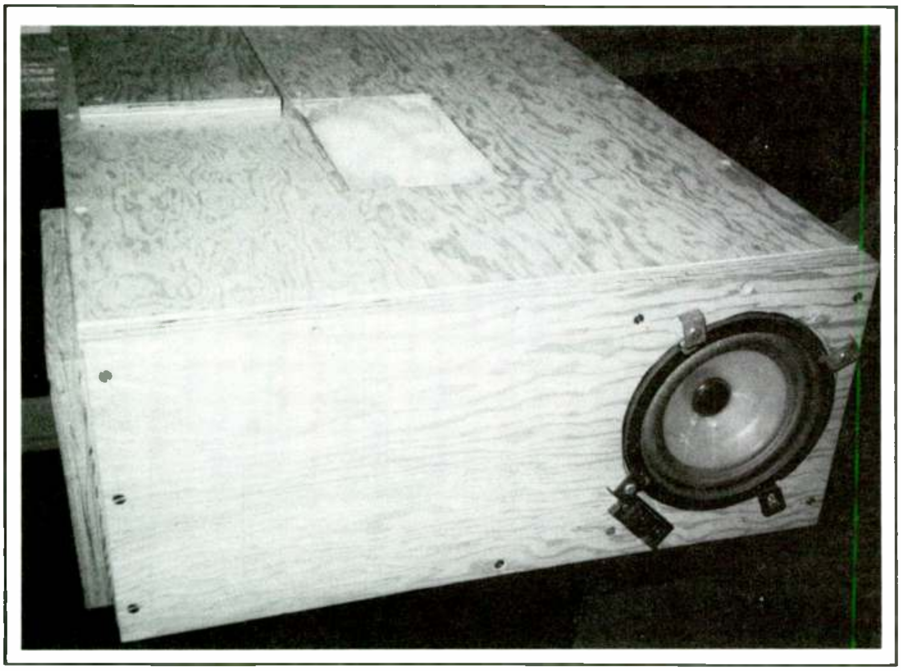

FIGURE 3: The completed experimental TL looks like this with the 39-inch port cover removed and all the other port covers and the top installed.

I used a Heathkit IG-5218 signal generator (specified frequency accuracy ±5 percent of the first two digits) to generate sine-wave audio signals. Separate frequency switches for units, tens and multipliers make frequency selection and repetition unusually easy. I determined the resonance peaks by connecting the drivers to the signal generators through a 600Ω, ½W resistor and measuring the voltage drop across the driver terminals with a B & K Model 277 FET electronic multimeter. Sine-wave input varied from 15Hz to 200Hz.

Table 2 shows the resonance peak information by line length, driver and line medium. I measured line lengths along the cross-section center line. Only two significant resonant peaks were measurable. At some of the longer line lengths, a "none" entry indicates a flattened response with no measurable resonant peak.

The lowest frequency impedance peak of the test system seems to be related to the driver's free-air resonant frequency. Data for the Madisound 6102 shows the lowest free-air resonant frequency and the lowest frequency impedance peaks when installed in the test line. The lowest frequency impedance peak for each of the three drivers did not vary much with changes in line length or stuffing material. At the higher frequency impedance peak, however, line length and stuffing material did affect peak frequency.

If internal slopes between the two measured impedance peaks are assumed to be symmetrical, it would be desirable to place the midpoint at the driver's free-air resonant frequency. The midpoint frequencies shown in *Tables 3* and *4* were derived from *Table 2* by adding half the frequency difference between the low and high peaks *(Fig. 4)* to the low peak frequency.

Table 3 shows midpoint relationships for various line lengths with only air in the TL. It also shows the calculated quarter-wavelength frequency (using a sound velocity of 13,560 inches per second) for each line length. Comparing the measured midpoint frequency of the driver/line combination with the calculated frequency for that length shows coincidence when the calculated quarter-wave frequency equals the driver's free-air resonant frequency. As noted earlier, this has always been the goal of acoustical labyrinth (a TL with air as the "stuffing" material) designers.

Now let's look at what happens when the line medium is changed to long-hair wool or polyester batting. *Table 2* shows little or no difference between the peak shifts from air to wool and from air to polyester. This does not mean that there is no audible difference between a line with wool and one with polyester. It does mean that the test data shows little difference in the stuffing material's effect on line *length.* Since the purpose of the test line is to determine optimum line length, I will use the wool data to represent polyester, too.

Results for the drivers when mounted in lines with long-hair wool are shown in *Table 4.* Midpoint frequencies for the drivers declined to approximately 90 percent of the midpoint frequency for air-filled lines of the same length. I did note an interesting difference in the wool results for the Peerless TP165F and the Speakerlab W618P. The calculated quarter wavelength (in air) minus the measured driver/line midpoint in *Table 3* shows positive variances from 39 to 54-inch line lengths and negative variances for longer line lengths on both drivers. The same column for wool-filled lines *(Table 4)* shows the TP165F with positive variances for all line lengths with a midpoint, but notice the difference in the W618P's performance. Variance for the W618P goes negative at the same line length as it did in *Table 3.* These results might help to explain why drivers installed in wool-filled lines with line lengths based on a quarter wavelength in *air* produce widely varying results.

APPLICATION EXAMPLE. Let's apply the data in *Tables 3* and *4* to a specific situation. Assume that a 6-inch driver with a free-air resonant frequency of 50Hz is to be matched with a TL filled with 8-ounce-per-cubic-foot long-hair wool or polyester batting. If the line medium were air, optimum line length would be quarter wavelength at 50Hz. We can find this length by dividing the velocity of sound in air (13,560 inches/second) by the free-air resonance (50Hz) times ¼. This equals 68 inches.

Table 4 shows, however, that the midpoint frequency in a wool or polyester line is approximately 92 percent of the midpoint frequency in air (interpolating between average values for the TP165F at $f_s = 46Hz$ and the W618P at $f_s = 54Hz$). Since the desired midpoint frequency is the driver resonant frequency of 50Hz, it must be divided by 0.92 to yield an equivalent air frequency for which a length can be calculated. Dividing 50Hz by 0.92 gives an equivalent frequency of 54Hz in air. Now we can calculate the optimum line length for a wool or polyester-filled line by dividing 13,560 inches/second by the equivalent for a wool line (54Hz) times ¼, which equals 63 inches.

The application given above assumes that the results in *Tables 3* and *4* can be applied to 6-inch drivers in general. This seems like a reasonable assumption because the drivers selected have a fairly wide range of physical characteristics. I have tested 4-inch drivers in another test line, which yielded similar wool/air ratios, but I have not tested drivers larger than 6 inches in diameter in this manner.

TABLE 1

DRIVER SPECIFICATIONS

	Nominal Diameter	Tested f_S	Manufacturer's Specs Q_{TS}	Manufacturer's Specs V_{AS}
Madisound 6102	6″	31Hz	0.39	44.5 liters
Peerless TP165F	6″	46Hz	0.42	15.8 liters
Speakerlab W618P	6″	54Hz	0.73	16.9 liters

TABLE 2

RESONANT PEAK INFORMATION

	Line Length	Lower Peak Air	Lower Peak Wool	Lower Peak Poly	Higher Peak Air	Higher Peak Wool	Higher Peak Poly
Madisound 6102	39″	28Hz	26Hz	26Hz	111Hz	96Hz	93Hz
	54	24	23	22	78	65	65
($f_S = 31Hz$)	71	23	23	22	65	53	54
	78	22	20	none	58	49	45
	89	22	20	none	54	47	45
Peerless TP165F	39″	38Hz	37Hz	37Hz	114Hz	100Hz	98Hz
	54	34	37	37	82	73	70
($f_S = 46Hz$)	71	31	30	33	69	60	58
	78	30	29	none	63	55	55
	89	28	none	none	59	54	52
Speakerlab W618P	39″	44Hz	45Hz	43Hz	114Hz	100Hz	100Hz
	54	38	40	38	84	73	75
($f_S = 54Hz$)	71	35	38	none	71	64	62
	78	33	33	none	66	59	57
	89	31	none	none	63	58	56

TABLE 3

MIDPOINT RELATIONSHIPS WITH AIR

	Line Length	Driver/Line Midpoint Freq.	Calculated ¼ Wave Freq.	Variance*
Madisound 6102	39″	70Hz	87Hz	+17Hz
	54	51	63	+12
($f_S = 31Hz$)	71	44	48	+4
	78	40	43	+3
	89	38	38	0
Peerless TP165F	39″	76Hz	87Hz	+11Hz
	54	58	63	+5
($f_S = 46Hz$)	71	50	48	−2
	78	47	43	−4
	89	44	38	−6
Speakerlab W618P	39″	79Hz	87Hz	+8Hz
	54	61	63	+2
($f_S = 54Hz$)	71	53	48	−5
	78	50	43	−7
	89	47	38	−9

*Variance equals ¼ wave frequency minus midpoint frequency.

ONE-TIME LINES. When your TL design requirements are more specific, the flexibility and reusability of this experimental TL may be unnecessary. For the 4-inch driver tests mentioned above, I used a straight-line, rectangular cross-sectional plywood tube (cross-sectional area larger than test driver cone area) rather than a folded design. I mounted the driver under test on a panel, which sealed one end of the tube, and left the other end open. I adjusted line length by cutting off a series of small sections from the

TABLE 4

MIDPOINT RELATIONSHIPS WITH WOOL

	Line Length	Midpoint Wool/ Midpoint Air (%).	Midpoint Freq. (wool)	Calculated ¼ Wave Freq. (air)	Variance*
Madisound 6102	39″	87%	61Hz	87Hz	+26Hz
	54	86	44	63	+19
	71	86	38	48	+10
(f_s = 31Hz)	78	88	35	43	+8
	89	89	34	38	+4
		avg. = 87%			
Peerless TP165F	39″	91%	69Hz	87	+18Hz
	54	95	55	63	+8
	71	90	45	48	+3
(f_s = 46Hz)	78	89	42	43	+1
	89	—	none	38	—
		avg. = 91%			
Speakerlab W61BP	39″	92%	73Hz	87Hz	+14Hz
	54	93	57	63	+5
	71	96	51	48	−3
(f_s = 54Hz)	78	92	46	43	−3
	89	—	none	38	—
		avg. = 93%			

*Variance equals ¼ wave frequency minus midpoint frequency.

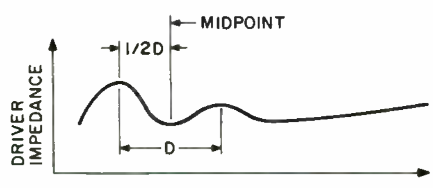

FIGURE 4: The midpoint frequencies shown in *Tables 3* and *4* were derived by adding half the frequency difference between the low and high peaks to the low peak frequency.

open tube end with a hand saw.

Simplicity of construction and line-length adjustment are the major advantages of a straight-line experimental TL. Disadvantages are one-time usage and the exclusion of any sound velocity effects due to bends in the line. My own experience with a one-time straight-line experimental TL yielded useful data for determining length, even though I eventually folded the TL to conserve space.

In sum, optimum TL length in a test line was dependent on driver characteristics. For example, variations in free-air driver resonance seem to have an effect on midpoint frequency shift in wool-filled lines. The lower resonance drivers had a wider midpoint frequency shift when the line medium changed from air to wool than occurred on drivers with higher free-air resonance. Other driver characteristics may also have an effect that is not apparent but is still included in the test results.

After looking over the data on these drivers, I am convinced that methods for determining optimum line length must consider the driver and TL load as an interactive system rather than separately measurable components. Using an experimental TL as a tool for line-length determination provides the interactive system data needed for design confidence.

ABOUT THE AUTHOR

Thomas Cox has been interested in audio equipment construction since the 1950s, when he worked for the developer (Stromberg-Carlson) of the acoustical labyrinth. His current interest lies in smaller transmission lines in columnar arrangements. He works in data communications market research for IBM.

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2. Bradbury, L.J.S., "The Use of Fibrous Materials in Loudspeaker Enclosures," *JAES Anthology 1953–1977*, pp. 404–412.
3. Galo, G.A., "Transmission Line Loudspeakers, Part I," *SB* 1/82, pp. 7–9.

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A SMALL DOUBLE-CHAMBER REFLEX

BY DAVID B. WEEMS

In these days of Thiele/Small data, some speaker builders may consider the double-chamber reflex enclosure an anachronism. Instead of a precisely engineered box, tuned to the theoretically ideal frequency, it is tuned to two frequencies. For the enclosures described by Augspurger[1] and Marsh,[2] the upper frequency is set an octave above the lower one. This spreads the loading on the driver over a range of bass frequencies, reducing speaker distortion through a band of about two octaves.

Regardless of how you view the "dumb luck reflex," the concept has some practical advantages. How many speaker builders have arrived at a "final" set of speaker cabinets, using expensive materials and detailed cabinet work, only to be locked into a one-woofer system? You may use the double-chamber reflex with a variety of woofers with no change in box dimensions or tuning. It is also a safe bet if you are ever asked to recommend a ported system for distant acquaintances with nondescript woofers.

The main reason for choosing the double-chamber reflex described here is that I was asked to suggest an enclosure design to fit existing spaces at each end of a small wall cabinet. The owner wanted the maximum bass response from the available space, which turned out to be rather tall and shallow. This made the ratio of length to the other dimensions too great for best results with a simple box that might easily develop the characteristics of a pipe. By dividing the longest dimension, the double chamber virtually thrust itself into our plans. A few calculations suggested the possibility of a 6½-inch woofer. Having narrowed the field, we went on to design the enclosure.

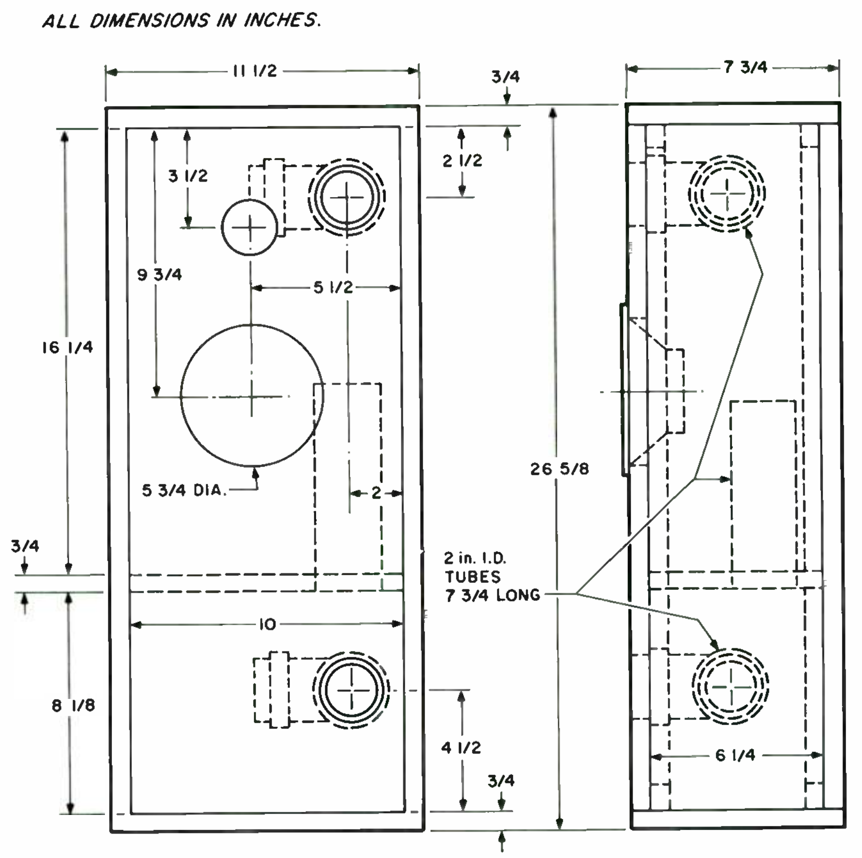

FIGURE 1: Dimensions for the double-chamber reflex enclosure.

BOX DESIGN. How do you design a double-chamber reflex? I went back to Augspurger's article to see how the system works. At first glance, the enclosure appears a bit complex with its two external ports and one connecting port, but analyzing the essential design points simplified the concept.

A prime goal, as with any speaker enclosure, is to set the cubic volume. In the double-chamber box, this would be the total volume. Augspurger's enclosure had a total cubic volume of about 2.7 cubic feet.

Another important design step is to establish the frequency of the lower resonance, the one at which the volume of both chambers react with the two external ports. In Augspurger's enclosure, this action occurred at 35Hz. The cross-sectional area of the two tubes that vented to the room was 12 square inches, 6 for each tube. Running those values through Keele's pocket calculator program for vent dimensions,[3] I found that we could expect to use vent lengths of 6.86 inches to tune a 2.7-cubic-foot box to 35Hz. In fact, Augspurger specified 7½-inch vents. It seems to be a fact of life that you must add about 10 percent to the length of any vent and at least that much to any calculated cubic volume to get the desired performance. But the point here is that you can use the total volume and double vent area to find the length of vent to use.

It is also instructive to consider the kind of speakers Augspurger used in his double-chamber box. His favorite seemed to be the JBL LE-8. My tests on one LE-8 several years ago produced these values: $f_S = 44$Hz, $Q_{TS} = 0.5$ and $V_{AS} = 1.7$ cubic feet. Running these through Keele's calculator program, I arrived at some suggested box specifications: $V_B = 3.5$ cubic feet and $f_B = 35$Hz. An old JBL design sheet for the LE-8 specified a 3.0-cubic-foot enclosure. If JBL recommended that cubic volume, it is hardly surprising that Augspurger chose a similar total volume. As he noted, the speaker does not see the partition at low frequencies.

Considering all this, you can reduce the design of a double-chamber reflex to a four-step procedure:

1. Choose the size woofer you want to use, or set the total cubic volume and choose a suitable woofer. If you have test data for your woofer, make sure that the total volume equals or exceeds the ideal vented box volume. If you have no test data, be generous.
2. Set the lower frequency of resonance for the box. This should be at least as low as the calculated f_B, in some cases lower. (More about this later.)
3. Choose a convenient tube size to obtain a suitable vent area. Note that the tube area must be multiplied by 2 to obtain the total vent area that interacts with room air.
4. Use the total cubic volume and 2 times the tube area to find the duct length from a chart or by formula. This length will apply to all three tubes.

As mentioned earlier, in designing the enclosure shown in *Fig. 1*, I began with a given total cubic volume (1,500 cubic inches) and went on to choose a woofer. I checked the characteristics of a typical contemporary 6½-inch driver, the Peerless TP 165F, and found these specifications: $f_S = 53$Hz, $Q_{TS} = 0.42$ and $V_{AS} = 15.8$ liters, or 0.56 cubic feet. These suggested an ideal box volume of 1,200 cubic inches tuned to 48.6Hz with a theoretical cutoff at 46.4Hz. Our 1,500-cubic-inch enclosure would allow a 25 percent overvolume, which is not a bad idea.

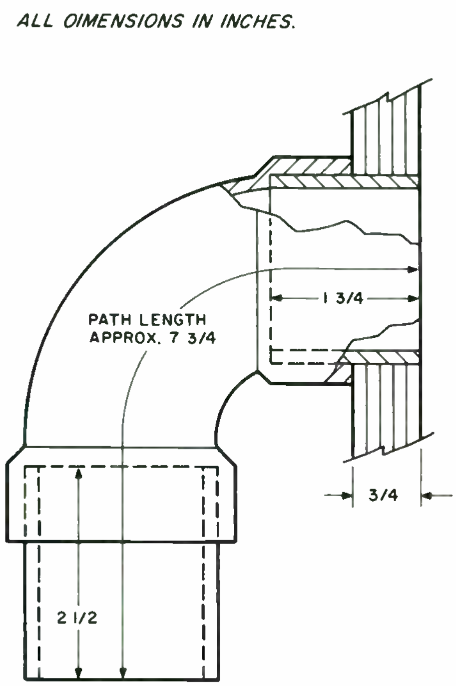

FIGURE 2: Dimensions for the ports on the speaker board. The connecting port is a straight pipe that is 7¾ inches long.

It turned out that my friend who was building the enclosures wanted to use some old Norelco woofers, Model 7065/W8, obtained from McGee almost 15 years ago. These drivers were designed for use in a 7-liter, or 0.25-cubic-foot, closed box. Tests on one showed $f_S = 43$Hz, $Q_{TS} = 0.3$ and $V_{AS} = 0.9$ cubic feet.

We had a problem. Having constructed the boxes with the Peerless woofer in mind, we suspected that they were too large for the Norelco. The 7065/W8 would fit a QB_3 alignment that would require just about half the box volume we had built. Such an alignment would require the box to be tuned to 53Hz and would raise the cutoff frequency to almost 60Hz. Considering that the real-life cutoff frequency is almost always above the calculated value, that was

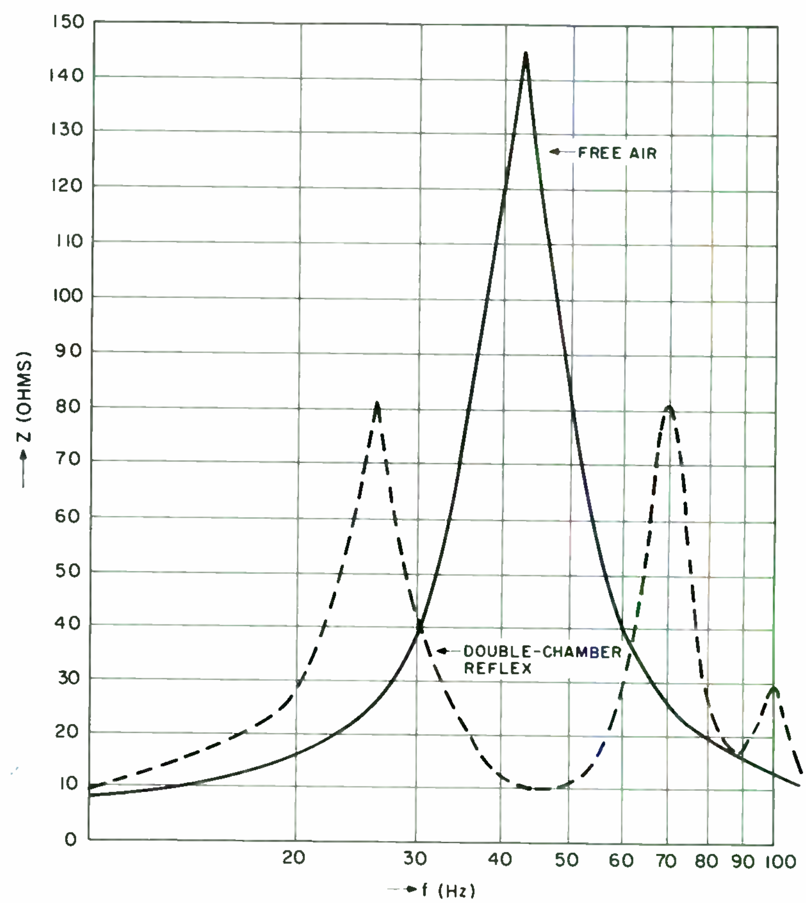

FIGURE 3: Impedance curves for the Norelco AD 7065/W8 in free air and in the double-chamber reflex enclosure.

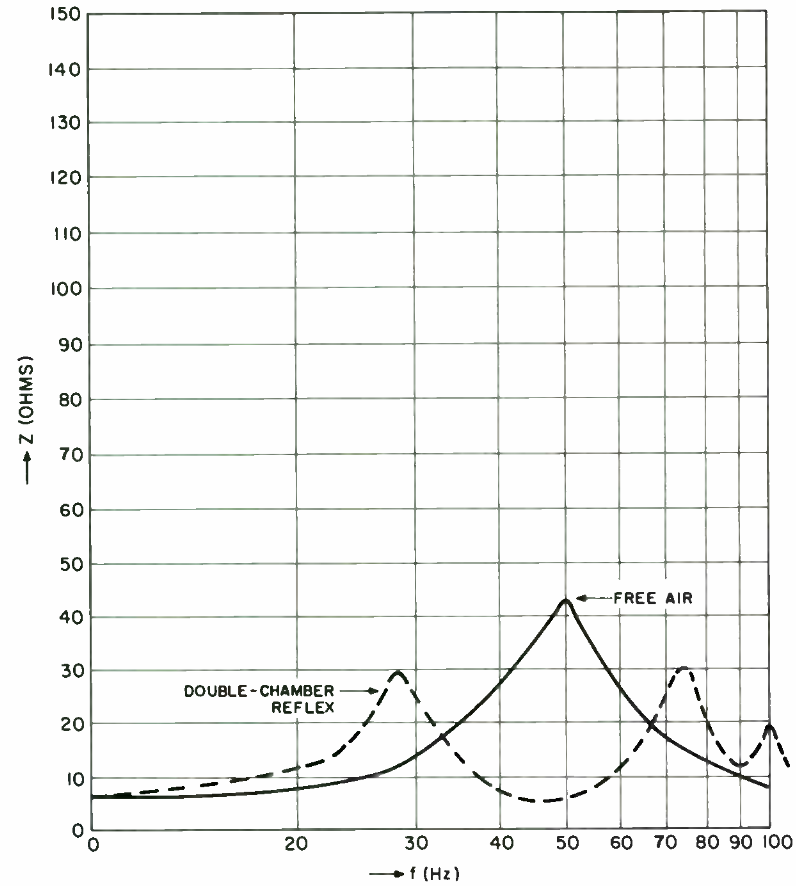

FIGURE 4: Impedance curves for the Peerless TP 165F in free air and in the double-chamber reflex enclosure.

not encouraging. In addition, we wanted to substitute the Peerless woofer in case the old Norelco did not perform to our expectations or failed in service.

The chief cause of the mismatch was the difference in the driver Q's. Instead of the usual Q problem with a vented system (i.e., a Q that is too high), the Norelco's Q was too low. We could, however, raise the Q by adding resistance to the woofer circuit.

Taking a fresh look at the situation, we realized that with a Q of 0.38, the Norelco would fit into a B_4 alignment, requiring a tuning frequency at f_S and a cubic volume of 0.86 cubic feet. That just happened to be the total volume of our box. We calculated the needed resistance from the following formula, where R_e is the DC resistance of the voice coil:

$$R = \frac{Q \text{ (required)}}{Q \text{ (measured)}} R_e - R_e$$

For the Norelco, we calculated that 1.9Ω would be right. Remember to subtract any resistance in crossover components. In fact, you can cut costs and improve performance by selecting a gauge of coil wire that gives the proper resistance. In this system, we used less than the calculated resistance, preferring to err in that direction.

Considering the required tuning for the Peerless (48.6Hz) and the Norelco (43Hz, adjusted), we chose 45Hz as a design aim. From the start, we had hoped to tune below 50Hz to obtain loading in that frequency range. Checking out available kinds of vent tubes, we chose 2-inch PVC pipe. This pipe has a cross-sectional area of 3.14 square inches, so the total port area to consider in calculating low-frequency tuning is 6.3 square inches. Plugging the values for port area and box volume into the calculator, we found that the vent tubes should be 7.6 inches long to tune the enclosure to 45Hz. With an internal box depth of only 6¼ inches, it was obvious that the two external tubes must be bent if they were to be mounted on the speaker board where the grille cloth would hide them. When we bought the pipe, we also bought four elbows of matching diameter.

Measuring the path length through an elbow requires an estimation of the length of an imaginary line through the center of the elbow. We used a piece of string to approximate the line (7¾ inches). Note the unequal sections of straight pipe fitted to the elbows *(Fig. 2)*. The 1¾-inch length, at least for the elbows we bought, allowed 1 inch of pipe to fit into the elbow, leaving a ¾-inch projection to feed through the speaker board. This puts the shoulder of the elbow against the rear of the board, ensuring a better seal between pipe and board.

We glued the short sections into the elbows with a multipurpose PVC pipe cement. Then we stuck the pipes into the boards with silicone sealer. We had intended to add some extra length to the pipe to cover the usual lack of precision in predicting dimensions, but forgot to do that. Not to worry. As the impedance curves in *Figs. 3* and *4* show, the lower box resonance occurred at 46Hz.

Looking back, we wondered whether the connecting tube should have been located in the smaller compartment, a la Augspurger and Marsh. That would have given us greater dicretion in placement of the upper port. But putting the tube in the woofer chamber (as we did) might aid in breaking up that volume. We did wrap the smooth external pipe surfaces with fiberglass and covered the walls (except for the speaker board) with damping material *(Fig. 5)*. We left the lower chamber bare.

CHOICE OF DRIVERS. We tested a Peerless TP 165F (available from McGee, 1901 McGee St., Kansas City, MO 64108) before installing the old Norelco woofers. The impedance curves for the two types of driver *(Figs. 3* and *4)* indicate the similarity of enclosure performance with different speakers. The equal amplitude of the two main impedance peaks with both drivers was a surprise. In earlier days, such equal peaks were considered evidence of proper enclosure tuning. Comparing these curves to those obtained by Augspurger, the greatest difference is in the amplitude of the third peak. In Augspurger's system, that peak was the highest. In the case of the Goodmans woofer, it was the only prominent peak. As you can see, the third peak here is significantly lower in amplitude than the two main peaks.

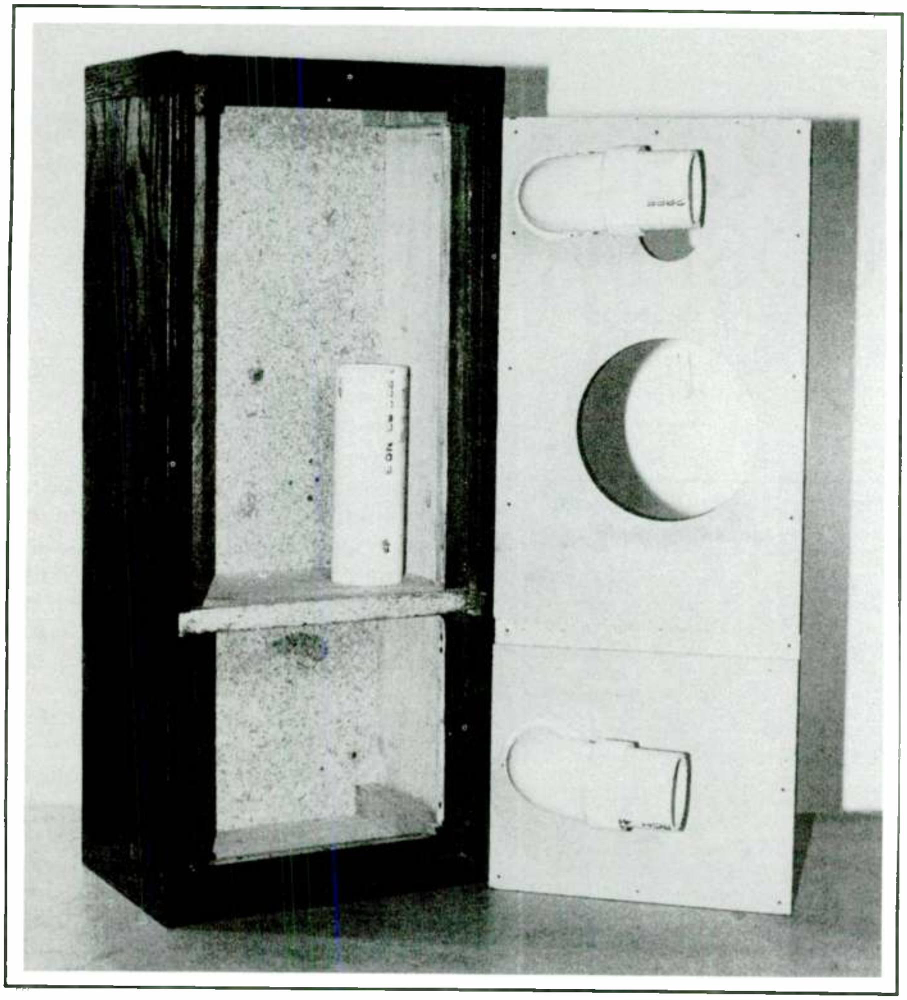

FIGURE 5: The external pipe surfaces and the walls of the upper compartment are covered with 1-inch fiberglass damping material.

FIGURE 6: The builders settled on the Norelco woofers and a Peerless 2-inch cone tweeter. The left channel speaker is shown here without the grille cloth. The left enclosure is a mirror image of the right.

To complete the system, we used a Peerless 2-inch cone tweeter that we had on hand *(Fig. 6)*. The small system was to be used at moderate power levels in a vacation cabin. The owner wanted clean sound, but the power requirements for the location and his listening habits would be low. For those purposes, the little system performed admirably.

When we connected the speakers, we noted that the bass was relatively deep and smooth for 6½-inch woofers, but we wondered how the double-chamber reflex would compare to a closed-box system with the same woofer. An alternate system was available for testing—the closed-box version recommended by Philips complete with the specified crossover network and Philips 1-inch dome tweeter. Everyone who heard the comparison preferred the double-chamber reflex.

FURTHER STUDY. If you want to experiment with this design, you might want to try these variations:

1. A double-woofer, double-chamber reflex. By doubling the enclosure volume, you can use two 6½-inch woofers. Perhaps you could install them in a symmetrical woofer/tweeter arrangement such as the one described by Joseph D'Appolito.[4] Note that the port area should be doubled for equal tube length.

2. The connecting tube could be moved into the lower compartment. This would permit moving the exterior port in the upper compartment to a point farther from the tweeter. There is a possibility that the discontinuity presented by the open port may have some effect on high-frequency performance when it is placed on a level with the tweeter, as shown here.

As mentioned earlier, the system described met our design goals. We had to tinker with filters to remove some response peaks, and everyone who heard the speakers before and after the filters agreed that peak removal, at least with these speakers, offered a significantly noticeable improvement in listening quality for a minor expenditure in time and money.

ABOUT THE AUTHOR

David B. Weems began experimenting with speakers in the 1950s and has published speaker projects in many periodicals, including Popular Electronics. *He is the author of* How To Design, Build & Test Complete Speaker Systems *(Tab Books #1064, out of print) and* Designing, Building & Testing Your Own Speaker System, *2nd Ed. (Tab Books #1964).*

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A LOW-RESONANCE LOUDSPEAKER

BY L.A. WHITE JR.

Editor's Note: This controversial article no doubt challenges a lot of conventional wisdom. The author has invested time, energy and imagination in the thesis. The adventurous will want to try the idea; reports of your findings are welcome.

Author's Note: This article describes a new technology for the construction of loudspeaker enclosures and crossovers that eliminates or greatly reduces resonance problems. The type of enclosure described is patented in the US and Canada, with an application pending in England. The crossover with equalizer system is the subject of patent applications in the US and other countries. Readers may use this technology for their personal, noncommercial use. Any other use of this material, including the selling of kits, is prohibited unless a license is obtained from the inventor.

I became interested in speaker enclosures four years ago when I was trying to find quality speakers to sell in my small hi-fi business. After trying to make several enclosures myself, I began to see that many things written about loudspeaker enclosures are misleading or untrue.

It is generally believed that the chief function of loudspeaker enclosures is to contain the backwave from the woofer so that it does not cancel the frontwave with which it is 180 degrees out of phase, thus markedly reducing the bass output. In fact, the chief function of every rigid enclosure is to provide resonance to enhance the bass output. Without this resonance, it is not possible to make a small loudspeaker system with sufficient bass output without using equalization in the amplification system or in the crossover. Resonance also enables the speaker to put out more bass with a given amount of input power.

In spite of the above advantages of resonance, certain drawbacks make it impossible for a resonant system to provide the best possible sound. The more resonance is used to enhance the bass, the worse the system will sound. In most speakers, the bass resonance is balanced by a larger high-frequency output. This produces a system that at first sounds "better" than live music, but is irritating after about ten minutes.

FIGURE 1: A front view of the author's speaker design with clear plastic sides attached.

Think of a rigid loudspeaker enclosure as an organ tube and the driver cone as an open end of that tube. In addition to the fundamental frequency, a sealed enclosure will produce harmonics in the ratio of 1:3:5, and a ported enclosure will produce them in the ratio of 1:2:3. Using a soft material to line the enclosure can reduce the higher-frequency harmonics, but will have little effect on the fundamental resonance.

Because a rigid enclosure is like an organ tube, it colors all the sound it produces. This coloration may be difficult to measure, and the usual tests may even make the loudspeaker appear to perform much better than it actually does.

A loudspeaker is generally tested by playing a pure tone through the speaker at a constant voltage and measuring the sound output as the tone is varied from 20Hz to 20kHz. The frequency of the output is not measured. To give an extreme example, a speaker that put out only one frequency no matter what the input might appear to be accurate in such a test, even though it would be worthless for listening to music or speech.

Most rigid boxes are not this extreme. The impedance curves of such speakers usually show one or two very strong peaks, which are caused by the driver resonance. When the driver exhibits excessive displacement for the amount of current at a given frequency, it causes a rise in impedance just as an electric motor has a higher impedance after it speeds up. Tones near the resonant frequency will produce some sound at the resonant frequency, giving the impression that the speaker has a "one-note bass."

A NOVEL APPROACH. The above considerations led me to develop a loudspeaker enclosure that prevents the driver backwave from canceling the frontwave, but does not resonate.

The key element in my enclosure is one or more movable sides. In the model described here *(Fig. 1)*, the movable top, bottom, sides and back are made of ⅛-inch-thick plastic or hardboard. You may mount these in pieces of rubber tubing or suspend them with pieces of string so that they do not touch the frame. (If they touch the frame, they will rattle.) The sides may also be suspended by using tape around the four edges, thus closing the spaces between the sides and frame.

Although this loudspeaker system lacks enough output in the bass frequencies, you can compensate for this by using an amplifier equipped with tone controls and boosting the bass. If the rest of the design is correct, the system will produce a very good sound. Obviously, the best result is obtained by designing the speaker and amplifying systems together to produce a flat frequency response. I have designed my own crossover system with an equalizer to make the bass louder.

CONSTRUCTION OPTIONS. You may construct this system according to your own needs and desires. The quality of the finished system will depend primarily on the quality of the drivers and very little on the method of construction, provided you adhere to my basic principles. To obtain the best results, you must spend at least $75 on each woofer and $35 on each tweeter. In my system, I use Dynaudio 21W540 8-inch, 4Ω woofers and Siare TWZV 8Ω tweeters. Drivers of lesser quality have resonance problems in this design and are less efficient. You might be able to devise a similar design using less expensive components, but I have not experimented with this idea.

In the beginning, I recommend that you put the crossover components outside the enclosure, especially if you are working on your own design, because you will have to modify them for optimum performance. Remember, however, that these components present a possible shock hazard.

The enclosure is basically a frame *(Fig. 2)* that holds the movable back, side, top and bottom panels, along with the fixed or movable panel in which the drivers are mounted. The frame may be of any rigid material

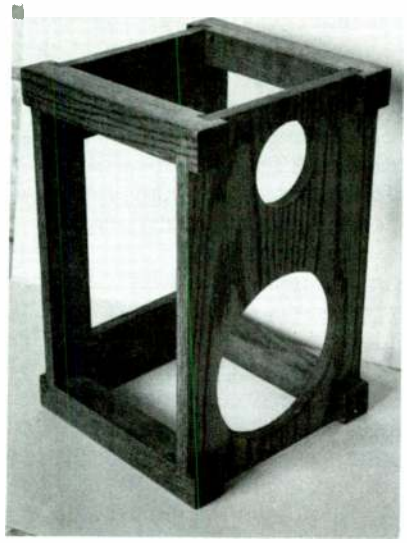


FIGURE 2: The front and back of the speaker frame are made of ⅝-inch solid oak, but plywood will work as well. The four struts connecting the back and front are made of 1¼-inch oak.

such as wood, metal or plastic. The frame in *Fig. 2* is made of oak. The front and back pieces are ⅝ inch thick with square notches at the corners. These notches fit corresponding notches milled into the struts that connect the front and back. The parts are glued together.

For the movable panels, use a material that has a low inherent tendency to ring. Plastic and hardboard work well, but thin wooden panels will not work unless you glue another material such as heavy felt to them. The felt will damp vibrations in the panels themselves. I am currently using ⅛-inch plastic or hardboard. *Figure 3* shows the enclosure with hardboard panels, which seem to work slightly better than plastic ones.

FIGURE 3: This speaker has hardboard instead of plastic sides. The sides must not touch the frame or they will rattle.

You may mount the drivers on a rigid board such as ⅝-inch oak, on plywood or on something slightly flexible but not too resonant such as ¼-inch hardboard. The board may be securely attached to the frame (as in my design) or suspended from the top of the frame.

This design works best if the enclosures are at least 17 inches tall, 12 inches wide and 11 inches deep (outside dimensions), with movable panels on the top, bottom, sides and back. With larger speakers, you might be able to get by with movable panels on just the sides and back. If you place a fixed panel close to the woofer, it will cause resonance problems and degrade the sound. If the movable panels are not sufficiently free to move, performance will be poor.

Because of the novel principles involved, this design offers the possibility of producing the lowest and clearest bass of any type of system if large, high-quality woofers are used. Such drivers tend to be prohibitively expensive for most builders, however, and require a three-way design that includes a complex crossover. Such a design is beyond the scope of this article.

CROSSOVER PROBLEMS. Most books on loudspeakers include a watered-down version of what happens in the crossover. This is pretty useless to a person designing his or her own crossover.

Figure 4 is a simple resonant crossover circuit. Although not everyone may recognize it as such, it becomes more obvious when shown as in *Fig. 5.* For the purpose of this discussion, the woofer and tweeter can be considered as just resistance. (Their reactance is small at most frequencies.) The resonant frequency of this circuit is the same as the crossover frequency—the frequency at which the impedance of the coil and the capacitor are equal. The Q of the circuit is determined by the inductor and capacitor values, by their internal resistances

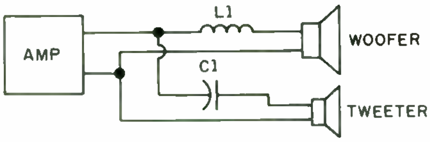


FIGURE 4: A simple resonant crossover circuit.

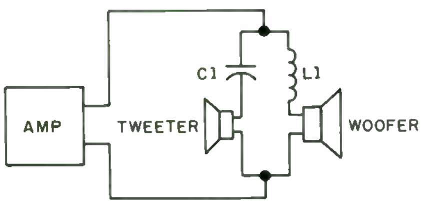


FIGURE 5: The nature of the resonant circuit becomes more obvious when it is drawn like this.

and by the woofer and tweeter resistances. Even though the Q value of most crossover circuits is low, it has a substantial effect on the sound produced. One of the more significant effects of biamping is the elimination of this resonant effect.

In my efforts to enhance the bass output of the speakers using low-resonance enclosures, I found that I could achieve this goal by using a large-inductance coil in series with the woofer. Because of the large reactance this produced at the crossover frequency, the resonance problem was worse than with usual box-type speakers. After a great deal of trial and error, I found that adding an equalizer circuit *(Fig. 6)* greatly reduced the resonance effects.

The equalizer circuit consists of a coil, a resistor and a capacitor. The coil and capacitor are the same as those used in the other part of the crossover. The resistor is equal to the DC resistance of the rest of the circuit—i.e., the resistance of the woofer and tweeter in the example shown.

To calculate the values for your crossover network, you must use the following two equations:

$$X_L = 2\pi f L$$

$$X_C = \frac{1}{2\pi f C}$$

X_L is the reactance (in ohms) of a coil or inductor having the inductance L (in henries) at the frequency f (in hertz). X_C is the reactance of a capacitor having the capacitance C (in farads) at the frequency f.

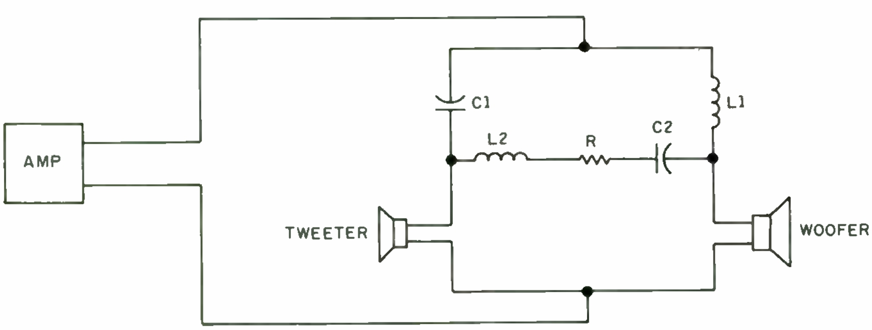


FIGURE 6: An equalizer circuit reduces the speaker's resonance effects.

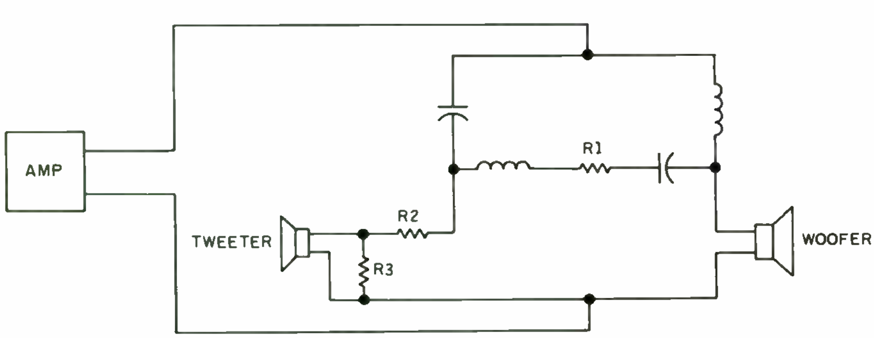


FIGURE 7: The final crossover circuit incorporates R2 and R3 into a variable L-pad.

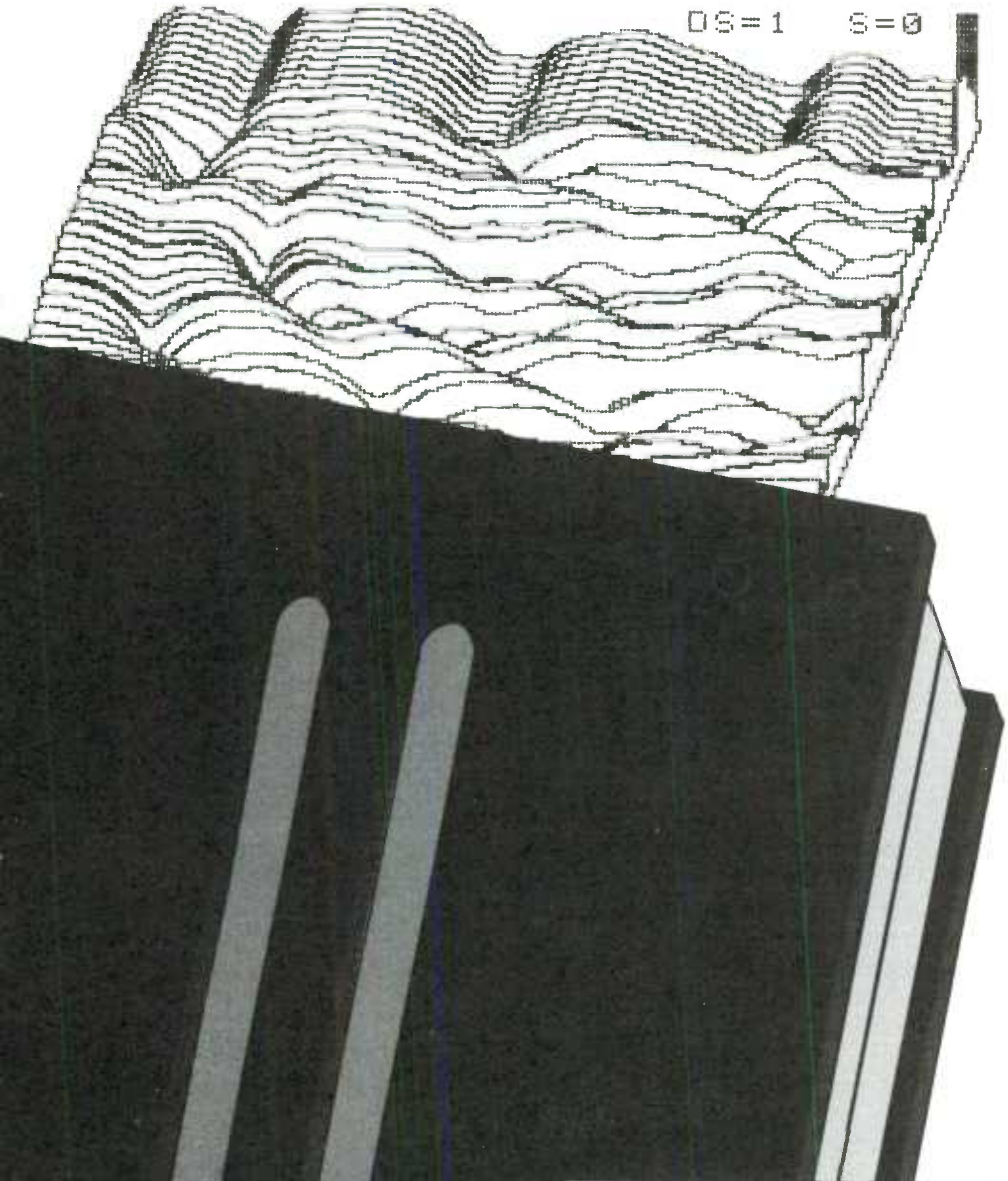
From these equations, you can see that as the frequency doubles, X_L doubles and X_C is cut in half. Because of this, it is possible to construct a crossover that will enhance the bass frequencies. This is done by selecting a large-value inductor such as a 6.5mH device. You should also use a woofer with a 4Ω impedance. The woofer output in series with an inductor will be down 50 percent at the frequency at which the inductor reactance is equal to the woofer resistance. Therefore, a given inductor will produce a greater effect with a 4Ω woofer than with an 8Ω one.

Substituting in the above equation, we find that using a 6.5mH inductor in series with a 4Ω woofer produces a 4Ω reactance at a frequency of 98Hz. We must add the inductor resistance to that of the woofer, so the effect is not quite as good as predicted. (I did not consider the fact that reactance and resistance are actually vectors that are 90 degrees apart when added, as the practical effect of this is not very important to this discussion.)

After you have chosen the inductor value, use the above equations to find the capacitor value that will produce the desired crossover frequency. For a 6.5mH inductor and a crossover frequency of 500Hz, the capacitor value should be about 15μF. This is computed by setting up the equation $2\pi f L = \frac{1}{2\pi f C}$, since the crossover frequency is that frequency at which the capacitor reactance equals the inductor reactance. Plug in the values for f and L and solve the equation for C. Remember that for crossover parts, most coils are expressed in *milli*henries, and most capacitors are expressed in *micro*farads.

The requirements for high-quality drivers dictate that you must use large magnets and lightweight material for the speaker cone. As a result, the tweeter output is much greater than the woofer output given the same amount of power. Because of this, you must use an L-pad to reduce the tweeter output. I suggest using a variable L-pad because this gives you some tone control over the speakers. The final circuit design would look like *Fig. 7.*

In designing your own speaker, the main problems are selecting the woofer, tweeter and crossover frequency. The woofer should have a free-air resonance of 50Hz or below and should have 4Ω or less DC resistance. The tweeter should be able



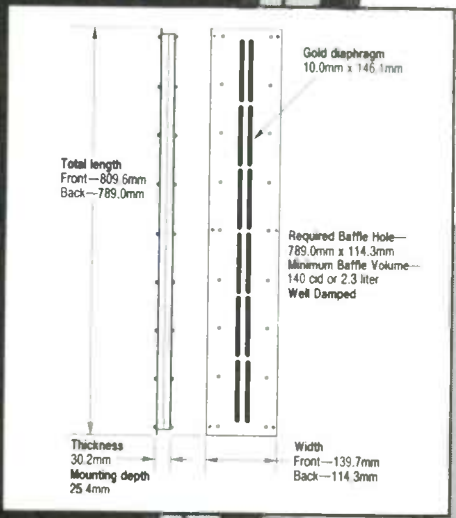
THE GOLDEN RULES

Historically, the ribbon loudspeaker has been an interesting alternative to high-performance loudspeaker design since the early 1930's. Though cost-effective production technology has not been available until now, ribbons were seen by many as an attractive solution to the inherent problems which continue to plague even the best dynamic, electrostatic, and field-type transducers today. Vacuum technology and computerization has enabled Gold Ribbon Concepts to present an affordable esoteric loudspeaker for the 21st century. For example. . . . . .

Most dynamic cone loudspeakers are rated at approximately 3% Total Harmonic Distortion (THD). The GOLD 3.0 ribbon satellite's THD is 1/10th (.3%) this amount. And with a moving mass close to a gram per 1100 grams of magnet, the rise and decay speed of the GOLD 3.0 is so fast that it can best be exhibited as a live sound reinforcement transducer, where the dynamic range exceeds even digital recording capabilities.

The GOLD 3.0 operates from 200 hz to 30kHz, thereby releasing speaker designers from the complex phase and distortion problems which result from the use of cross-over networks in the delicate vocal region above 200 Hz. And for unparalleled accuracy, Gold Ribbon Concepts uses computerized manufacturing techniques to match each GOLD 3.0 voice coil to within an incredible thickness tolerance of 25 atoms.

The performance of the Gold Ribbon Concepts GOLD 3.0 ribbon satellite is best illustrated in the full expression of a beautiful piece of music.



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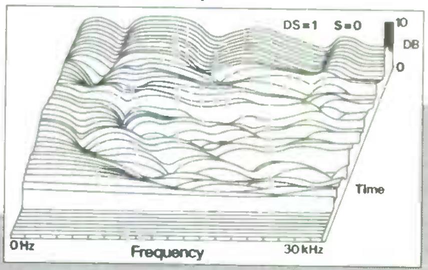

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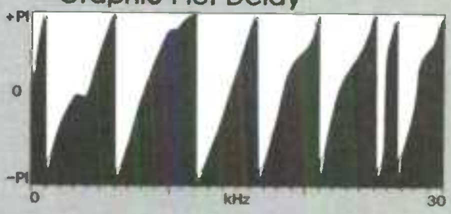

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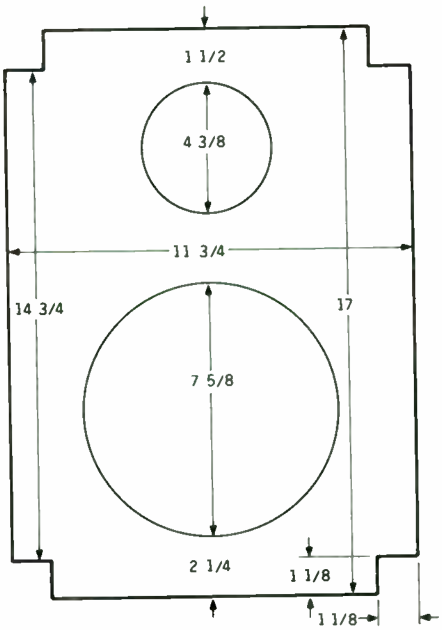

FIGURE 8: Cutting diagram for the front of the speaker frame. Cut a 1⅛-inch square from each corner to accommodate the strut.

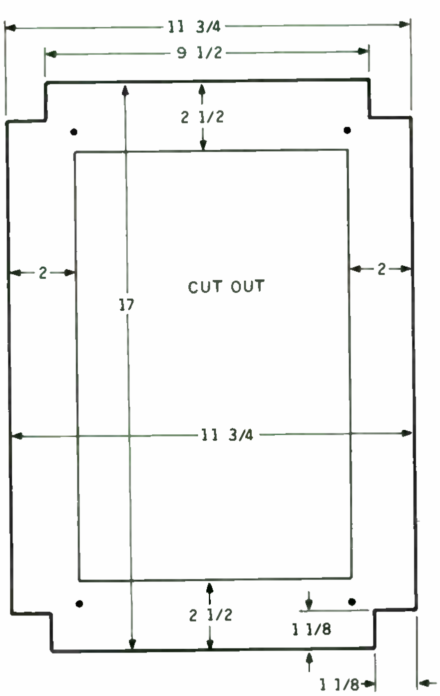

FIGURE 9: Cutting diagram for the back of the speaker frame. Drill holes as marked to accommodate your leather thong. Cut a 1⅛-inch square from each corner to accommodate the strut.

to cover frequencies substantially lower than the highest frequencies covered by the woofer. The optimal crossover frequency must be determined by listening. If the crossover frequency is too high, the midrange will not sound clear; if the crossover frequency is too low, the sound from the tweeter will be distorted. The output from the tweeter must be greatly attenuated by the L-pad. The amount of attenuation needed will vary with different amps, cartridges and records.

Because of the increased clarity of my speakers, the differences among various cartridges are more noticeable. I am currently using a Dynavector ruby cartridge with a Systemdek turntable and Profile tonearm. My system also includes a David Berning TF10 preamp and EA 30W amp.

ASSEMBLY DETAILS. Cut out the front panel *(Fig. 8)* and back frame *(Fig. 9)* of each speaker. Also cut pieces for eight struts *(Fig. 10)*, four for each speaker. You may cut the grooves in the struts on a vertical milling machine, on a radial arm saw or by hand with a hammer and chisel. Drill the holes in the struts as shown in *Fig. 10.*

Assemble the frames, including the front panels, without gluing. See *Fig. 11* for a side view of the assembled frame. If everything fits, glue and clamp. Avoid using too much glue and wipe off any excess after clamping.

Let the glue dry for 18 hours. Remove the clamps and sand and finish the frames. After the finish is dry, place the frames on a bench with the front facing up. Put the woofers in the frames and drill holes for the bolts used to attach the woofers. Run the

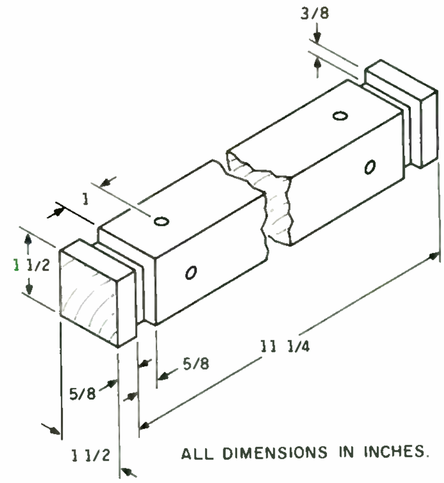

FIGURE 10: Eight struts are required (four for each speaker). Cut grooves ⅝ inch wide and ⅜ inch deep on two adjacent sides ⅝ inch from the end. Drill holes (5/32 inch diameter, ½ inch deep) 1 inch from each groove, as marked.

bolts through the holes, put the washers and nuts on the ends of the bolts inside the enclosure, and tighten. Put the tweeters in the frames, drill the necessary mounting holes and attach the tweeters with screws.

Drill the holes for the terminals and attach these at the rear bottom of the frames, making sure they are above the center lines of the holes drilled in the struts that will hold the bottom panels.

Cut the aluminum angle iron into 9-inch lengths. Attach the inductors to the angle iron as shown in *Fig. 12,* leaving room at each end for screws. Attach the inductors with foam mounting tape and iron wire. You must drill a hole in the top of the angle

MATERIALS LIST

2 woofers—Dynaudio 21W5404, 4Ω
2 tweeters—Siare TWZ-V, 8Ω
4 inductors, iron core, 6.5mH
2 L-pads, 8Ω
4 capacitors, 15μF, 100V
2 resistors, 15Ω
Sears automotive vacuum tubing, 5/32 inch diameter, 90 inches
1½-by-1½ inch oak, 8 feet long
Oak or high-grade chipboard, ⅝ inch thick by 11¾ inches wide by 6 feet long
Hardboard, ⅛ inch thick by 24 inches wide by 8 feet long
12 bolts with washers, 8 by 32 by 1¼ inches
16 wood screws, #8 by ¾-inch Phillips round heads
2 terminal sets with five-way binding posts
16-gauge stranded insulated wire for crossover connections
Rosin-core solder
Leather thong, 24 inches
⅛-inch-thick aluminum angle iron, 1½ by 1½ by 18 inches
Foam mounting tape, sticky on both sides
Iron wire for attaching inductors
Titebond yellow wood glue
Wood stain and finish

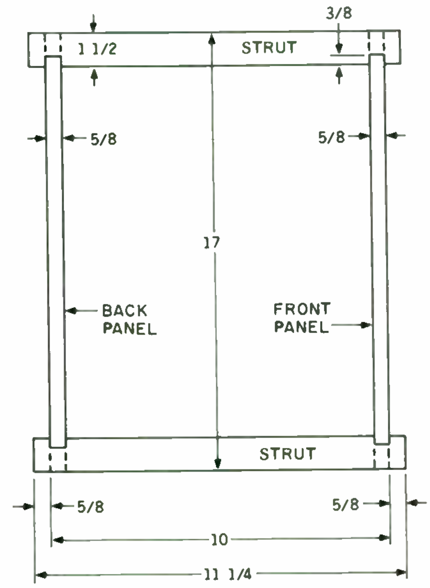

FIGURE 11: Side view of the assembled speaker frame.

iron near the angle to pass the iron wire.

Attach the angle iron to the rear of the front panel with four screws as shown in *Fig. 12.* Attach the L-pad to the top of the angle with foam mounting tape placed between the front panel and the angle iron and L-pad. You may also attach the capacitors and resistors with foam mounting tape. Carefully install 16-gauge stranded insulated wire to complete the crossover. Solder all connections. The finished frames with the woofers and tweeters installed should look like *Fig. 12.*

Before connecting the speakers to your audio system, test them with an ohmmeter to make sure neither speaker has a short circuit. The resistance should be 5 to 7Ω. If it is 0 to 1Ω, there is a short that could damage your amp. If there is no short, you may connect the speakers to your audio system. Listen to make sure the woofer and tweeter both work and the tweeter responds to the volume control knob on the L-pad.

Cut the remaining panels out of 1/8-inch hardboard. The dimensions for each are as follows: top and bottom, 8 1/2 by 8 1/2 inches; sides, 8 5/8 by 13 1/2 inches; backs, 10 by 13 1/2 inches. Finish the panels with lacquer or varnish.

To mount the rear panels, drill holes in the corners corresponding to the holes in the back of the frame. Attach the panels with pieces of leather thong by passing it through the holes and putting a knot in each end.

The sides, tops and bottoms are mounted in pieces of 5/32-inch-diameter vacuum tubing. Use wire cutters to cut the tubing into 32 one-inch pieces, then split each piece 1/2 inch with the cutters. Insert the tubing in the holes in the struts *(Fig. 12)* and place the panels in the splits.

SPEAKER PERFORMANCE. These speakers work best when placed on stands that put them at about the same height as the listener's ears. You must adjust the L-pad tweeter level controls to different settings for different recordings depending on the disk's equalization and on when it was made. You will seldom have to turn the control more than 90 degrees from the off position, and with recent recordings, a setting of 20 degrees is often adequate.

I have found that my records sound clearer than with conventional speakers and that good recordings sound almost like a live performance. Listening fatigue is also reduced, enabling me to enjoy several hours of listening at a time.

The specific components and design shown in this article are presented only as an example. I encourage you to apply these principles in creating a design that meets your own loudspeaker needs.

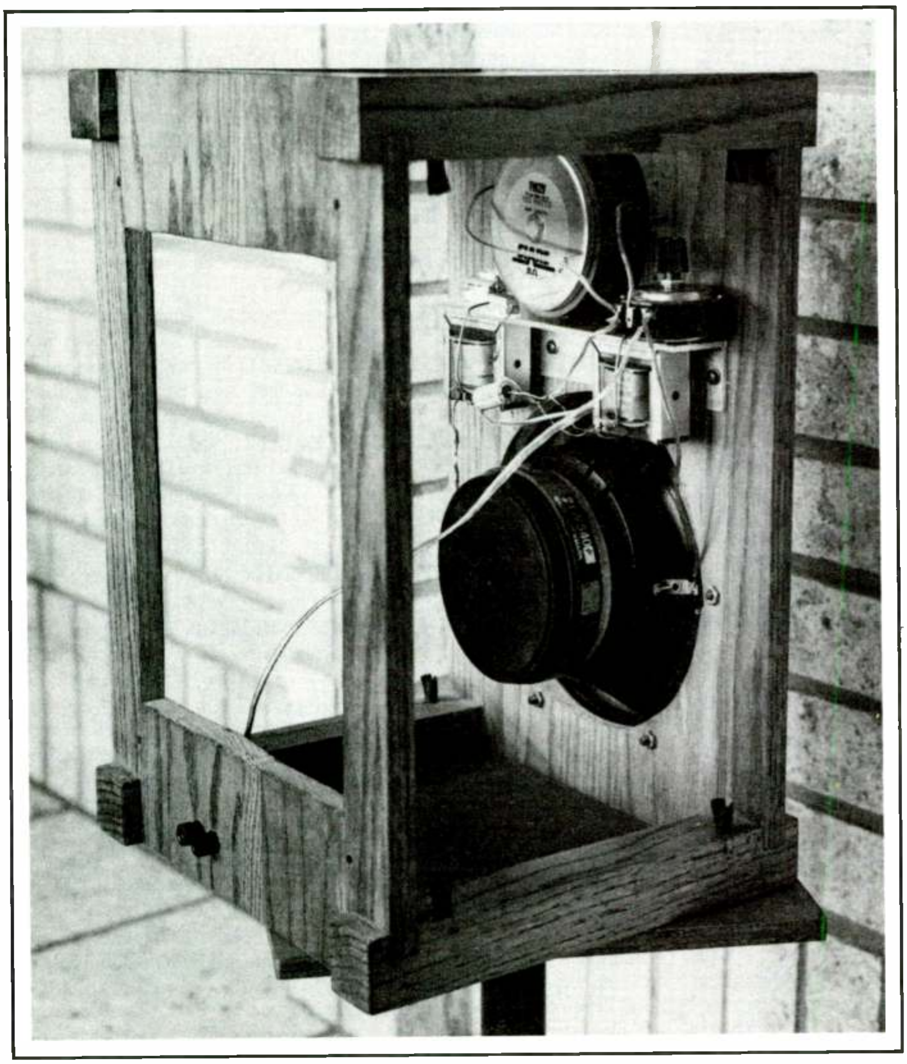

FIGURE 12: Your finished frames should look like this with the woofer and tweeter installed. The steel-core inductors are made like small transformers. Attach them to a piece of angle iron screwed to the front of the frame. The woofer is bolted in place.

ABOUT THE AUTHOR

A native of Amarillo, Texas, L.A. White, Jr., is a graduate of the University of Texas Law School and of the University of Texas Southwestern Medical School. He operates a mail-order company that sells, among other things, high-end audio components. When he is not testing loudspeakers, he practices family medicine.

THE MODIFIED DALINE

BY CARLOS E. BAUZA

When the Webb transmission-line (TL) project appeared in *The Audio Amateur* 1/75, I knew nothing about loudspeakers and woodworking. But that project fascinated me, and I decided to do something about it. I explored my Rectilinear III speakers and inquired about cabinetmaking. I obtained excellent information from *TAA,* Philips, Altec, Electro-Voice and Peerless. My pen pal from the Boston Audio Society, James Nichol, also provided invaluable support.

My first few construction projects included drivers from the manufacturers mentioned above. Then came my *magnum opus,* the Webb TL design. My next project was inspired by the LS3/5A. *(For a discussion of the LS3/5A, see* SB *4/81, p. 32.—Ed.)* Although it is quite a performer, its one drawback is diminishing bass response. Thus a matching subwoofer is a must. Enter the Daline, developed with the B-110 woofer and T-27 tweeter used in the LS3/5A.

The original Daline design was developed by Robert Fris, a British designer whose construction project appeared in *Hi-Fi News* (May 1975). He describes it as follows: the woofer works into a bass-reflex chamber tuned to support upper bass adequately. This vents into an acoustic line, which works only at frequencies below the reflex tuning point (thus *D*ecoupled *A*ntiresonance *Line*). Larger portions of the line are progressively coupled as frequency descends. This is seen by the woofer as damping and added mass. The two-step woofer loading produces deep, controlled bass.

I grafted the LS3/5A components into the Daline enclosure *(Fig. 1)* with superb results. This combination produces excellent imaging, extended bass and moderate loudness. The only problem was a too-full upper bass, which I corrected with acoustic damping. I also attentuated the T-27 tweeter because it was too loud for my room.

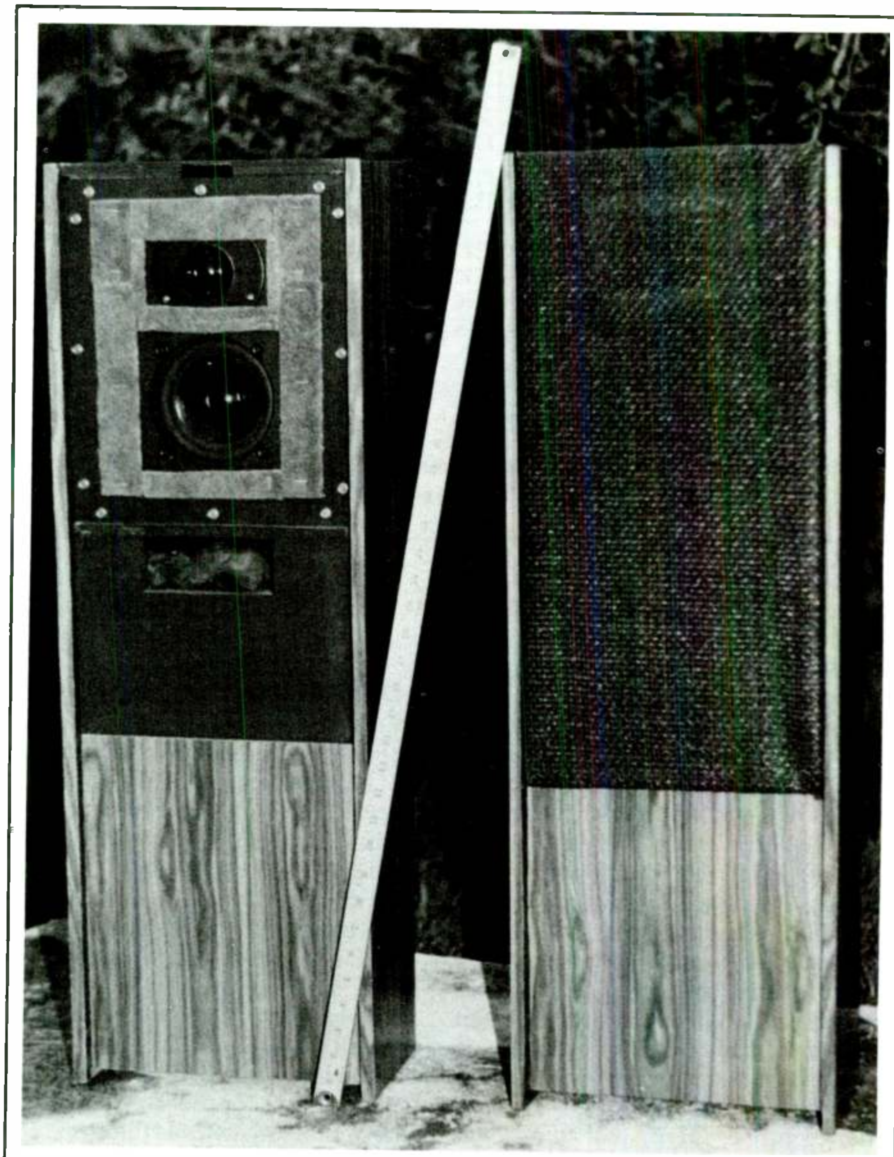

FIGURE 1: The modified Dalines have an "acoustic blanket" to solve diffraction problems. A 1-meter ruler rests on the cabinets to give you an indication of their size.

GETTING STARTED. I have taken the following instructions almost word for word from Mr. Fris's *Hi-Fi News* project* and have added the changes necessary for my modification. For cosmetic reasons, I cut the sides of my cabinets to extend about ¼ inch from the front and bottom. This contradicts diffraction theory and is not included in the specifications given below. To deal with diffraction problems, I stapled an "acoustic blanket" to the baffle. I calculated its size so that it would not interfere with the grille assembly.

The $^3/_8$-inch felt pieces surrounding the tweeter control diffraction. They are included with the Falcon LS3/5A

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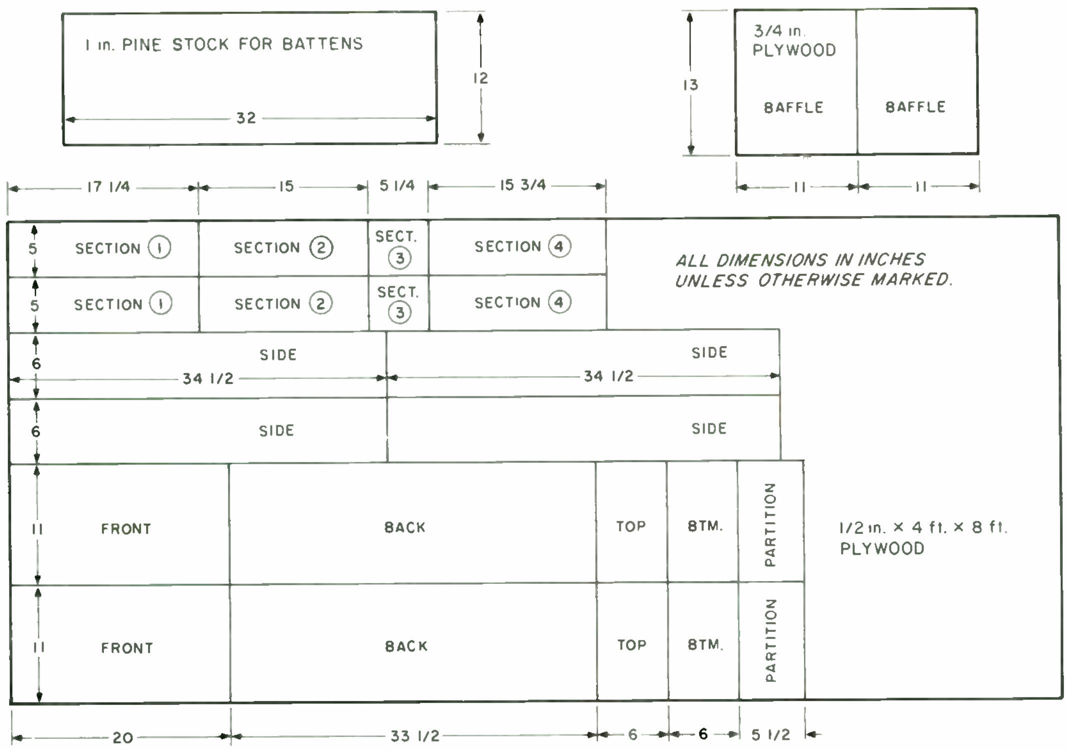


FIGURE 2: Cutting guide for two modified Dalines. When cutting, do not draw the guidelines on the wood, but measure each cut as you go. This automatically compensates for the ⅛ inch cut away with each pass of the blade.

kit and are installed on the baffle's front surface with dabs of glue. (See *Fig. 4a.*) The rest of the blanket is made of Scotch-Brite, a fibrous material about 3/16 inch thick and manufactured by the 3M Company. Usually green, it is available under various trade names at your local supermarket.

The B-110 is rear mounted, as in the LS3/5A design. Three knowledgeable persons, who prefer anonymity, tell me that this mounting came about for two reasons: front mounting seemed unimportant, and the number of systems originally built for the BBC did not warrant the cost of tooling for recessed front mounting. Because the system was designed that way, any change in position will dictate a crossover change.

The cabinets are made of ½-inch plywood or chipboard, except for the baffles, which are ¾ inch thick. The cabinet joints are glued, with brads inserted to hold them while the glue dries. Battens are not required. For maximum rigidity and airtight construction, the only removable panel is the baffle. Assembly begins with the back panel, and damping materials are inserted during assembly. The crossover assembly and connectors may be mounted high on the rear panel. Use stand-offs to avoid compressing the rear panel's foam padding.

CONSTRUCTION DETAILS. Cut all panels accurately according to *Fig. 2.* Verify that the sections for each cabinet are all *exactly* the same width, and plane them down if necessary. For "mirror image" cabinets, reverse one baffle.

Draw pencil lines 1 to 4 on each back panel *(Fig. 3).* Make two stacks of panels, one for each cabinet, and make sure all the sections in each stack match.

Mark up and cut the holes in the baffles *(Figs. 4a* and *4b).* Using a router, cut the recess for the T-27 and B-110. Cut out the areas from the fronts and partitions shown in *Figs. 5* and *6.* Cut out the hole in the backs for the loudspeaker connectors, making sure this does not interfere with the back brace or the crossover.

On one back, apply glue to the short edge farthest from the pencil lines and lay the panel, pencil lines up, on a clean, flat surface. Fix the top to the glued edge of the back, as shown in *Fig. 7.* Make sure the top is square with the back and the edges are flush, then drive two or three brads through the top into the edge of the back to

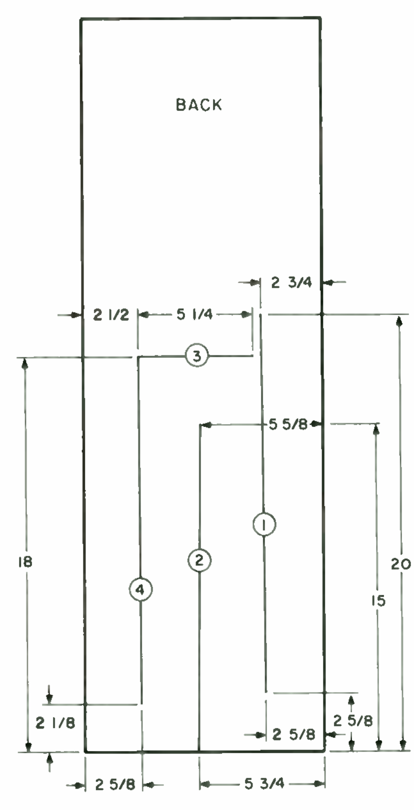


FIGURE 3: Draw pencil lines 1 to 4, in sequence, on the inside surface of each back panel.

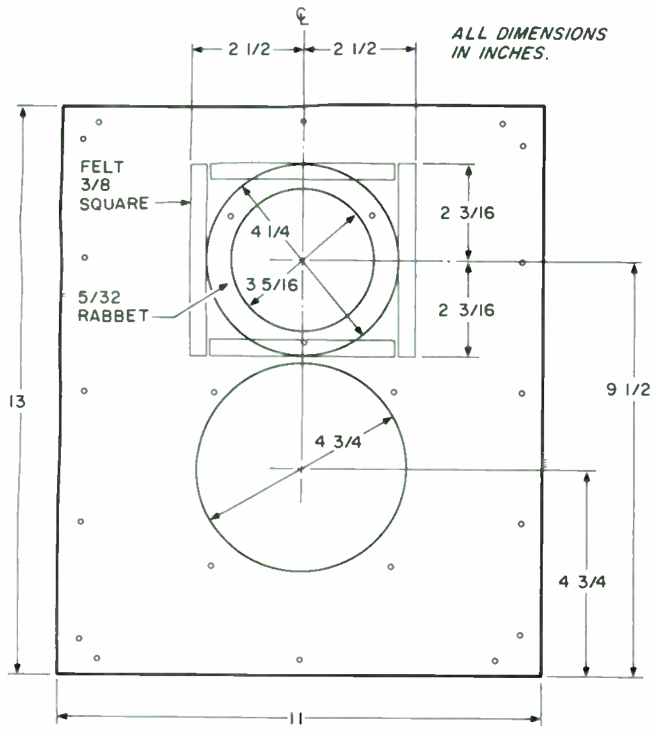


FIGURE 4a: Front view of the baffle. The ⅜-inch felt strips around the tweeter control diffraction. They were not yet installed when the photo in *Fig. 1* was taken.

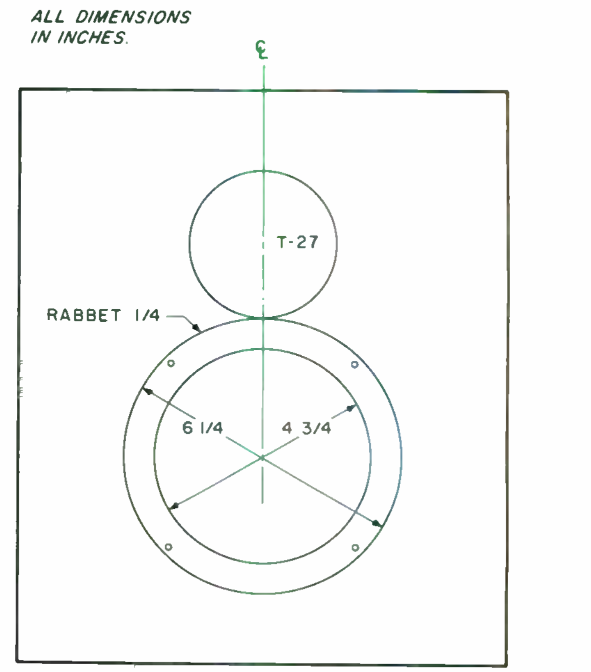


FIGURE 4b: Rear view of the baffle. A ¼-inch rabbet is necessary for the B-110 to maintain the relationship between the drivers.

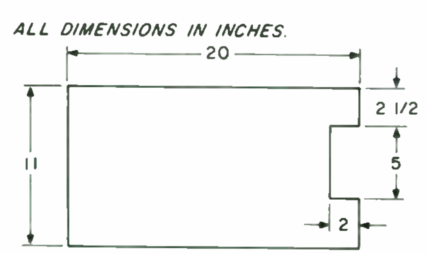


FIGURE 5: Cutting guide for the front panel.

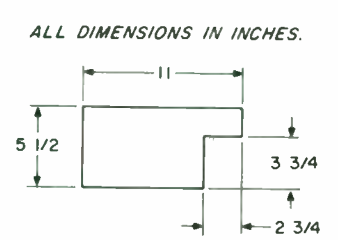


FIGURE 6: Cutting guide for the partitions.

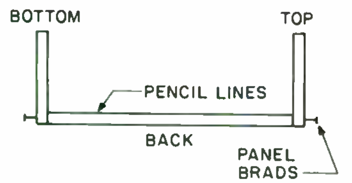


FIGURE 7: Attach the top and bottom panels to the back as shown.

hold the joint. Apply glue to the other short edge of the back and join the bottom to it as described above.

Apply glue along one long edge of the back, continuing along the adjacent edges of the top and bottom. Mount one side on the glued edges. Make sure the panels are all square and the surfaces and edges are flush. Drive brads through the side into the other three panels. Repeat this procedure for the other side.

While the first cabinet dries, construct the second cabinet as described above.

Return to cabinet 1 and install the partition. To ensure an airtight joint between the partition and front, measure off the length of the front between the partition and bottom. Lay the front in the partly assembled box as though it were being fitted. Because there is no support for it, lay one long edge on the back and rest the other on the top edge of one side, so the front is at an angle with the back.

Press the partition firmly against the top edge of the front. Apply glue to the two short edges and the interrupted long edge of the partition and install it as described above, with the cutout to the rear and right of the cabinet *(Fig. 8)*. Make sure it is square with the sides and back. Insert brads through the sides into the edges of the partition and remove the front, taking care not to disturb the partition.

Apply glue to one surface of the brace and press it onto the back, to one side of a diagonal across the cavity. Be sure this does not interfere with the connector or the crossover.

Apply glue to one surface of one long batten. Fix the batten to the inside surface of one side, leaving a ¾-inch gap between the batten and the front edge of the side. Repeat for the other long batten and the other side of the cabinet.

Apply glue to one surface of each short batten and fix the battens to the other two walls of the cavity to form a continuous ledge around the cavity.

Now install the four sections as shown in *Fig. 8*. Liberally apply glue to one long and one short edge of section 1. Mount the section with its glued long edge along the back and its glued short edge in contact with the partition. The surface of the section facing the right side of the cabinet must be against pencil line 1. Make sure the section is perpendicular to the back.

Apply glue to one long and one short edge of section 2. Mount the section

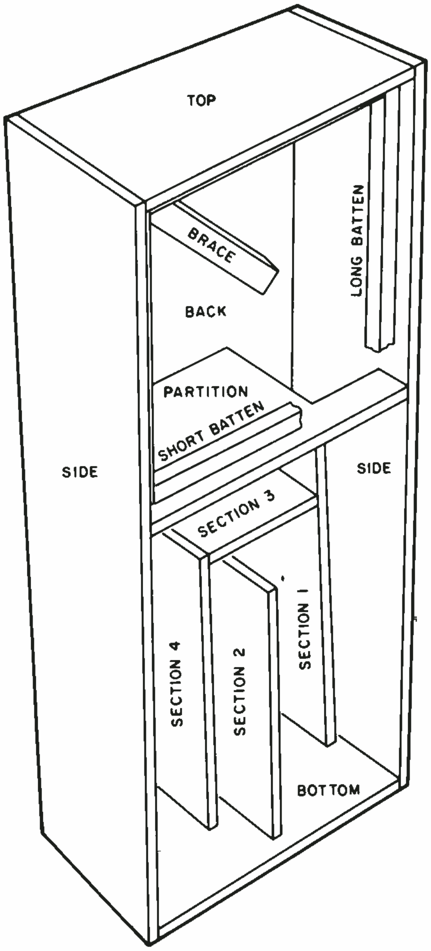


FIGURE 8: Partially assembled cabinet, with the baffle and front panel removed.

MATERIALS LIST

(1) 4-by-8-foot sheet ½-inch plywood or chipboard
(1) 13-by-22-inch sheet ¾-inch plywood or chipboard
(1) 1-by-4-foot sheet 1-inch pine stock*
(8) chassis stand-offs
(½) pint white or woodworker's glue
(1) box 1-inch brads
(50) inches ¼-inch foam sealing strip
(1) 40-by-24-inch sheet bonded acetate fiber (BAF)
(2) 13-by-11-inch sheets 1-inch polyurethane foam (used in cushions)
(3) ounces Terylene
(20) 1½-inch #6 countersunk steel screws
(9) ounces silicone
optional (but recommended) hearing protectors (Sears part #9GT1863); several sheets of Scotch-Brite

* Cut six 1-by-13-inch strips for long battens and braces. Cut four 1-by-n-inch short battens. Note that n equals 11 minus twice the exact thickness of the wood used. This simple calculation is necessary because the planed size of 1-inch timber can vary from ¾ to ⅞ inch and it is essential to have no gaps between the battens when they are fitted in the cabinet cavity.

with the side facing section 1 along pencil line 2 and the glued short edge in contact with the bottom. Make sure this section also is perpendicular to the back.

Liberally apply glue to one long and two short edges of section 3. Mount the section with the side facing the partition in contact with pencil line 3 and one glued edge butted against section 1. Make sure it is perpendicular to the back and you have not moved section 1.

Similarly apply glue to one long edge of section 4. Mount the section on the back so that one end of the side facing section 2 is in contact with the remaining glued edge of section 3 and the same side runs along pencil line 4. Once again, make sure the section is perpendicular to the back.

Check that all the sections are correctly installed, square with the back and well bedded down. Do not remove surplus glue, except if it will interfere with fitting the front. Let this cabinet dry and repeat the above procedure on the second cabinet.

Prepare six lumps (¼ ounce each) of Terylene (a polyester-based yarn) for each cabinet. (Falcon supplies the specified amount of Terylene, which is about the same density as long-fiber wool.) The weight is critical. The best method of measuring is to weigh the total amount (3 ounces), then divide it into two 1½-ounce pieces. Divide each piece into two ¾-ounce pieces, then each ¾-ounce piece into three ¼-ounce pieces.

Apply dabs of glue at about 4-inch intervals along three walls of the cabinet that form the line's pipe. Tease out and insert one piece of Terylene in each section of the pipe. The piece in the fourth section follows the pipe around the corner to the short section that forms the aperture. The pipe should now be lined with a continuous length of Terylene, with no lumps or bald patches. Repeat this procedure for the pipe in the second cabinet.

Return to the first cabinet. To form a gasket between the sections and the front, apply sealing strip or silicone glue (about a ¼-inch bead) along the top edges of the sections. Make sure there are no gaps.

Liberally apply glue to all four edges of the front but not around the aperture cutout. Lay the front on the sections, with the aperture toward the top and displaced to the left of the cabinet *(Fig. 9)*. With a block of wood interposed for protection, hammer down the front until it is flush with the front edges of the sides. Insert brads through the sides into the edges of the front. Repeat this procedure for the second cabinet.

Mount the terminal panel or socket on the back of the first cabinet. After connecting the wires, plug any gaps. Insert the polyurethane foam into the cavity so that it lies against the back and over the brace. It is not necessary to glue the foam, but you may do so if you wish by applying a little glue to each corner. Bring the wire from the socket around the edge of the foam.

Now cut out the four pieces of bonded acetate fiber (BAF) (14 by 7 inches) that will be stapled behind the woofers. Then cut 3¼-inch-wide strips of BAF to line the sides of the cavity between the battens and the back. Do not cover the entrance to the pipe.

Tease out two more lumps of Terylene and install them in the cavity wherever it is convenient, possibly opposite the two sides of the brace. Lay the unassembled baffle on the battens to make sure it fits. Drill the pilot holes for the screws that will connect the baffle and battens. An ideal tool for doing this is a Stanley Screwmate *(Fig. 10)*. Repeat this procedure for the second cabinet.

Mount the drive units on the baffles according to the design logic of the kit chosen, using the gasket supplied with the T-27. (A sealant rubber strip is supplied for the B-110 in the mini-monitor kit.) Make sure there are no air gaps between the drive units and the baffle.

Ordering Information

Much of the material you need for this project is available from Falcon Acoustics. These items include the drivers, BAF damping material, crossovers, felt pieces and Terylene. Falcon also offers grille cloth in various designs. A catalog listing Falcon's products is available for $3 by writing to them at Tabor House, Norwich Road, Mulbarton near Norwich, Norfolk NR14 8JT, England.

Ordering from England is a cinch. Your local bank can supply you with a draft drawn on a British bank in sterling pounds. Simply mail this, along with your order, to Falcon.

You can obtain the L-pads from Radio Shack stores or McGee Radio (1901 McGee St., Kansas City, MO 64108).

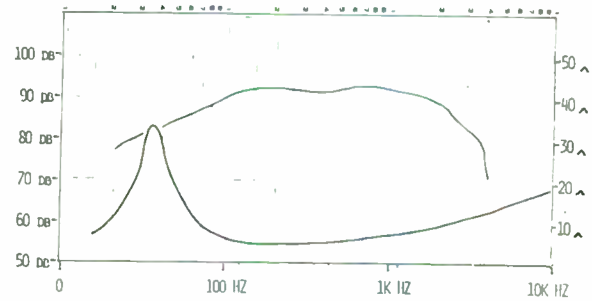
DUAL COIL WOOFERS

MADISOUND 81524 DVC

Fs	36Hz +/−2Hz
Mmd	25 Grams
Cms	0.8 x 10-6 CM/D
Vas	51 Liters
Rscc	3.7Ω
Z min	4.0Ω
Z max	32Ω
vcL	0.6mH
Qms	2.64
Qes	0.34
Qts	0.30

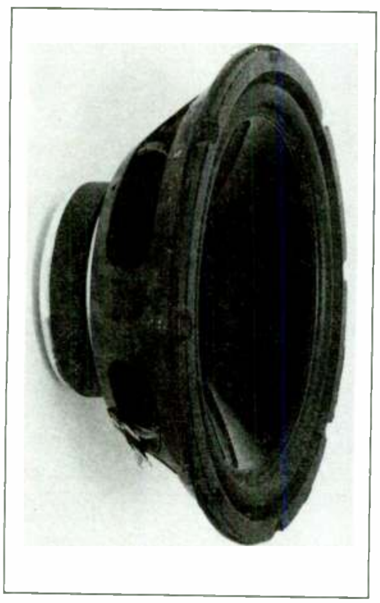
SURROUND: FOAM
MAGNET: 20 oz. CERAMIC
POWER HANDLING: 75W
FREQUENCY RESPONSE: 35-3kHz
EFFICIENCY: 92dB 1W/1M
USES: HOME HI-FI, AUTOSOUND WOOFER
PRICE: $22.80 EACH

VOICE COIL, 2 LAYER, 4Ω IMPEDANCE
MADISOUND SPEAKER COMPONENTS



MADISOUND 81524 BASS REFLEX ALIGNMENTS

BOX VOLUME: VB	0.85 CUBIC FT. 24 LITERS	28.3 CUBIC FT. 28.3 LITERS	42.5 CUBIC FT. 42.5 LITERS	63.7 CUBIC FT. 63.7 LITERS
BASS ½ PWR: F3	52Hz	48Hz	39.5Hz	32Hz
BOX-VENT RES FREQ: Vb	45Hz	43Hz	38.1Hz	33.5Hz
PEAK at RES: R	+0.12dB	−0. 5dB	−1.5dB	−3.0dB
PORT: D diameter	D 2"	D 2"	D 2"	D 2"
L length	L 3.5"	L 3.1"	L 2.4"	L 1.9"

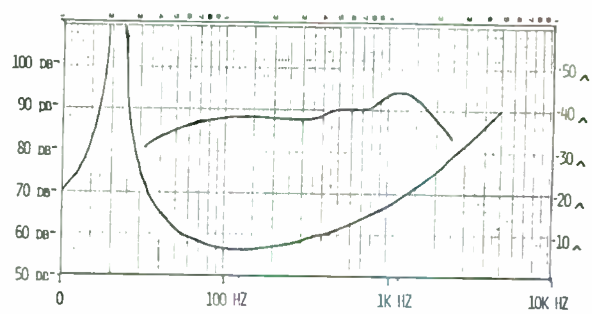


MADISOUND 1052 DVC

THE MADISOUND 1052 IS A TEN INCH POLYPROPYLENE WOOFER, WITH A BLACK CONE, 1.5 INCH KAPTON DUAL VOICE COIL, 8Ω IMPEDANCE PER COIL
MADISOUND SPEAKER COMPONENTS

Fs	21Hz
Mmd	46 Grams
Cms	1.3 x 10-6 CM/D
Vas	212 Liters
Rscc	5.7Ω
Z min	6.5Ω
Z max	86Ω
vcL	0.7mH
Qms	4.11
Qes	0.29
Qts	0.27

SURROUND: FOAM
MAGNET: 30 oz. CERAMIC
POWER HANDLING: 100W 50/50
FREQUENCY RESPONSE: 25-2.5kHz
EFFICIENCY: 91dB 1W/1M
USES: HOME OR AUTOSOUND SUBWOOFER COILS IN PARALLEL FOR 4 OHM RESULT
PRICE: $33.00 EACH



MADISOUND 1052 DVC BASS REFLEX ALIGNMENTS

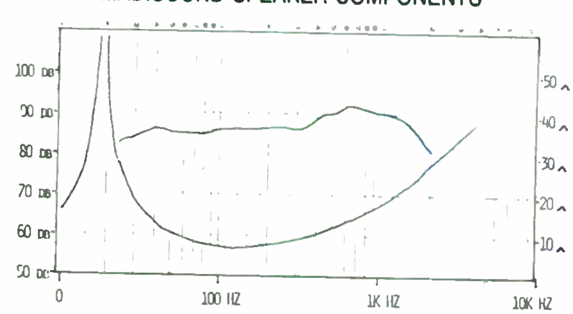
BOX VOLUME: VB	1.5 CUBIC FT. 42 LITERS	2.0 CUBIC FT. 57 LITERS	2.6 CUBIC FT. 74 LITERS	3.0 CUBIC FT. 85 LITERS
BASS ½ PWR: F3	46Hz	39.8Hz	34.8Hz	32.5Hz
BOX-VENT RES FREQ: Vb	34.5Hz	31.4Hz	28.1Hz	27.6Hz
PEAK at RES: R	+1.8dB	+0.9dB	+0.1dB	−0.3dB
PORT: D diameter	D 3"	D 3"	D 3"	D 3"
L length	L 8.4"	L 7.4"	L 7"	L 6.1"

MADISOUND 1252 DVC

THE MADISOUND 1252 IS A TWELVE INCH POLYPROPYLENE WOOFER, WITH A BLACK CONE, 1.5 INCH KAPTON DUAL VOICE COIL, 8Ω IMPEDANCE PER COIL
MADISOUND SPEAKER COMPONENTS

Fs	19Hz +/−2dB
Mmd	98 Grams
Cms	0.75 x 10-6 CM/D
Vas	318 Liters
Rscc	5.7Ω
Z min	7.0Ω
Z max	69Ω
vcL	1.7mH
Qms	4.4
Qes	0.39
Qts	0.36

SURROUND: FOAM
MAGNET: 30 oz. CERAMIC
POWER HANDLING: 100W 50/50
FREQUENCY RESPONSE: 20-1.8kHz
EFFICIENCY: 90dB 1W/1M
USES: HOME OR AUTOSOUND SUBWOOFER
PRICE: $34.00 EACH



MADISOUND 1252 DVC BASS REFLEX ALIGNMENTS

BOX VOLUME: VB	30 LITERS SEALED	56 LITERS SEALED	70 LITERS SEALED	120 LITERS VENTE	170 LITERS VENTED
BASS ½ PWR: F3	48.7Hz	43.8Hz	40.8Hz	28.7Hz	25.5Hz
FILLING IN BOX	Y	Y	N		
QTC	0.92	0.73	0.78		
BOX-VENT RES FREQ: Vb				26	23
PEAK at RES: R dB	+0.8dB	0.0dB	−0.3dB	+1.2dB	+0.3dB
PORT: D diameter				3.0"	3.0"
L length				4.5"	3.8"

FAST REPLY #IH20

MADISOUND SPEAKER COMPONENTS
8982 TABLE BLUFF ROAD • BOX 4283 • MADISON, WISCONSIN 53711 • PHONE (608) 767-2673

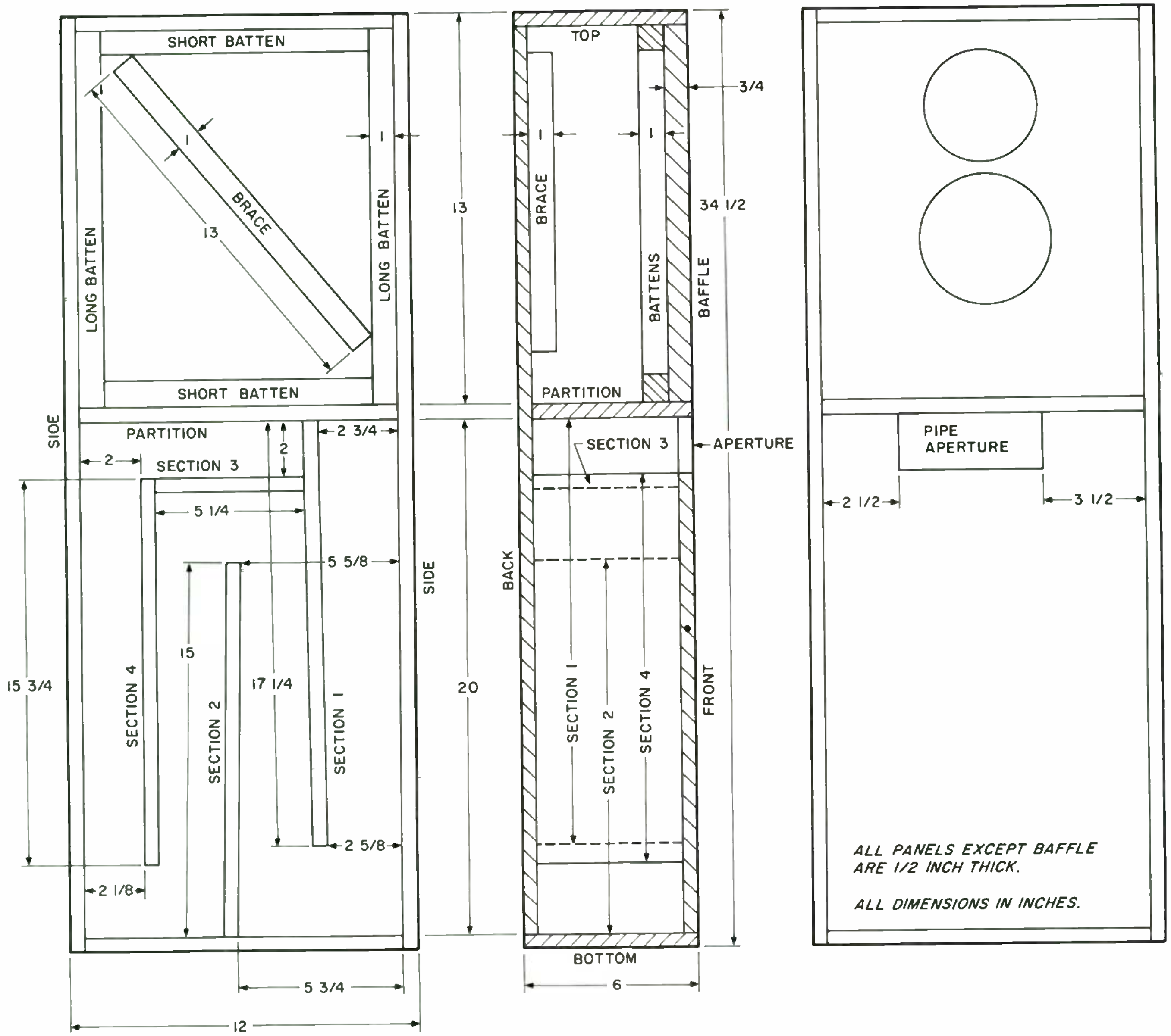


FIGURE 9: To the left is a front view of the enclosure with the baffle and front panel removed. In the center is a sectional view of the enclosure (as seen from the left) with the baffle and front panel installed. A front view with the baffle and front panel installed (right) shows the pipe aperture displaced toward the left side of the cabinet.

Solder the wire leads to the B-110, observing polarity. Orient the wires so that they will not interfere with the BAF damping. Determine the wire length visually, allowing enough slack for removal of the baffle for servicing.

Now staple the BAF damping to the back of the B-110 units to provide acoustical damping for the cones *(Fig. 11)*. To do this, place each baffle temporarily in its corresponding cabinet cavity, with the drivers looking inward. The rear of the woofers will face you. Arrange the BAF so that there will be no air gaps to the B-110 cone. Staple the BAF securely to the baffle *(Fig. 12)*.

Mount the crossover boards on the backs, using stand-offs to avoid compressing the polyurethane foam *(Fig. 13)*. Stand-offs are available in most electronics supply stores. If your store does not have them, you can make your own as follows. Locate a piece of suitable scrap wood and drill a series of holes to accommodate the screws (usually #6 or smaller) you will use to secure the crossover board. Cut off the drilled strip of wood and cut apart the individual stand-offs.

Now wire the drivers. Check that the electrical system is working correctly. Before fitting the baffles to the cabinets, connect the crossover board input to an amplifier with a music or white noise source. Set the bass and volume controls as low as possible. Advance the volume so that you can just hear something, then make sure each unit emits the correct part of the range.

If everything is okay, lay a continuous loop of sealing strip around the battens. As an alternative to the foam strip, you may use pieces of ⅛-inch felt cut from the large sheets available in fabric stores. Connect the cabinet connector wire to the crossover input pins, ensuring correct polarity.

Fit the baffle into the cavity, making sure it will not crush any crossover

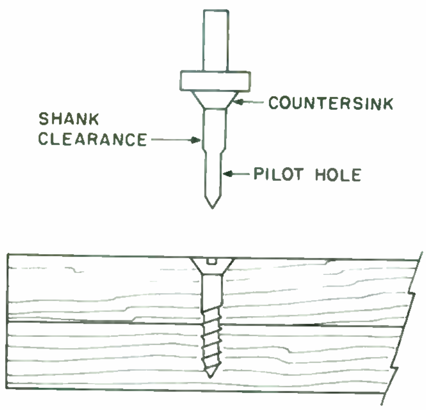


FIGURE 10: A Stanley Screwmate provides the pilot hole, shank clearance and countersink in one operation. The screw head should be flush with the surface.

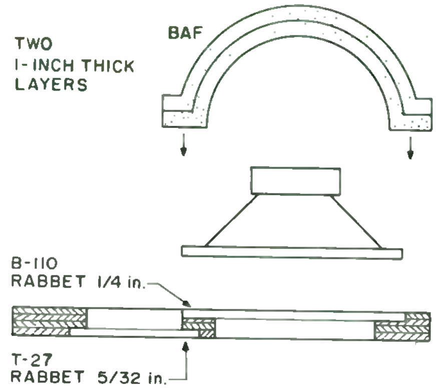


FIGURE 11: Staple bonded acetate fiber (BAF) behind the B-110 woofer to give you better control of the upper bass.

components and the cavity's vent is unobstructed. Do not screw down the baffle yet.

Connect the speakers to an amplifier. Apply a high-level 20Hz tone or organ bass notes, and listen carefully for any whistling or chuffing noises. Hold a piece of tissue paper over the pipe's aperture. The paper should flap vigorously and move farther than the B-110 cone. If all is well, screw down the baffle. Install the 3/8-inch pieces of felt supplied with the kit with dabs of glue (*Fig. 4a*). Now staple the "acoustic blanket" in place. Calculate its size so that it does not interfere with the grille-cloth assembly and the felt pieces. The speakers are now ready for final embellishment.

FURTHER CONSIDERATIONS. This modification satisfies me, but you may adapt your Daline to meet your own needs. Falcon Acoustics offers the components for the original three versions. The three-way design is particularly good for reproducing popular music. It uses the B-110, the Peerless K010DT and the Coles 4001G.

Alternative driver and crossover kits include the following: Falcon's "monitor-quality" kit, the original LS3/5A equivalent with your choice of original or aB tweeter section; Falcon's full specification kit, built by Falcon for RAM Electronics; the Focal Daline, Falcon's new version of the Daline; KEF's CS-1 kit, similar to the KEF 101 mini-monitor; KEF's CS-1a kit, a simplified version of the LS3/5A. I have not heard the drivers in the Focal Daline, but they are more sensitive than KEF's and as such constitute an improvement.

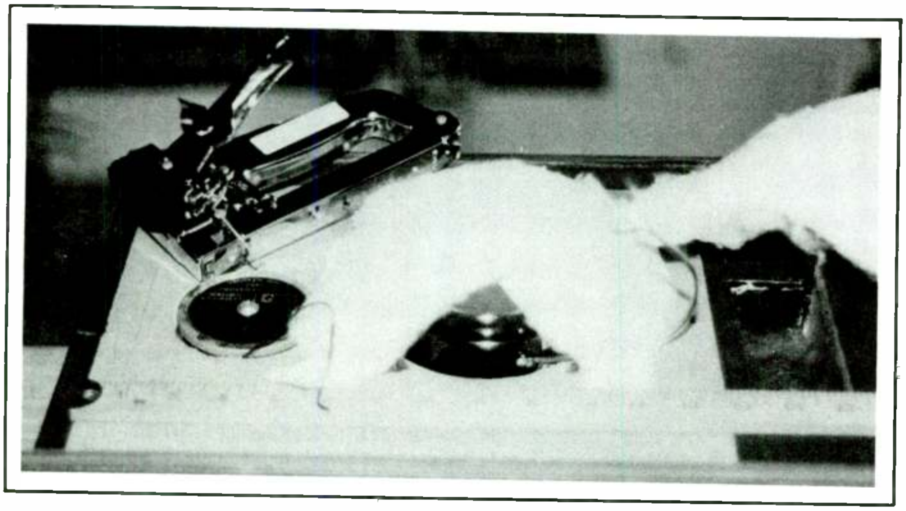


FIGURE 12: In this rear view of the baffle, note that one layer of BAF has been installed behind the woofer. Another layer should eliminate the remaining air gaps.

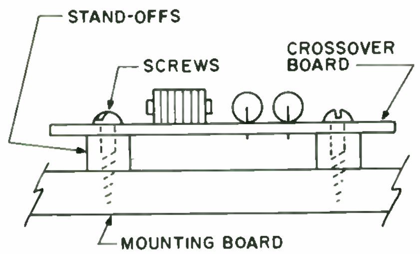


FIGURE 13: Use scrap wood or plastic stand-offs when mounting the crossovers to avoid compression of the polyurethane foam.

Another possibility for improvement is the "double" Daline. I have experimented with two woofers per channel, and the setup works very well with my Hafler DH-220 amplifier. Power handling is doubled, and low bass has more impact. I auditioned the Telarc *1812 Overture* on compact disk. The cannon shots were impressive, but could still overload the system. Other compact disk recordings with bass drums have solid impact without overload.

You may build the double Daline cabinet by joining two regular Dalines back to back. This cabinet is still compact and may be used one per channel. One double Daline per channel would involve using two woofers in parallel and one tweeter per channel. Two crossover configurations are possible. First, you could redesign the existing crossover for the lower impedance of the parallel woofers. This means that both units would be used up to 3kHz. Alternatively, and perhaps more advantageously, you could design a low-pass filter for the second woofer only (say 100 to 150Hz), using the original woofer and tweeter with their unmodified crossover.

In conclusion, my modified Daline has marvelous imaging and tonal balance, and it produces perfectly integrated bass in a compact, convenient package. It does not produce extremely loud output, but used within its limits, it will reward your efforts many times over.

Daline and Dynaquad

The modified Daline is ideal for "near-field" listening, in which the speakers are very close to the listener. (Although "near-field" has a specific technical definition, I am using it loosely to describe this listening arrangement.) Ideally, the speakers should be only inches from the ears, but this is not very practical. As with any system, certain circumstances should coincide for a successful effect: appropriately recorded program source, coherence between drivers, good imaging properties, clean disk surfaces and secure cartridge tracking. Any deficiency in these criteria will compromise the effect.

Very small speakers are the most desirable for near-field listening, but they lack true deep bass. The modified Daline retains all the sonic virtues of the small LS3/5A, but has the advantage of perfectly integrated bass down to 30Hz.

With near-field listening, the listener and speakers occupy very little space. The best subjective effect is obtained in the rear third of the room, where you see space in front of you. This is where sonic images appear to originate. Rarely do sounds appear to come from the drivers themselves. I placed the Dalines on the floor at a point 2 feet in front of me and about 2 feet to the left and right of this (*Fig. S-1*) with the drivers pointing at me. The effect is intensely realistic.

You can improve on this setup by adding Dynaquad, Hafler's ambience-derivation circuit. Note that the Hafler ambience circuit (*Fig. S-1*) looks slightly different from other published versions, but this is the way it is set up in the Dynaquad box once sold by Dynaco. I have experimented with it, and two improvements are apparent: the illusion of hall ambience is now more complete, and sounds that were recorded very close to the right or left microphone appear in their proper place within the stereo stage. Without ambience restoration, these sounds seem to come from the drivers themselves.

Traditional Dynaquad setups contribute a degree of realism, but some images seem to travel to the rear in an unnatural manner. This is because the front speakers are too far away and the rear speakers are too close. The desirable time delay between front and rear is thus inverted. With near-field setups, the time relationship between both pairs is corrected. The front speakers are closer, and the "rear" sound is slightly delayed. Therefore, full-range speakers at the rear are desirable and beneficial.

To set up your speakers, optimize the near-field stereo arrangement. Then add the "rear" speakers in line with your ears (maybe slightly to the rear), somewhat higher than ear level and a couple of feet farther out than the front speakers. Make sure your amplifier can tolerate a common connection between channels (Carver amps cannot) and listen. You will be mesmerized.

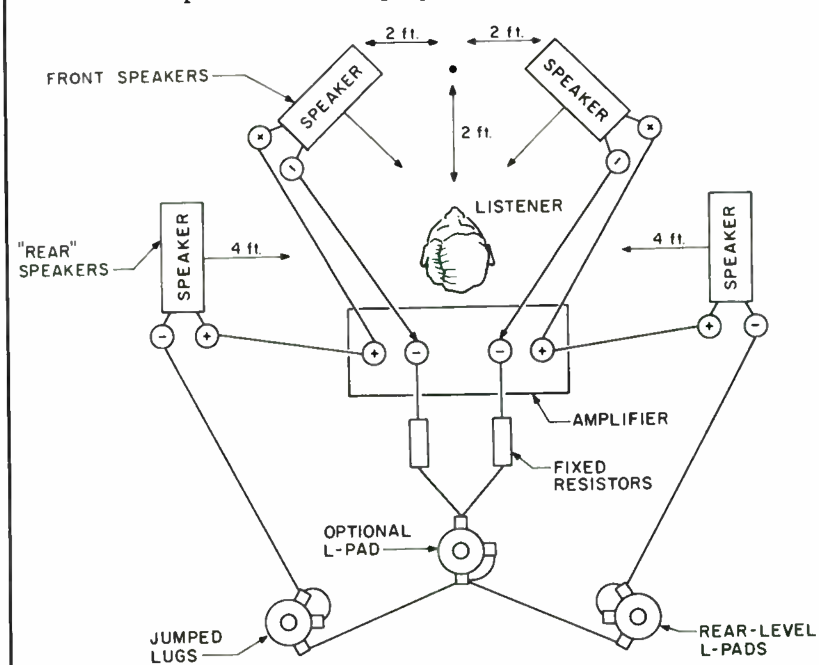


FIGURE S-1: This "near-field" listening setup includes the Dynaquad ambience system. The fixed resistors are 20Ω, 10W devices. Two L-pads are ganged together in Radio Shack part #40-978 or Calrad part #25-353. Two lugs are jumped on each. The optional L-pad varies front-to-rear separation, permitting experimentation for the best effect. The virtual stage is in front of, around and behind the listener.

ABOUT THE AUTHOR

Carlos Bauza is an officer in a commercial bank. His audio experience includes extensive kit and speaker building. His step-by-step instructions for building the Webb transmission line appeared in The B.A.S. Speaker *(Volume 6, Number 7). Mr. Bauza is also an active amateur tenor. He has sung lead parts in opera workshops and comprimario parts in professional productions.*

Craftsman's Corner

Custom Cabinet Designs

I have developed various speaker systems *(Photo 1)* for friends who share my interest in loudspeakers, but do not have the equipment, time or patience to build their own.

Note the unusual shape of the cabinets in *Photo 1*. My initial idea was to reduce diffraction from the SEAS H254X drivers, which had plagued other projects with a rectangular design. I simply reduced surface area around the driver by building a 5-degree angle into both sides of the cabinet. I believe I also (accidentally) reduced internal standing waves by angling the front panel back by 2 degrees and the back panel forward by 4 degrees. Inside the cabinets, I used 3-inch-thick fiberglass, covered with cheesecloth to prevent stray fibers from reaching the drivers. As you can probably imagine, I had a lot of "fun" calculating internal volume. I started by using the largest dimensions, then subtracted various triangles in true trigonometric style (yech!).

My cabinets might look a little complicated for hobbyist builders, but they are quite easy to construct with almost any power tool. If you do not have access to a large table saw, simply lay out the design on the board, clamp down a straight-edge and cut with a circular saw. Leave an extra ⅝ inch on the top and bottom of the side panels to allow sanding flush with the top and bottom cabinet panels. By using 2 degrees as a slope on the baffle, I have found that all voice coils are in almost perfect vertical alignment. I use dual banana plugs and 16-gauge wire to bring in the signal, and the convenience and terminal contact (electrically) could not be better.

Photo 2 shows a bass guitar cabinet I made for a friend who is a professional musician and wanted a 2-by-15-inch driver cabinet. He tours frequently, so he needed a very strong cabinet. I used aluminum angle on all the edges (about $30) and ¾-16 flat expanded metal as a grille (about $8). I also used a full 8 by 4 by ¾ inch sheet of plywood. The Thiele/Small parameters yielded 9.1 cubic feet for two 15-inch Pyle bass drivers. I used 3-inch ABS pipe for the two symmetrical vents, and the internal bracing yielded a cabinet resonance of 980Hz—nice and high.

I tested the cabinet with a bass guitar and decided to try it as part of my home system to see what it could do there. I used it as a subwoofer with an electronic crossover set at 70Hz. This unit sounded great in terms of SPL (sound-pressure level). Even when equalized with pink noise, it sounded authoritative, if a little slow. It only cost about $175 to build, but I am sure a similar commercial design would cost about $500.

I am always surprised at the abundance of inferior speakers on the market and have found that custom design is the best alternative. I urge others who want to achieve superior sonic quality to build their own speakers or to find a good custom builder who will work with them to attain their goals.

Steve Hope
Spandau Speaker Systems
Stockton, CA 95207

PHOTO 1: Mr. Hope has designed several speaker systems for friends.

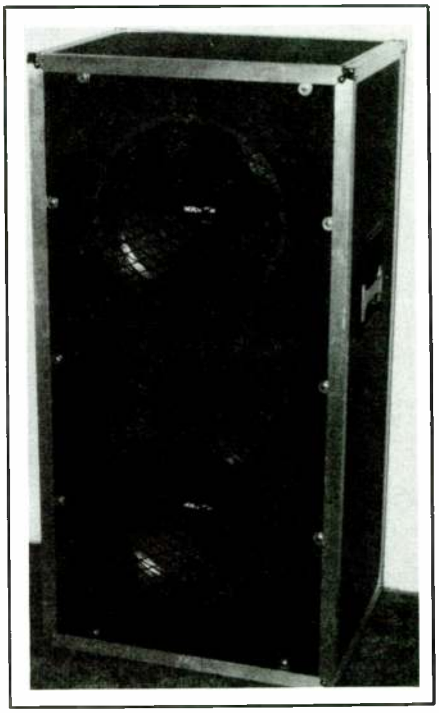


PHOTO 2: This bass guitar cabinet houses two 15-inch Pyle bass drivers.

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For example this is how FOCAL produced the highly acclaimed 7N303, which has by far the highest Acceleration Factor of any quality synthetic cone drive unit, thus assuring the best transient response without compromise. FOCAL discloses this fundamental characteristic for all its drive units. We want you to compare us with the other drivers. If not published you can find this factor for yourself: just divide the Force Factor (BL expressed in Tm or NA^{-1}) by the Moving Mass (Mmd expressed in Kg).

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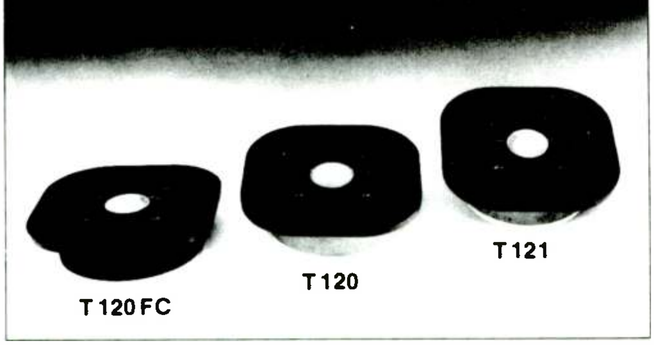
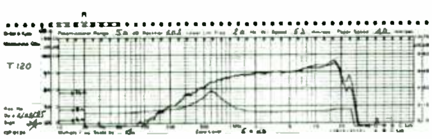
INVERTED DOME TWEETERS

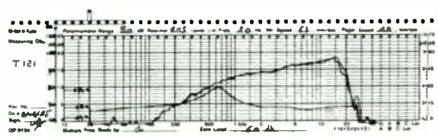


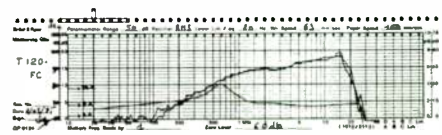
THE FOCAL tweeters conform to the very highest technical standards. The superactive 1.3 kg magnet circuit of T 120FC, constructed from a heavy ferrite magnet and a pure iron pole, ensures a magnetic flux density of 20, 500 G. The same large magnetic circuit is employed for T 120 and T 121 but with normal polar pieces. The specific shape of the inverted fiberglass coupled to a low resonance foam surround maintains a constant regular off-axis response over the widest directional coverage. The FOCAL tweeters achieve a very high sensitivity, a constant acoustical energy up to 15 Khz and a superbly transient response.

T 120 FC: 20,500 G, 1.4 kg

MODEL	DIMENSIONS (mm)	NOMINAL IMPEDANCE (Ω)	SENSITIVITY 2,8v/1m (dB)	RESONANT FREQ. (Hz)	POWER CAPACITY (w) CONT.	POWER CAPACITY (w) PROGRAM	LOWEST RECOM CROSS. FREQ.	VOICE COIL DIAMETER (mm)	CONE DIAMETER (mm)	CONE MATERIAL	SURROUND MATERIAL	FORMER MATERIAL	MOVING MASS (g)	FLUX DENSITY (T)	MAGNET WEIGHT (kg)	BL (NA^{-1})	MAGNETIC ENERGY (Ws)	MAGNET DIAMETER (mm)	NET WEIGHT (kg)
T120	120×120	8	92	600	10	75	3,2 kHz	20.4	30	Fiberglass	FOAM	Aluminium	0.30	1.8	0,725	3,41	0,108	96	1,4
T121	120×120	8	94	580	10	75	4 kHz	20.4	30	Fiberglass	FOAM	Aluminium	0.25	1.8	0,725	3,41	0,108	96	1,4
T120FC	120×120	8	95	580	10	75	4 kHz	20.4	30	Fiberglass	FOAM	Aluminium	0.25	2.05	0,725	3,90	0,140	96	1,4







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NEOFLEX MIDRANGES

7 N 303: ACOUSTIC DIFFUSER
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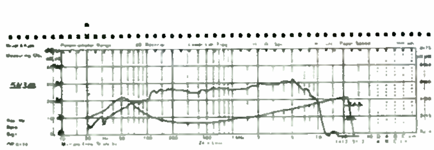
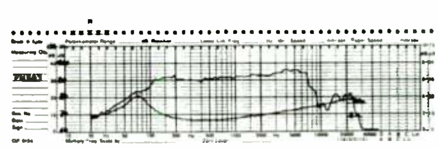
Adoption of an Aluminium edgewise 40 mm voice-coil greatly increases the total conductor volume within the magnetic circuit of 7 N 303. The use of Neoflex cones in 5 N 302 and 7 N 303 also contributes to improvements in linearity of frequency response and polar dispersion. Both units have a large bandwich reaching 6 KHz.

MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEDANCE (Ω)	MINIMUM IMPEDANCE (Ω)	DC RESIST. (Ω)	RESONANCE FREQ. (Hz)	SENSITIVITY 2,8v/1m (dB)	POWER CAPACITY (w) CONT.	POWER CAPACITY (w) PROGRAM	LOWEST RECOM. CROSS. FREQ.	VOICE-COIL DIA (mm)	VOICE-COIL WIRE	VOICE-COIL LAYERS	CONE MATERIAL	SURROUND MATERIAL	VOICE COIL FORMER	VOICE COIL LENGTH (mm)	GAP HEIGHT (mm)	MAGNET WEIGHT (kg)	MAGNET DIA. (mm)	NET WEIGHT (kg)
5N302	130	8	7,4	6,5	50	88,5	45	90	300 Hz	25,5	COPPER	2	NEOFLEX + PLASTIFLEX	NEOPREN + PVC	NOMEX	13	6	0.56	100	1.52
7N303	175	8	7	6,3	70	93	70	150	200 Hz	40	ALUMINIUM RIBBON	1	NEOFLEX + PLASTIFLEX	FOAM + PLASTIFLEX	NOMEX	7	6	0.87	121	2.65





MODEL	Q_{TS} TOTAL Q FACTOR	Q_{ES} ELEC. Q FACTOR	Q_{MS} MECH. Q FACTOR	C_{MS} SUSPENSION COMPLIANCE (mN^{-1})	S_D EMISSIVE PISTON AREA (cm²)	M_{MD} MOVING MASS (g)	R_{MS} MECHAN. RESISTANCE (kg/S^{-1})	V_{AS} EQUIV. VOLUME OF SUSPENSION (l)	BL FORCE FACTOR (NA^{-1})	Γ ACCELERAT. FACTOR (ms^{-2}A^{-1})	GAP VOLUME (mm³)	E MAGNETIC ENERGY (Ws)	B FLUX DENSITY (T)	V_B RECOM. ENCLOSURE VOLUME (l)
5N302	0.31	0.34	3.57	1.04 10^{-3}	86.6	9.8	0.86	10.9	8.2	837	567	0.375	1.29	5 → 8
7N303	0.45	0.54	2.81	0.49 10^{-3}	158	10.6	1.66	17.1	11.3	1066	963	0.698	1.35	7 → 11

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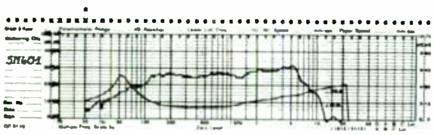
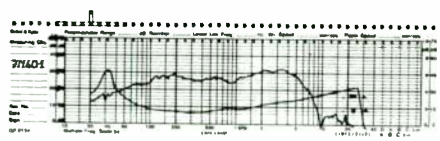
NEOFLEX BASS-MIDRANGES

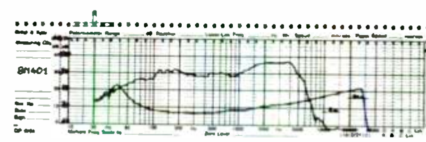
VOICE COIL DIAMETER: 25 mm

Focal has developped a new synthetic isotropic material for loudspeaker cones, NEOFLEX, which combines at last both rigidity and lightness. NEOFLEX gives excellent dispersion patterns, very linear response curves and gradual roll-off slopes at high frequencies without any peaking. Good sensitivity (much better than Bextrene and slighty higher than polypropylene), low colouration and extended bass response enable NEOFLEX units to be used with low rated power.

MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEDANCE (Ω)	MINIMUM IMPEDANCE (Ω)	DC RESISTANCE (Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2,8v/1 m (dB)	POWER CAPACITY (w)	VOICE-COIL DIA. (mm)	VOICE-COIL WIRE	VOICE-COIL LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP HEIGHT (mm)	MAGNET WEIGHT (kg)	MAGNET DIA. (mm)	NET WEIGHT (kg)
5N401	130	8	7,4	6,5	40,7	86,5	45	25,5	COPPER	2	NOMEX	NEOFLEX	NEOPREN	CLOTH + LATEX	PLASTIFLEX	13	6	0.56	100	1.52
7N401	175	8	7,4	6,5	30	87,6	50	25,5	COPPER	2	NOMEX	NEOFLEX	NEOPREN	CLOTH	PLASTIFLEX	13	6	0.56	100	1.62
8N401	200	8	7,4	6,5	31,5	89	60	25,5	COPPER	2	NOMEX	NEOFLEX	NEOPREN + PVC	CLOTH + LATEX	PLASTIFLEX	13	6	0.56	100	1.66



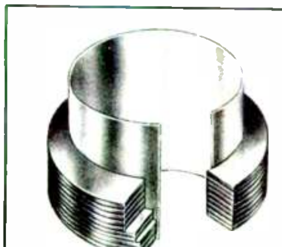




NEOFLEX BASS-MIDRANGES

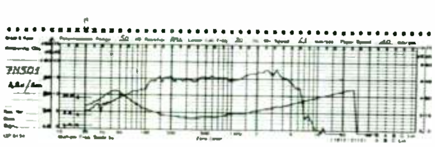
VOICE COIL DIAMETER: 40 mm

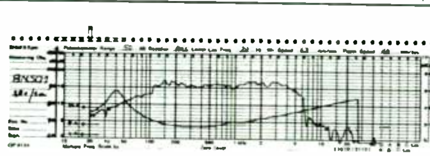
Focal manufactures its larger voice coils (>25 mm) with copper or aluminium flat wire, edgewound in a single layer. This sophisticated technique, mastered only by a limited number of manufacturers, permits a 25% increase in force and dynamics.

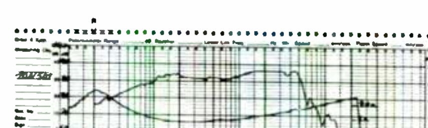


EDGEWOUND FLAT WIRE VOICE COIL

MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEDANCE (Ω)	MINIMUM IMPEDANCE (Ω)	DC RESISTANCE (Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8v/1 m (dB)	POWER CAPACITY (w)	VOICE-COIL DIA. (mm)	VOICE-COIL RIBBON WIRE	VOICE-COIL LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP HEIGHT (mm)	MAGNET WEIGHT (kg)	MAGNET DIA. (mm)	NET WEIGHT (kg)
7N501	175	8	7,4	6	37.1	89,6	80	40	COPPER	1	KAPTON	NEOFLEX	NEOPREN + PVC	CLOTH + LATEX	PLASTIFLEX	13	6	0.87	121	2.50
8N501	200	8	7,4	6	32.4	91.6	85	40	COPPER	1	KAPTON	NEOFLEX	NEOPREN + PVC	CLOTH	PLASTIFLEX	13	6	0.87	121	2.55
10N501	260	8	7,4	6	21.8	92	85	40	COPPER	1	KAPTON	NEOFLEX	NEOPREN + PVC	CLOTH	PLASTIFLEX	13	6	0.87	121	2.90







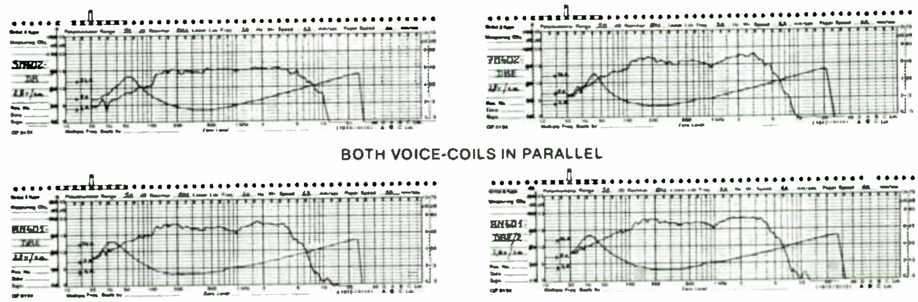
MODEL	Q_{TS} TOTAL Q FACTOR	Q_{ES} ELEC. Q FACTOR	Q_{MS} MECH. Q FACTOR	C_{MS} SUSPENSION COMPLIANCE (mN^{-1})	S_D EMISSIVE PISTON AREA (cm^2)	M_{MD} MOVING MASS (g)	R_{MS} MECHAN. RESISTANCE (kg/S^{-1})	V_{AS} EQUIV. VOLUME OF SUSPENSION (l)	BL FORCE FACTOR (NA^{-1})	Γ ACCELERAT. FACTOR $(ms^{-2}A^{-1})$	GAP VOLUME (mm^3)	E MAGNETIC ENERGY (Ws)	B FLUX DENSITY (T)	ENCLOSURE SYSTEM	V_B RECOM. VOLUME (l)	α THIELE ALIGN-MENT	F_3 FREQ. CUT OFF (Hz)	PORT AREA (cm^2)	PORT LENGTH (cm)
5N401	0.335	0.37	3.57	1.51 10^{-3}	86.6	10.2	0.73	15.8	8.2	804	567	0.375	1.29	Bass-Reflex	10	5.7	51	14.1	14.9
7N401	0.35	0 37	5.95	1.75 10^{-3}	154	16.3	0.51	58.1	8.2	503	567	0.375	1.29	CLOSED	13	—	60	—	—
8N401	0.45	0 53	3.0	1.30 10^{-3}	215	19.4	1.19	84.1	8.2	423	567	0.375	1.29	CLOSED	35	—	49	—	—
7N501	0.236	0 254	3.46	1 00 10^{-3}	154	18.3	1.23	33.4	13.4	732	963	0.698	1.35	Bass-Reflex	15	8	56	25 15	9 4
8N501	0.235	0 25	3.95	1 21 10^{-3}	215	20	1.03	78.3	13.4	670	963	0.698	1.35	Bass-Reflex	35	8	48	42 5	7 9
10N501	0.231	0 26	2.05	1.40 10^{-3}	330	38.0	1.40	212.7	13.4	353	963	0.698	1.35	Bass-Reflex	62	5 7	37	42 5	10.2

For information on kit applications Fast Reply #1066
For information on other products Fast Reply #1067

ALL ACOUSTICAL MEASUREMENTS REALISED ON IEC BAFFLE

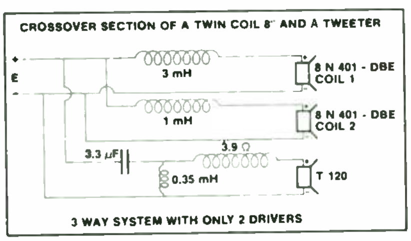
TWIN COIL NEOFLEX UNITS

Focal has developped a new design concept with small-sized twin coil units. The Focal range incorporates some new drive-units fitted with two concentric but separate voice coils. They have been specially designed for a specific application. Both voice coils work in different frequency ranges; one operates over the full range of the unit whilst the other only operates over the lower bass range, being rolled off at higher frequencies. In this way, it is now possible to modify the lower mid-range and bass levels as required and adjust the frequency response in an area not previously possible. The voice coils work together in the lower bass range, but have different roll-off frequencies using two cross-over sections. This design increases the total efficiency and simplifies the crossover networks. As it is not necessary to use many elements to obtain a linear response, the phase shift is reduced and the bass performance is quite outstanding for small units.

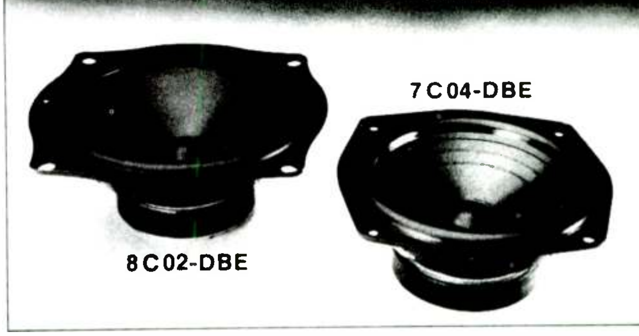


BOTH VOICE-COILS IN PARALLEL

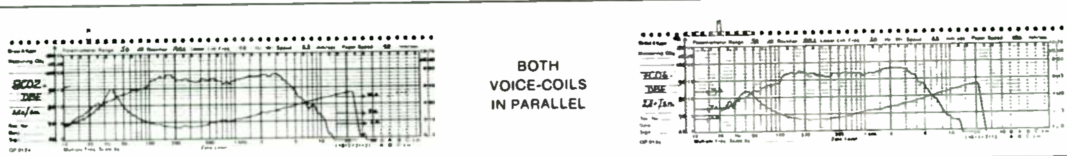
MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEO. OF EACH COIL	MINIMUM IMPEO. OF EACH COIL	DC RESISTANCE OF EACH COIL	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8v/1m (dB)	POWER CAPACITY (w)	DIA (mm)	VOICE-COIL WIRE	LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP LENGTH (mm)	MAGNET WEIGHT (kG)	MAGNET SIZE (mm)	NET WEIGHT (kg)
5N402-DB	130	8Ω	7Ω	6Ω	45	89.5	55	25 5 +26.3	COPPER	4	NOMEX	NEOFLEX	NEOPREN + PVC	CLOTH + LATEX	PLASTIFLEX	11 5	6	0 56	100	1 52
7N402-DBE	175	8Ω	7Ω	6Ω	34.9	90.6	60	25.5 +26.3	COPPER	4	NOMEX	NEOFLEX	NEOPREN + PVC	CLOTH	PLASTIFLEX	11 5	6	0 56	100	1.62
8N401-DBE	200	8Ω	7Ω	6Ω	30 9	92.0	65	25.5 +26 3	COPPER	4	NOMEX	NEOFLEX	NEOPREN + PVC	CLOTH	PLASTIFLEX	11 5	6	0 56	100	1 66
8N401-DBE/2	200	8Ω	7Ω	6Ω	30.9	93.2	65	25.5 +26.3	COPPER	4	NOMEX	NEOFLEX	NEOPREN + PVC	CLOTH	PLASTIFLEX	11 5	6	0 56 +0 73	100 +96	2.6



TWIN COIL PAPER UNITS



MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEO. OF EACH COIL	MINIMUM IMPEO. OF EACH COIL	DC RESISTANCE OF EACH COIL	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8v/1m (dB)	POWER CAPACITY (w)	DIA. (mm)	VOICE-COIL WIRE	LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP LENGTH (mm)	MAGNET WEIGHT (kG)	MAGNET SIZE (mm)	NET WEIGHT (kg)
7C04-DBE	175	8Ω	7Ω	6Ω	38.8	92 5	65	25.5 +26.3	COPPER	4	NOMEX	PAPER	NEOPREN + PVC	CLOTH	LATEX	11.5	6	0.56	100	1.62
8C02-DBE	200	8Ω	7Ω	6Ω	36 4	94.5	70	25.5 +26.3	COPPER	4	NOMEX	PAPER	NEOPREN	CLOTH	LATEX	11 5	6	0.56	100	1.66



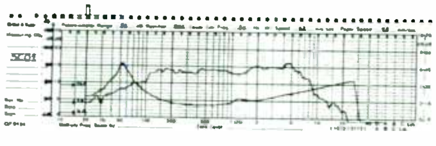
BOTH VOICE-COILS IN PARALLEL

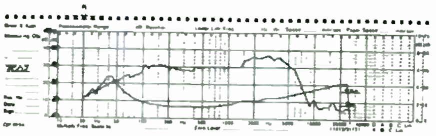
MODEL	Q_{TS} TOTAL Q FACTOR	Q_{ES} ELEC. Q FACTOR	Q_{MS} MECH. Q FACTOR	C_{MS} COMPLIANCE OF SUSP. (mN^{-1})	S_D EMISSIVE PISTON AREA (cm^2)	M_{MD} MOVING MASS (g)	R_{MS} MECHAN. RESISTANCE (kg/s^{-1})	V_{AS} EQUIV. VOLUME OF SUSPENSION (l)	BL FORCE FACTOR (NA^{-1})	Γ ACCELERAT. FACTOR ($ms^{-2}A^{-1}$)	GAP VOLUME (mm^3)	E MAGNETIC ENERGY (Ws)	B FLUX DENSITY (T)	ENCLOSURE SYSTEM	V_B RECOM. VOLUME (l)	n THIELE ALIGNMENT	F_3 FREQ. CUTT OFF (Hz)	PORT AREA (cm^2)	PORT LENGTH (cm)
5N402-DB	0.23	0.25	2.92	$1.16\ 10^{-3}$	86.6	10.8	1.05	12.2	10.7	931	776	0.360	1.08	Bass-Reflex	6.5	10	62	14.1	8.1
7N402-DBE	0.31	0.34	3.26	$1.04\ 10^{-3}$	154	20.0	1.35	34.5	10.7	535	776	0.360	1.08	Bass-Reflex	13.3	4	56.3	14.1	13.0
8N401-DBE	0.33	0.37	2.97	$1.30\ 10^{-3}$	215	20.4	1.33	84.1	10.7	525	776	0.360	1.08	Bass-Reflex	36.6	4	46.8	25.15	11.4
8N401-DBE/2	0.275	0.30	2.70	$1.30\ 10^{-3}$	215	20.4	1.47	84.1	11.8	578	776	0.437	1.19	Bass-Reflex	36.2	5.7	47.1	25.15	7.2
7C04-DBE	0.315	0.35	3.03	$1.06\ 10^{-3}$	158	15.8	1.27	39.4	10.7	677	776	0.360	1.08	Bass-Reflex	15.6	4	61.8	14.1	8.7
8C02-DBE	0.303	0.32	5.82	$1.01\ 10^{-3}$	222	19.0	0.75	69.7	10.7	564	776	0.360	1.08	Bass-Reflex	36.5	5.7	50.3	25.15	5.8

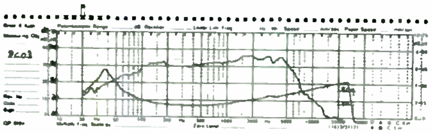
ALL ACOUSTICAL MEASUREMENTS REALISED ON IEC BAFFLE

For information on kit applications Fast Reply #1066
For information on other products Fast Reply #1067

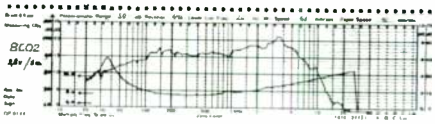
VOICE COIL DIAMETER: 25 mm







PAPER BASS-MIDRANGES



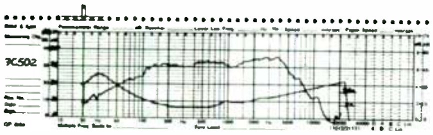
MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEDANCE (Ω)	MINIMUM IMPEDANCE (Ω)	DC RESISTANCE (Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8v/1 m (dB)	POWER CAPACITY (w)	VOICE-COIL DIA. (mm)	VOICE-COIL WIRE	VOICE-COIL LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP LENGTH (mm)	MAGNET WEIGHT (kg)	MAGNET SIZE (mm)	NET WEIGHT (kg)
5C01	130	8	7.4	6.5	42.7	88	40	25.5	COPPER	2	NOMEX	PAPER	NEOPREN	CLOTH	—	13	6	0.56	100	1.52
7C02	175	8	7.4	6 5	31.5	89.5	50	25 5	COPPER	2	NOMEX	PAPER	NEOPREN	CLOTH + LATEX	LATEX	13	6	0 56	100	1 62
7C03	175	8	7.4	6.5	37.1	91.5	55	25.5	COPPER	2	NOMEX	PAPER	FOAM	CLOTH + LATEX	LATEX	13	6	0.56	100	1.62
8C02	200	8	7.4	6.5	39.4	91.5	60	25.5	COPPER	2	NOMEX	PAPER	NEOPREN	CLOTH + LATEX	LATEX	13	6	0.56	100	1 66

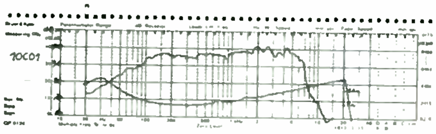
VOICE COIL DIAMETER: 40 mm

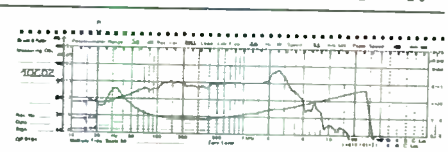
FOCAL has developped KAPTON formers for their 40 mm copper flat wire voice coil. Because of an ideal heat resistance within the range of — 269° C and 400° C, KAPTON plymide films have been used by the NASA for the last APPOLO missions. Besides, KAPTON is exceptionaly stable dimension-wise. High temperature resistant KAPTON does not melt, does not burn, does not carbonize. Its qualities remain unaltered at extreme temperatures. Highly effective glues have been developped to bond together the copper ribbon-wire, coiled in one layer, and the 0.005 inch film. Power-handling has improved by 60% as compared to NOMEX.

PAPER BASS-MIDRANGES

MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEDANCE (Ω)	MINIMUM IMPEDANCE (Ω)	DC RESISTANCE (Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8v/1 m (dB)	POWER CAPACITY (w)	VOICE-COIL DIA. (mm)	VOICE-COIL RIBBON WIRE	VOICE-COIL LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP HEIGHT (mm)	MAGNET WEIGHT (kg)	MAGNET SIZE (mm)	NET WEIGHT (kg)
7C502	175	8	7.4	6.1	30.5	91.2	75	40	COPPER	1	KAPTON	PAPER	NEOPREN	CLOTH	LATEX	13	6	0 87	121	2 5
10C01	260	8	7.4	6.1	25.7	96	95	40	COPPER	1	KAPTON	PAPER	PVC	CLOTH + LATEX	LATEX	13	6	0.87	121	2 9
10C02	260	10.5	9.5	7.8	27.2	90	130	40	COPPER	1	KAPTON	PAPER	NEOPREN	CLOTH	—	16.5	6	0.87	121	2 9







MODEL	Q_{TS} TOTAL Q FACTOR	Q_{ES} ELEC. Q FACTOR	Q_{MS} MECH. Q FACTOR	C_{MS} COMPLIANCE OF SUSP. (mN^{-1})	S_D EMISSIVE PISTON AREA (cm^2)	M_{MD} MOVING MASS (g)	R_{MS} MECHAN. RESISTANCE (kg/S^{-1})	V_{AS} EQUIV. VOLUME OF SUSPENSION (l)	BL FORCE FACTOR (NA^{-1})	Γ ACCELERAT. FACTOR ($ms^{-2}A^{-1}$)	GAP VOLUME (mm^3)	E MAGNETIC ENERGY (Ws)	B FLUX DENSITY (T)	ENCLOSURE SYSTEM	V_B RECOM. VOLUME (l)	α THIELE ALIGN-MENT	F_3 FREQ. CUTT OFF (Hz)	PORT AREA (cm^2)	PORT LENGTH (cm)
5C01	0.252	0.266	5.03	$2.01\ 10^{-3}$	86.6	6.9	0.37	21.1	8.2	1188	567	0.375	1.29	BASS-REFLEX	7.6	5.7	71	14 1	9 5
7C02	0.35	0.384	3.94	$1.82\ 10^{-3}$	163	14.0	0.70	67.7	8 2	626	567	0.375	1.29	CLOSED	15 0	—	63.5	—	—
7C03	0.30	0.325	4.05	$1.70\ 10^{-3}$	158	10.8	0.62	59.4	8 2	759	567	0.375	1.29	BASS-REFLEX	21 4	4	61 8	25 15	11
8C02	0.423	0 46	5 26	$0.97\ 10^{-3}$	222	16.7	0.79	67.4	8.2	491	567	0.375	1 29	CLOSED	26	—	65	—	—
7C502	0.16	0 17	1.84	$1.90\ 10^{-3}$	163	14.3	1.49	70.7	13.4	937	963	0.698	1.35	BASS-REFLEX	14 5	8	67 4	25 15	5.8
10C01	0.20	0.222	2.05	$1.75\ 10^{-3}$	343	21.9	1.72	288	13.4	612	963	0.698	1 35	BASS-REFLEX	65 7	5.7	53.8	72 40	7.3
10C02	0.446	0.51	3.63	$1.00\ 10^{-3}$	340	34.0	1.60	163	13.5	397	963	0.698	1.35	CLOSED	72	—	43	—	—

For information on kit applications Fast Reply #1066
For information on other products Fast Reply #1067

ALL ACOUSTICAL MEASUREMENTS REALISED ON IEC BAFFLE

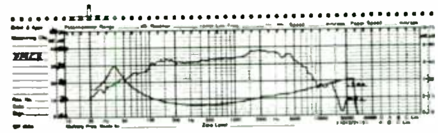
PAPER MIDRANGE

VOICE COIL DIAMETER: 25 mm

FOCAL has designed a very specific technical solution in order to increase drive-units efficiency without any change in their internal structure.

In fact, the rear part of the primary circuit has been fitted with a second magnetic circuit which proves to be an original device insofar it is magnetized reverse to the first one.

So, the different magnetic losses of the primary circuit are repulsed and concentrated within the gap. The force factor grows by 15%.

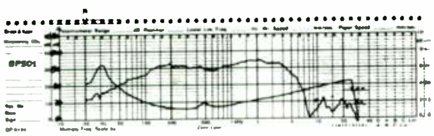


MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPED. (Ω)	MINIMUM IMPED. (Ω)	DC RESIST. Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8 v/1 m (dB)	POWER CAPACITY (w) CONT.	POWER CAPACITY (w) PROGRAM	LOWEST RECOMM. CROSS. FREQ.	VOICE-COIL DIA. (mm)	VOICE-COIL WIRE	VOICE-COIL LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP LENGTH (mm)	MAGNET WEIGHT (kg)	MAGNET SIZE (mm)	NET WEIGHT (kg)
7MC2	175	8	7.4	6.5	38.1	96.5	55	120	—	25.5	COPPER	2	NOMEX	PAPER	FOAM	PAPER	—	13	6	0.56 + 0.73	100 + 96	2.5

POLYPROPYLENE WOOFER-MIDRANGE

VOICE COIL DIAMETER: 40 mm

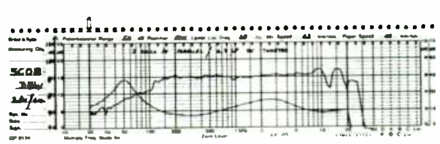
Only polypropylen cone unit in FOCAL range, the 8P501 is an 8" woofer fitted with a 40 mm edge-wound copper ribbon wire voice coil. It offers excellent transient response. For 2 ways systems 8N501, in Neoflex, is more adapted.

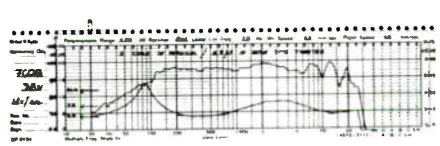


MODEL	NOMINAL DIAMETER (mm)	NOMINAL IMPEDANCE (Ω)	MINIMUM IMPEDANCE (Ω)	DC RESISTANCE (Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8 v/1 m (dB)	POWER CAPACITY (w)	VOICE-COIL DIA. (mm)	VOICE-COIL WIRE RIBBON	VOICE-COIL PLAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	CONE TREATMENT	VOICE COIL LENGTH (mm)	GAP HEIGHT (mm)	MAGNET WEIGHT (kg)	MAGNET SIZE (mm)	NET WEIGHT (kg)
8P501	200	8	7.4	6	29.1	92	80	40	COPPER	1	KAPTON	POLYPRO	NEOPREN	CLOTH	—	13	6	0.87	121	2.5

TWIN-COIL COAXIAL UNITS

The 5" and 7" FOCAL coaxial units are unlike any others. Both have a twin-coil for the bass and a small dome tweeter for the treeble. A 3 ways crossover is possible to be matched. They are specialy adapted for high quality car hifi.





MODEL	NOMINAL DIAMETER (mm)	BASS NOMINAL IMPED. (Ω)	TWEETER NOMINAL IMPED. (Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8 v/1 m (dB)	POWER CAPACITY (w)	BASS VOICE-COIL DIAMETER (mm)	BASS VOICE-COIL LAYERS	TWEETER VOICE COIL (mm)	BASS VOICE COIL FORMER	TWEETER VOICE COIL FORMER	BASS CONE MATERIAL	BASS SURROUND MATERIAL	TWEETER DOME MATERIAL	BASS CONE TREATMENT	BASS VOICE COIL LENGTH (mm)	BASS GAP LENGTH	MAGNET WEIGHT (kg)	MAGNET SIZE (mm)	NET WEIGHT (kg)
5C08-DBW	130	4	4	53.2	90	35	25.5 + 26.3	4	10(1)	NOMEX	—	PAPER	NEOPREN + PVC	POLYCARB	—	11.5	6	0.56	100	1.74
7C08-DBW	175	4	4	71.4	94	70	25.5 + 26.3	4	10(1)	NOMEX	—	PAPER	FOAM + PLASTIFLEX	POLYCARB	—	11.5	6	0.56	100	1.84

MODEL	Q_{TS} TOTAL Q FACTOR	Q_{ES} ELEC. Q FACTOR	Q_{MS} MECH. Q FACTOR	C_{MS} COMPLIANCE OF SUSP. (mN^{-1})	S_D EMISSIVE PISTON AREA (cm^2)	M_{MD} MOVING MASS (g)	R_{MS} MECHAN. RESISTANCE (kg/S^{-1})	V_{AS} EQUIV. VOLUME OF SUSPENSION (l)	BL FORCE FACTOR (NA^{-1})	Γ ACCELERAT. FACTOR ($ms^{-2}A^{-1}$)	GAP VOLUME (mm^3)	E MAGNETIC ENERGY (Ws)	B FLUX DENSITY (T)	ENCLOSURE SYSTEM	V_B RECOM. VOLUME (l)	n THIELE ALIGNMENT	F_3 FREQ. CUTT OFF (Hz)	PORT AREA (cm^2)	PORT LENGTH (cm)
7MC2	0.27	0.29	4.23	$1.70\ 10^{-3}$	158	10.3	0.57	59.4	9.05	879	567	0.454	1.42	—	—	—	—	—	—
8P501	0.214	0.23	3.75	$1.59\ 10^{-3}$	221	18.3	0.91	109	13.4	732	963	0.698	1.35	BASS-REFLEX	28	5.7	57	25.15	5.8
5C08-DBW	0.232	0.25	3.33	$0.98\ 10^{-3}$	86.6	9.2	0.92	10.2	10.7	1163	776	0.360	1.08	BASS-REFLEX	4.4	8	81	14.1	8.9
7C08-DBW	0.38	0.42	4.35	$0.35\ 10^{-3}$	158	14.2	1.47	12.2	10.7	1176	776	0.360	1.08	BASS-REFLEX	14	8	66.5	25.15	6.4

ALL ACOUSTICAL MEASUREMENTS REALISED ON IEC BAFFLE

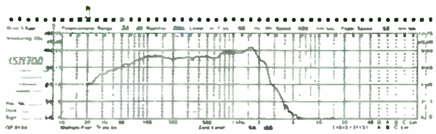
(1) 10 mm tweeter voice-coil is heat-cooled by Ferrofluid

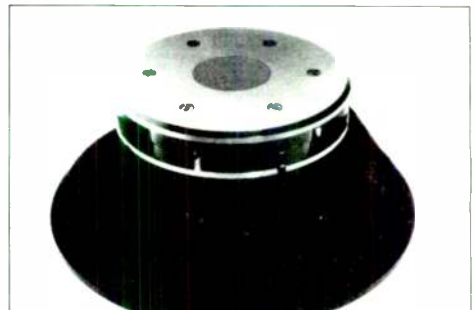
For information on kit applications Fast Reply #1066
For information on other products Fast Reply #1067

15" NEOFLEX SUB-WOOFER

VOICE COIL DIAMETER: 75 mm

Super high quality 15" Neoflex woofer. The 3 inch ribbon wire coil and the 9.5 inch magnetic circuit made of 12 magnets give to 15N700 outstanding performances in volumes between 5 to 6 cubic feet. The 15N700 has very low resonance (16 Hz), high sensitivity (96 dB) and weighs not less than 29 pounds.





15 N 700

NOMINAL IMPEDANCE (Ω)	MINIMUM IMPEDANCE (Ω)	DC RESISTANCE (Ω)	RESONANCE FREQUENCY (Hz)	SENSITIVITY 2.8v/1 m (dB)	POWER CAPACITY (w)	VOICE-COIL DIA. (mm)	VOICE-COIL RIBBON WIRE	VOICE-COIL LAYERS	VOICE COIL FORMER	CONE MATERIAL	SURROUND MATERIAL	DUST CAP MATERIAL	VOICE COIL LENGTH (mm)	GAP LENGTH (mm)	MAGNET WEIGHT (kg)	MAGNETIC CIRCUIT SIZE (mm)	MAGNET NUMBER	TOTAL WEIGHT (kg)
8	6.9	6	16	96	150	77.9	COPPER	1	KAPTON	NEOFLEX	FOAM	PAPER + CLOTH	15	10	2.9	235	12	13

Q_{TS} TOTAL Q FACTOR	Q_{ES} ELEC. Q FACTOR	Q_{MS} MECH. Q FACTOR	C_{MS} COMPLIANCE OF SUSP. (mN^{-1})	S_D EMISSIVE PISTON AREA (cm^2)	M_{MD} MOVING MASS (g)	R_{MS} MECH. RESISTANCE ($kg\ s^{-1}$)	V_{AS} EQUIVALENT VOLUME OF SUSP. (l)	BL FORCE FACTOR (NA^{-1})	Γ ACCELERATION FACTOR ($ms^{-2}A^{-1}$)	GAP VOLUME (mm^3)	E MAGNETIC ENERGY (Ws)	B FLUX DENSITY (T)	∅ FLUX (MAXWELL)	ENCLOSURE SYSTEM	V_B RECOMM VOLUME (l)	n	F_3 (-3 dB) (Hz)	PORT AREA (cm^2)	PORT LENGTH (cm)
0.149	0.155	4.20	$1.0\ 10^{-3}$	855	98.5	2.36	1023	22.5	228	3513	2.01	1.20	291000	Bass-Reflex	159	7	40	500	36.6

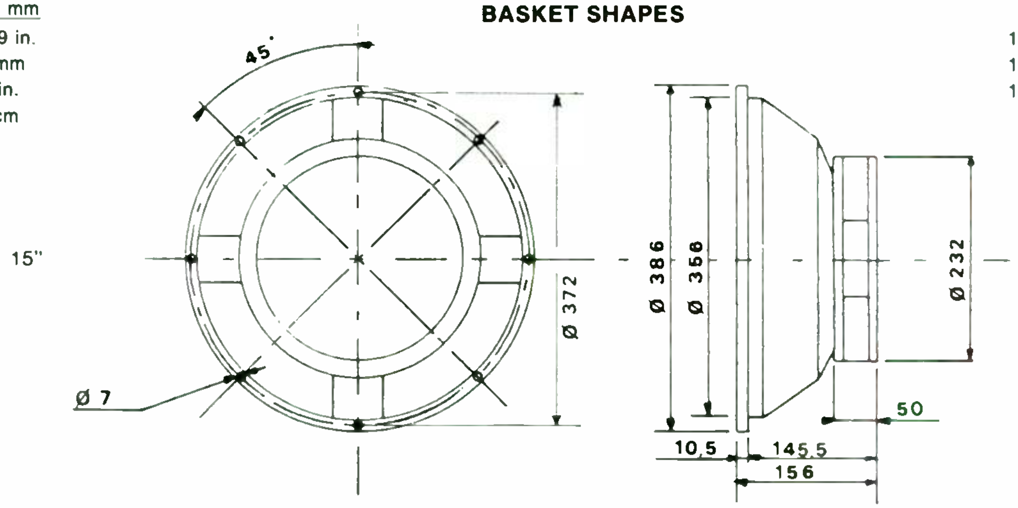
Dimensions in mm

1 mm = 0.039 in.
1 in. = 25.4 mm
1 cm = 0.39 in.
1 in. = 2.54 cm

BASKET SHAPES

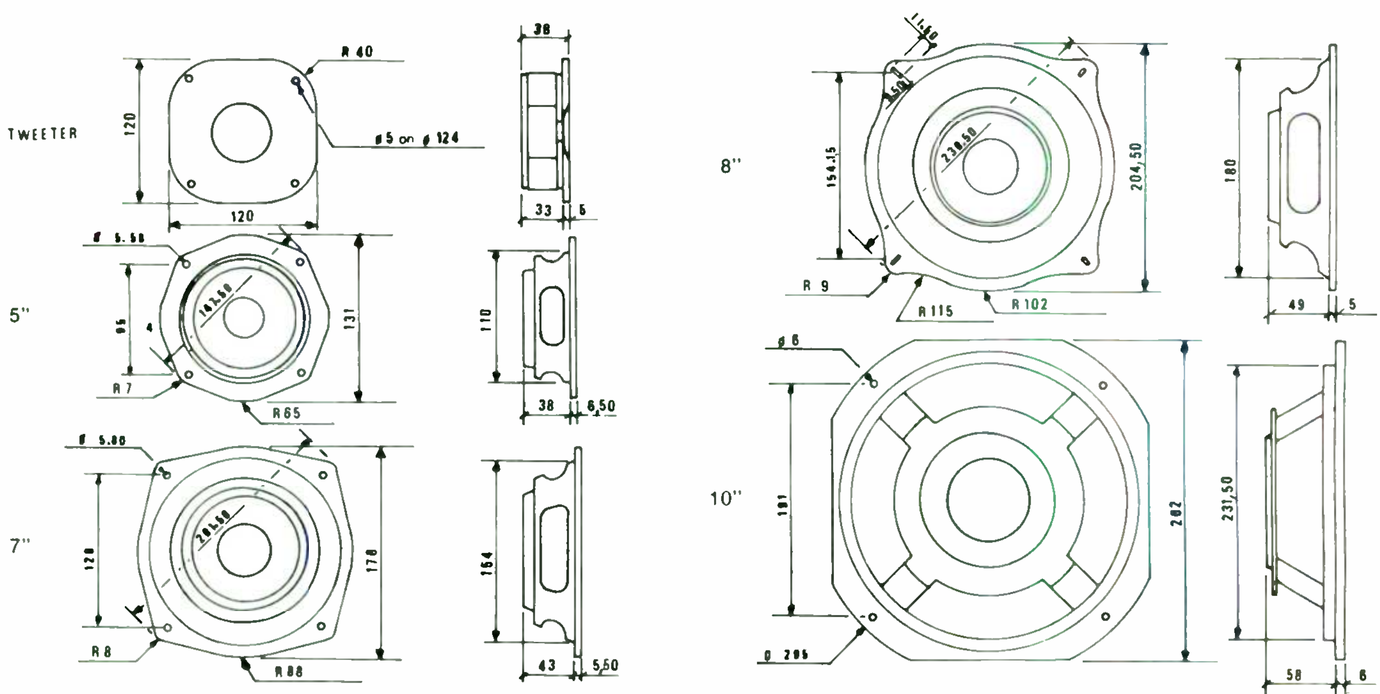
Volume

1 mm³ = 6.1 10⁻⁵ cu. in.
1 Liter = 0.0353 cu. ft.
1 cu. ft. = 28.317 Liters



Surface

1 cm² = 0.155 sq. in.
1 sq. in. = 6.452 cm²



Because of continuing design improvements, FOCAL reserves its right to modify or replace any product listed herein.

For information on kit applications Fast Reply #1066
For information on other products Fast Reply #1067

Tools, Tips & Techniques

Rear-Channel Speaker Design

I built this pair of column speakers *(Photo 1)* some years ago to serve as rear channels in my listening room. The acoustical and electrical design are of no special interest to *SB* readers, but some of the construction features and techniques may be.

The drivers were a McGee Radio special—an Elcom 8-inch woofer and 10-inch passive radiator combination with the ubiquitous horn-loaded Motorola piezo tweeter—plus an excellent Panasonic 1½-inch soft-dome midrange/tweeter from the same source. I simply sized the internal volume of the woofer enclosure to the manufacturer's recommended 1.6 cubic feet for a low-frequency cutoff of (allegedly) 38Hz. Since the external dimensions of my cabinet are 12½ inches wide by 10½ inches deep by 35¾ inches high—why use speaker stands if you can make them tall enough to start with?—I had volume left over. I used it for a separate compartment behind the supertweeter under a removable lid giving ready access to the crossover *(Photo 2)*. The network is a series circuit designed for crossover points of about 1.5kHz and 10kHz. I was not confident of getting it right on the first try, so why seal it inside?

The cabinet is made of ¾-inch birch plywood with quarter round pine molding on the outside corners and cleats on the inside. The wavefront diffraction benefits of rounded edges may be nugatory (see *SB* 1/80), but this method of concealing plies is far easier to cut and align than mitering. The flush-mounted cone radiators are exposed to view but protected with wire-cloth grilles made by a surprisingly easy technique, described below. The horn tweeter needs no mechanical protection, and the dome midrange came with its own. Spring terminals for the amplifier connection are recessed into the bottom panel *(Photo 3)*. The four compliant feet *(Photo 4)* add 1½ inches in height and are made by tapping the center hole of surplus stock mounts to accept swivel glide stems with a 5⁄16-inch (18, coarse) thread. Leveling glides are a necessity on an uneven floor, especially for any column speaker.

Flush mounting the drivers. For the round cutouts, first rout a wide circular groove, then saw out the center. I used a Dremel Moto-Tool with a router bit and a simple circle-cutting jig made with its router attachment, a thin slat of wood and a pivot screw. If you intend to mount wire-cloth grilles as described below, the diameter of the rabbet must be precise. (If you must, err on the small side.) For the square rabbets (for the piezo supertweeters), I used the router attachment freehand.

Quarter round corners. First screw cleats to the side panels flush with the long edges. (If you make cleats of plywood, put the screws across the plies.) Check the right angle with a try square and trim with a plane if necessary. Then disassemble the cleats and glue them to

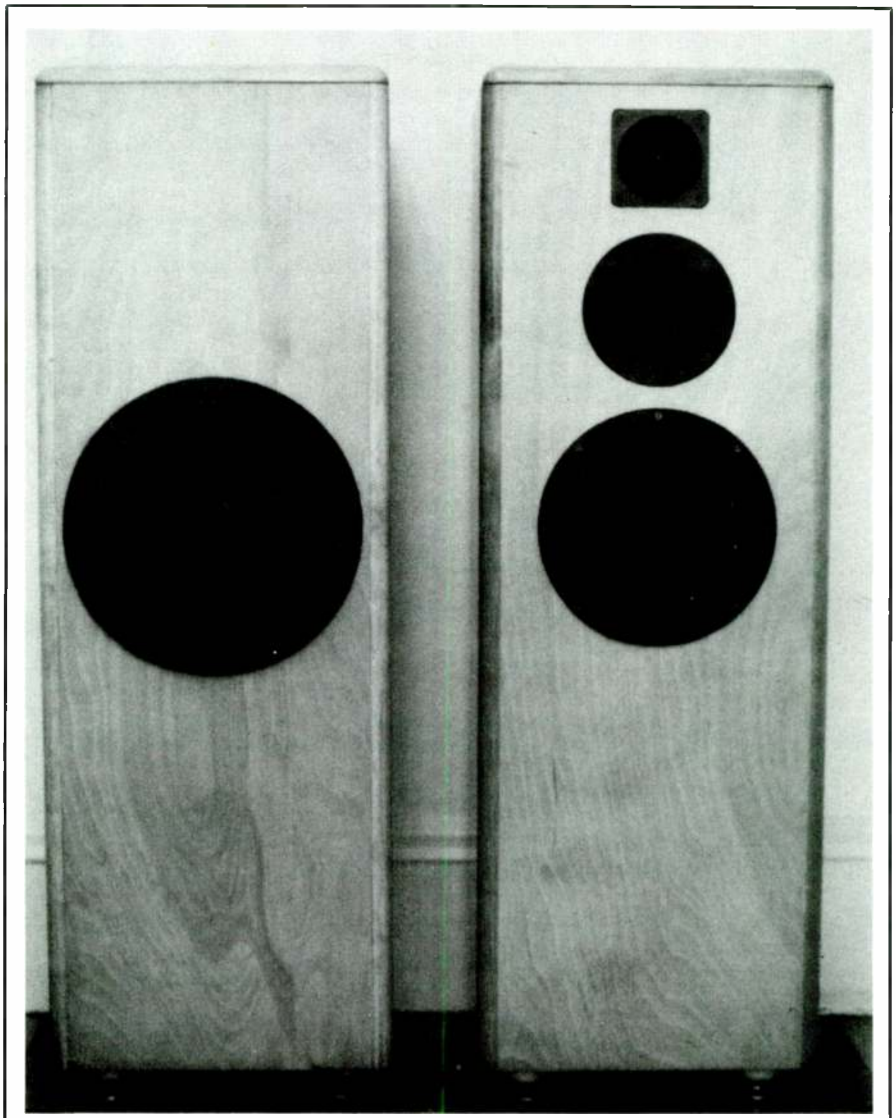


PHOTO 1: These column speakers served as rear channels in the author's listening room.

the front and back panels, using nails to provide clamping pressure. Attach horizontal cleats, interior bracing, bituminous damping and fiberglass lining to the inside of all four panels.

When the joints have set, glue the side panels onto the vertical cleats using the screws to align and clamp. You will need an offset screwdriver to tighten the screws from inside the cabinet, reaching in from the top and bottom and through the driver cutouts, so Phillips heads are a must (wallboard screws are ideal). Cover the top and bottom panels with wax paper or plastic wrap and slide them in place to hold the assembly square while the glue sets.

Simply glue on the quarter round corner molding, using masking tape to hold it in place. To avoid glue stains, seal the panels with at least one coat of finish before this step. You can stain the sides a different color from the front and back if you choose.

Round wire-cloth grilles. I used eight-mesh (i.e., eight to the inch) woven steel wire cloth, which can be cut and bent easily by hand. I used the woofers and passive radiators themselves as bending templates.

First wash the wire cloth with solvent to remove any greasy film. With snips or shears, cut a circle of radius somewhat larger than half the woofer frame diameter plus the depth of your rabbet plus the clearance you are allowing for cone excursion. Place this circle near the edge of the workbench, center the woofer on its face down, and bend the mesh up around the frame a bit at a time, rotating as you go. (Wear gloves for this operation.) Finish the forming by rolling edgewise on the workbench with the woofer and grille between your hands.

With the grille still on the woofer, trim to a uniform depth. (Wear eye protection!) Before you snip, cover the woofer magnet with plastic wrap and secure it with a rubber band—this will make it easier to pick off the wire ends.

Remove the grille and spray paint it. Push the grille between the woofer frame *after* you have installed the woofer with screws. Check the fit before you apply any silicone seal and, if necessary, enlarge by careful routing. Lay down a generous bead of sealant and screw down the woofer, making sure that it is concentric to the rabbet and that enough sealant is squeezed out to adhere the grille. Before the sealant cures, push on the grille.

Compliant feet. The shock mounts help to decouple the speaker from the floor, at the cost of making the column somewhat tipsy. They also serve as standoffs to keep the shafts of the glides from penetrating the cabinet.

The shock mounts I used have a 2⅜-inch square aluminum base and an unthreaded ¼-inch ID steel bushing in

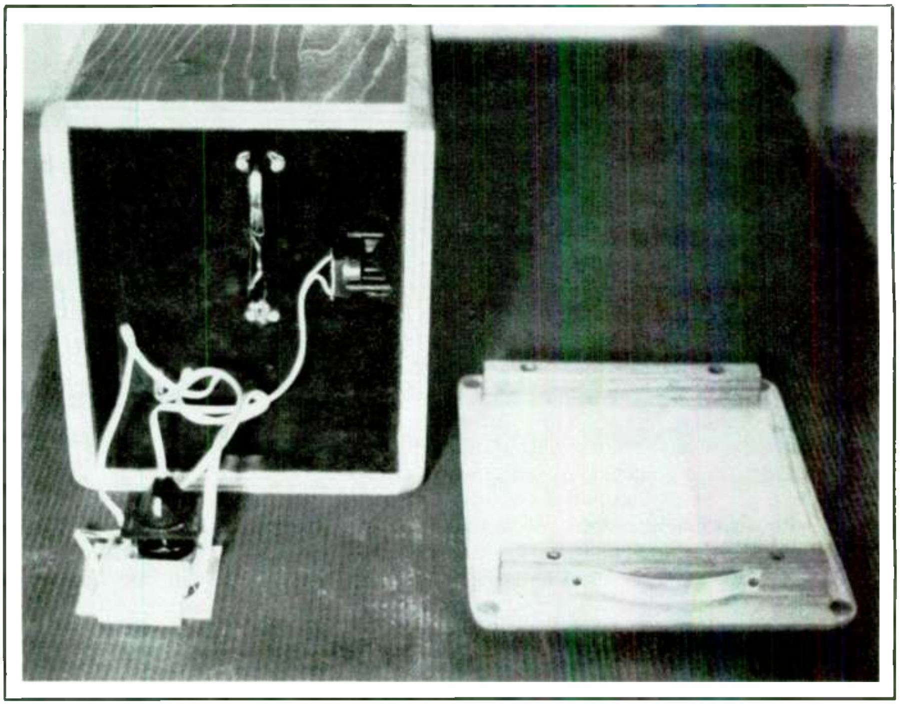


PHOTO 2: Mr. Killingsworth used the extra cabinet space for a separate compartment behind the supertweeter. A removable lid allows ready access to the crossover.

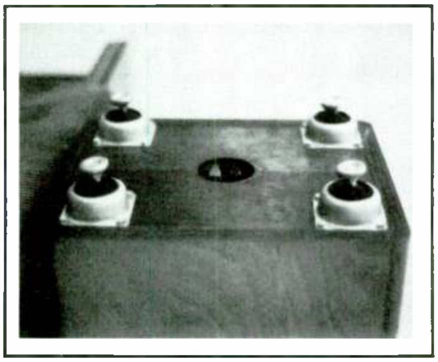


PHOTO 3: Spring terminals for the amplifier connection are recessed into the bottom panel.

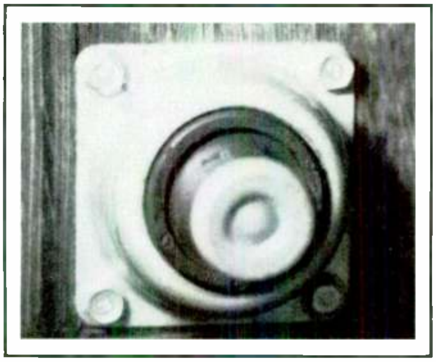


PHOTO 4: The four compliant feet are used as leveling glides.

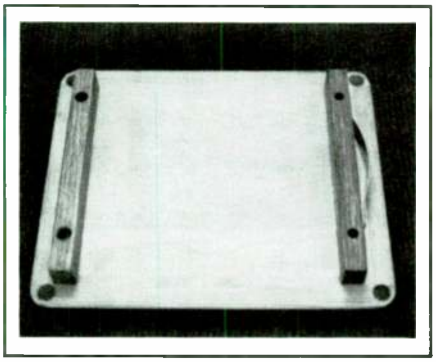


PHOTO 5: The underside of the lid has two hardwood cleats and a window sash spring on one side.

PHOTO 6: You can remove the lid by pushing sideways and lifting from the side opposite the spring.

Tools, Tips & Techniques

the center. If you intend to thread them yourself for height-adjustable glides, get a few extra for practice. Before you drill and tap the bushing, secure it *firmly* in a hand vise or it will twist away from the rubber. I managed to get purchase on it only by grinding parallel flats on the inside, taking away some rubber in the process. Pack the rubber cavity with steel wool for additional damping and improved lateral stability.

Lift-off lid. The lid is a plywood rectangle edged in quarter round with two hardwood cleats underneath and a window sash spring on one side *(Photo 5)*. Install the cleats and test the fit before trimming and finishing the lid. To prevent rattles, you should line the interior of the crossover compartment. I glued on some suede that I had on hand, but felt or billiard cloth would do nicely also.

To remove the lid, push sideways and lift from the side opposite the spring *(Photo 6)*. The inside of the compartment is the ideal place for a carrying handle. Avoid the temptation to hide valuables, however. There is room for them, and it is certainly well concealed, but do you think the burglars won't take your speakers?

Robert Killingsworth
Watertown, MA 02172

Varathane & Veneer

I have seen many construction details that suggest using flat black paint for cabinet baffles and backs. A superior finish for this purpose (and entire cabinets) is black satin Varathane such as that made by Flecto (color #96).

The result is a smooth, hard, plastic coating much like that used on commercial loudspeakers. You can apply it over virtually any surface indoors or out, and it will cure as tough as a bowling alley's surface. The company claims that it will resist alcohol, acids, abrasion, marring, chipping, weathering and corrosion. I strongly suggest that you thin it slightly and practice applying it (use a poly brush) on a smooth piece of scrap wood to obtain the best results.

A superior material for constructing cabinets is multidensity fiberboard (MDF). It is denser, easier to work with and much stronger than high-grade particle board. You might have trouble finding it, though. In Tucson, I know of only one supplier—a wholesale house (it will do retail) of hardwoods and veneered material. You may also buy it with a high-grade oak veneer. The cost at my supplier is about $17 ($42 if you want it in oak) for a 4-by-8-foot sheet.

David Tryon
Tucson, AZ 85716

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SB Mailbox

W/HERE'S THE FOCAL

In *SB's* 2/85 Mailbox Mr. D'Appolito indicated he has a circuit worked out for using Focal in place of KEF drivers in his satellites. If possible I would appreciate obtaining a copy of his crossover design for the Focal version.

I have built his original version, as detailed in *SB* 4/84, p. 7, and find them excellent. The only weakness in an otherwise flawless design is in voice reproduction. This, it would appear, is a fault of the B110 SP1003 driver, and I hope the Focal units will correct the problem.

I also understand from Mr. D'Appolito's reply to Mr. K. P. Miller, this information may be presented in a later letter to *SB*. However a lot of time could be saved if I could obtain the crossover design soon.

I would like to thank *SB* and Mr. D'Appolito for sharing his excellent design, and for the well written article. I have been dabbling in audio since 1958, and would rate Mr. D'Appolito's satellites (assuming the voice quality enriched) as by far the best obtainable at any price.

R. J. Bosch,Jr.
Metairie, LA 70003

Mr. D'Appolito replies:

I will describe the crossover design for use with Focal drivers as you requested, but first let me comment on the voice reproduction problem. As discussed in my SB *article, the coloration of human voices (particularly male voices) is caused by the interaction of a small loudspeaker with its environment, and not by any driver deficiency. Actually all program material is colored, but it is most apparent with voices. This coloration is due to frequency response irregularities in the 100-500Hz range. These irregularities, in turn, are caused by diffraction loss, near-wall reflections and room boundaries. (Note: diffraction loss can be eliminated completely by mounting the satellites flush with the wall.) The effect on frequency response of satellite placement is illustrated in* Fig. 11 *of my article. If this is the type of coloration you are experiencing, I would explore the*

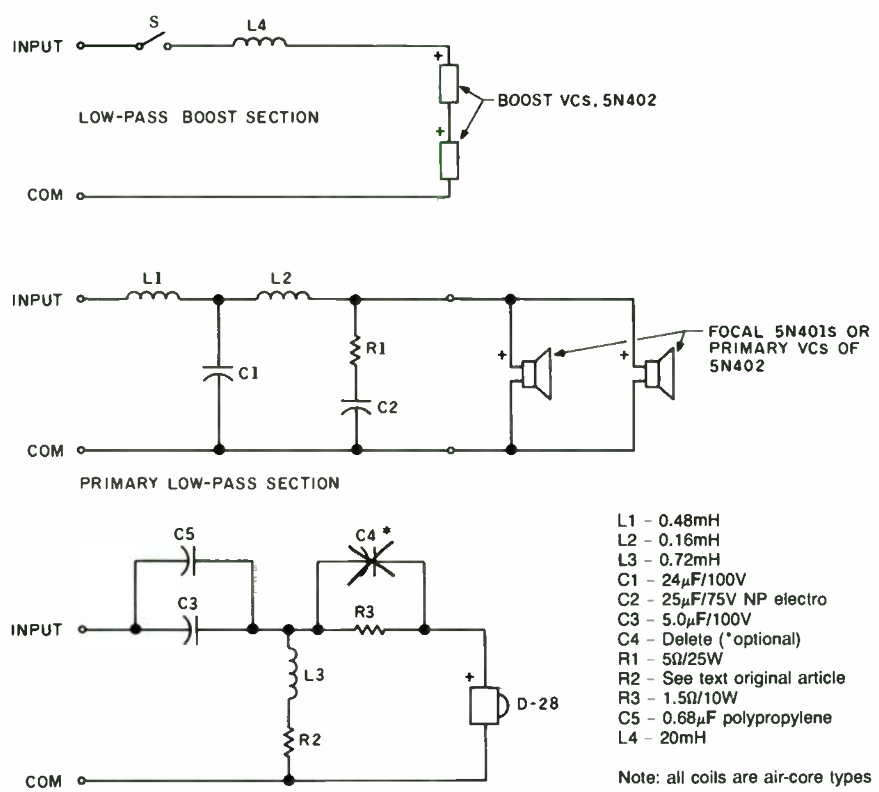

FIGURE 1: The revised satellite crossover for Focal drivers.

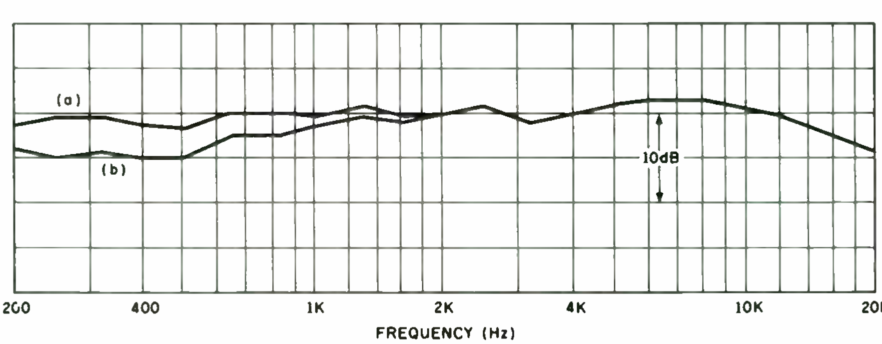

FIGURE 2: Free-standing, one-meter, ⅓-octave frequency response of satellites with Focal drivers. (a) 5N402s with active boost coils. (b) 5N401s with inactive boost coils.

suggested cures in the article before buying new drivers.

The Focal drivers are smoother than the KEFs in the midrange, and since they are less expensive I am recommending them now for new construction. Focal makes a single-voice-coil 110mm mid-bass driver, the 5N401, and a dual-voice-coil unit, the 5N402DB. The second voice coil in the 5N402 can be used to compensate for diffraction loss. Unfortunately, application of the dual-voice-coil unit to my design is not straightforward.

The dual-voice-coil Focals have a minimum impedance of about 36Ω at 250Hz, when both voice coils are active. This happens to be the frequency of peak music power in most program material. Two of these drivers in my satellites would have a minimum impedance of 1.8Ω at 250Hz. Few amplifiers can handle this load well. I reduced this problem by connecting, in series, the boost coils in each driver rather than connecting them in parallel. The series connection produces a minimum system impedance of 2.8Ω (still low, but better than before). Series connection of the boost coils reduces the maximum diffraction loss compensation available from 6dB to 3.5dB. This seems to work well in most home installations, which have some near wall reflection, and therefore do not require complete diffraction loss compensation.

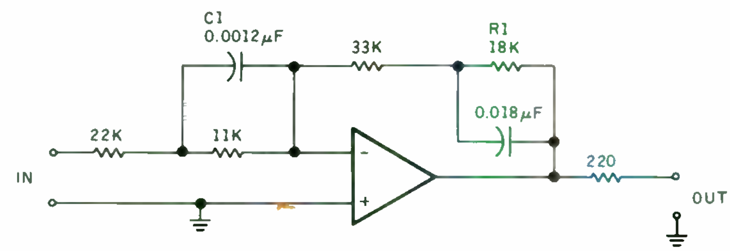

FIGURE 3: Inverting the opamp compensator. For LF boost only, delete C1. For HF boost only, short R1.

The revised satellite crossover for Focal drivers is shown in Fig. 1. *The primary low-pass section (L1, L2, C1, C2, R1) is the same for both voice coils in the 402dB unit are electrically identical. Choose one as the main voice coil, and the second as the boost coil. The main voice coils are connected in parallel. The boost coils are connected in series. A switch is added to the boost coil circuit*

SB Mailbox

to switch the diffraction compensation in or out. The Focal drivers are about 2dB more sensitive than the KEFs. To compensate for this, resistor R3 is changed from 4Ω to 1.5Ω and C4 is eliminated. The values of C3, L3 and R1 also change.

The free-standing (no nearby vertical walls) frequency response of the satellites between 200Hz and 20kHz with Focal drivers is shown in Fig. 2. *A response below 200kHz is similar to that of the original system. Responses with and without the boost circuit are shown. With the boost circuit active, response is ±2dB from 75Hz to 15kHz, and down 4dB at 20kHz. I find this response well balanced, especially with CDs as program source material. For younger ears the small drop between 15 and 20kHz is easily corrected electronically. A revised op-amp compensation circuit correcting for both diffraction loss (when needed) and the high frequency roll-off is given in* Fig. 3.

A comment on the choice of Focal drivers is in order. I prefer the single-voice-coil units with electronic diffraction loss compensation to the dual-voice-driver for two reasons. First, the op-amp compensator is easily modified to get just the right amount of correction. Also most users of satellite systems are already bi-amping, making addition of the extra op-amp to their existing electronic crossover relatively easy. Secondly, the 2.8Ω minimum impedance of the system with 5N402DB drivers is still too low for many amps.

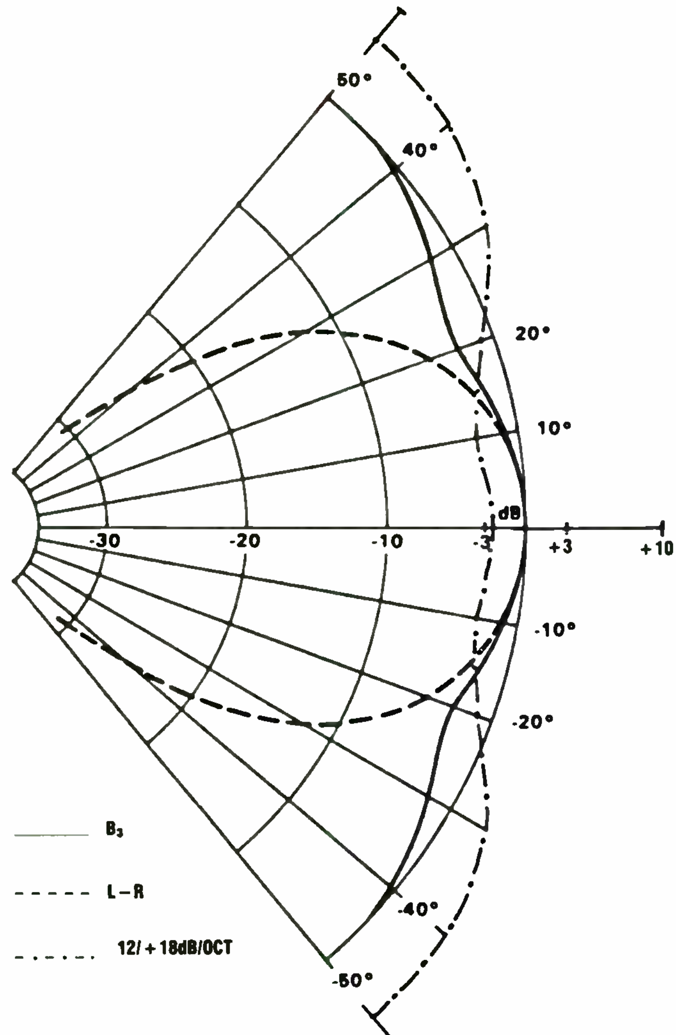

FIGURE 1: The (3,2) polar response pattern.

OF TIME AND PHASE

In *SB* 3/85, p. 45 Mr. Miller directed a few questions about my three-driver, two-way (3,2) geometry, and the concept of phase coherence to contributing editor Bob Bullock. Let me take this opportunity to respond to Mr. Miller's questions and amplify Bob's responses.

With regard to polar response, quoting directly from my *SB* 4/84, p. 7 article, the (3,2) geometry "is inherently (read *always*) symmetric. . . .This arrangement yields a stable vertical polar response independent of driver phase or magnitude differences." The radiation pattern will be symmetric regardless of individual driver crossover slopes, and any axial displacement, or electrical phase correction of the paired drivers or center tweeter to obtain time alignment. This is the beauty of the (3,2) geometry, and it also applies to five driver, three-way configurations.

Crossover slopes and interdriver phase corrections will change the detail shape of the polar pattern. The unequal slope crossover (−12dB/+18dB) suggested by Mr. Miller will produce an interdriver phase angle of 135° at the crossover frequency (assuming drivers are phase aligned). The (3,2) polar response pattern for this crossover is shown in *Fig. 1.* Patterns for the B3 and Linkwitz-Riley (L-R) crossovers are also shown for comparison. The (−12dB/+18dB) crossover polar response is down 2.3dB relative to the L-R and B3 curves on-axis. It also peaks 5.3dB at ±48.6° off-axis.

For my (3,2) geometry, phase angles between drivers should not exceed 90° (including effects from the crossover network) in the crossover region where their outputs are comparable. This causes the amplitude of the off-axis response to exceed the on-axis response, and leads to poor imaging. With conventional geometries the situation is much worse since any phase difference between drivers causes polar response tilt.

Turning to Mr. Miller's question on the relationship between phase coherence and time alignment, we should first recognize that the sine wave frequency response of a loudspeaker, and its time response to a sudden narrow pulse, are alternative (not different) descriptions of the same device. They are related mathematically by the Fourier transform. This relationship allows us to get the frequency response of a loudspeaker from FFT (Fast Fourier Transform) of its pulse response. (See the Spangler and McKenzie aritcle in *SB* 3/85, p. 22, for more on FFT techniques.)

Loudspeaker frequency response has two components: magnitude response, generally plotted in dB versus frequency, and phase response plotted in degrees versus frequency. The term "phase coherent" has been borrowed from communication theory and applied somewhat inappropriately to loudspeakers. As applied to loudspeakers, phase coherent means that every output frequency is in phase with its corresponding input frequency (after allowing for a fixed delay between loudspeaker and listener locations). The phase shift of a coherent loudspeaker is therefore zero at *every* frequency.

For casual systems (one with no output before an input is applied) zero phase shift implies absolutely flat magnitude response. Zero phase shift and flat magnitude response in turn imply (through the Fourier transform) perfect pulse response, which can only happen when all frequency components of the pulse arrive in their proper "time alignment." Thus, "phase coherent" loudspeakers must be "time aligned" and vice versa.

Notice that time alignment does not necessarily mean that woofer and tweeter wavefronts arrive at the listening point at the same time. It means that they arrive in the correct time relationship to produce the original imput waveform. Although time aligned drivers are in-phase at the crossover frequency, having the drivers in phase at crossover alone is not enough to guarantee that they are time aligned. Drivers can only be time aligned with time domain measurements, like pulse testing or time delay spectometry.

Joseph D'Appolito
Andover, MA 01810

NO FREE LUNCH REVISITED

This is a reply to Tom Nousaine's letter to Tools, Tips and Techniques, *SB* 2/85, p. 44, titled No Free Lunch.

The test set-up I used to verify whether two speakers closely coupled with their axes in line will exhibit half of the V_{AS} of the individual drivers, was exactly the same one Mr. Nousaine employed. I did not "plug" my vented system. Instead, I used the formula shown on p. 78 of David Weems' book, *Designing, Building and Testing Your Own Speaker System* (Tab Books, 2nd Edition, 1984).

I agree, there is "no free lunch." The penalty is the cost of a second driver, and a cone excursion limit, that is no greater than that of a single driver. I cannot agree that the other Thiele/Small parameters are changed.

My test of two eight-inch woofers, bolted together through a spacer and suspended in free air, exhibit parameter values with a variance of less than five percent of the values exhibited by individual drivers.

With an f_S at 16Hz, and a Q_T of 0.6, Nousaine's drivers do not appear well suited to vented systems. Mr. Koonce's *SB* 2/84, p. 21 article explores this idea in detail.

Mr. Nousaine seems interested in reducing the box volume requirements. An alternate to reducing V_{AS} (via two drivers in line) is to reduce Q_T by gluing fiberglass or felt to the openings in the rear of the speaker basket, as described on p. 71 of Weems' book. I have realized a 20 percent V_{AS} reduction with this method.

David J. Meraner
Scotia, NY 12302

AND RE-VISITED

Mr. Nousaine's analysis of the coupled driver configuration (*SB* 2/85, p. 44) is incomplete, and therefore leads him to the wrong conclusions. If two identical drivers are coupled together through a small sealed chamber, the composite driver does indeed have half the mechanical compliance C_{MS}, or equivalently one-half the acoustic volume, V_{AS}, and twice the moving mass M_{MS} of a single driver (ignoring the small mass of the trapped air volume) as Mr. Nousaine asserts. However, the composite driver also has twice the mechanical resistance, R_{MS} and twice the motor efficiency, $(BL)^2/Re$, of a single driver. The changes in these last two parameters are important. All four parameters are required to compute the Thiele/Small parameters of the composite driver. For the interested reader I have done this as follows:

1. Free Air Resonance, f_S
   In general:

SB Mailbox

$$f_S = \frac{1}{2\pi\sqrt{C_{MS}\,M_{MS}}}$$

For the composite driver:

$$f_S' = \frac{1}{2\pi\sqrt{C_{MS}'\,M_{MS}'}} =$$

$$\frac{1}{2\pi\sqrt{\frac{C_{MS}}{2} \times 2M_{MS}}} = f_S$$

2. Mechanical Q, Q_M
In general:

$$Q_M = \frac{1}{2\pi\, f_S\, C_{MS}\, R_{MS}}$$

For the composite driver:

$$Q_M' = \frac{1}{2\pi\, f_S'\, C_{MS}'\, R_{MS}'} =$$

$$\frac{1}{2\pi\, f_S \times \frac{C_{MS}}{2} \times 2R_{MS}} = Q_M$$

3. Electrical Q, Q_e
In general:

$$Q_e = \frac{2\pi\, f_s\, M_{MS}}{(BL)^2/R_e}$$

For the composite driver:

$$Q_e' = \frac{2\pi\, f_s'\, M_{MS}'}{[(BL)^2/R_e]} =$$

$$\frac{2\pi\, f_s \times 2M_{MS}}{2(BL)^2/R_e} = Q_e$$

4. Reference Efficiency, N_o

$$N_o = \frac{4\pi^2}{C^3} \cdot \frac{f_S^3\, V_{AS}}{Q_e};$$

C = speed of sound

For the composite driver:

$$N_o' = \frac{4\pi^2}{C^3} \cdot \frac{(f_S')^3\, V_{AS}'}{Q_e'} =$$

$$\frac{4\pi^2}{C^3} \cdot \frac{f_S^3\, V_{AS}/2}{Q_e} = \tfrac{1}{2} N_o$$

The result of this calculation is that the composite driver free air resonance f_S and all Q's (Q_M, Q_E and Q_T) are the *same* as those of the individual drivers. Because V_{AS} is halved, the mid-band or reference efficiency of the composite driver is half that of the individual drivers.

The physical reasons for these results are easily seen. For example, f_S is a function of the *product* of mechanical compliance and moving mass. Although C_{MS} is halved, M_{MS} is doubled, so their product and f_S is unchanged. Similarly, although the moving mass is doubled, the motor efficiency is also doubled, so Q_E, which is proportional to the *ratio* of these parameters, is unchanged. These results are true regardless of the voice coil interconnection, which may be series or parallel.

The situation is more complicated when the drivers are not identical. This fact, coupled with Mr. Nousaine's measurement of the composite speaker parameters in a box, may have confused his results.

If the identical drivers are mounted in the so called push-pull configurations (back-to-back or front-to-front), and driven electrically out-of-phase, the effect of odd-order nonlinearities in the suspension or drive motor will be cancelled, greatly reducing driver distortion. This configuration is the basis for several commercial subwoofers.

In summary, the major benefit of the composite driver is that it yields a given response function in *half* the box size required by a single driver. Also, for a given distortion level the composite driver will generally produce a higher SPL than the single driver. The *price of the lunch,* however, is a 3dB loss in efficiency and, of course, the cost of a second driver.

On another issue, a minor point concerning Phil Todd's interesting subwoofer article *SB* 2/85, p. 20. A closed box response with a Q of 0.5 does produce the flattest amplitude response with no ringing, but this is not a Bessel response. A Bessel response has a Q of 0.58 and produces the flattest possible delay, or equivalently the most linear phase response.

Joe D'Appolito
Andover, MA 01810

Mr. Nousaine replies:

Boy, I'm glad that both Mr. Meraner and Mr. D'Appolito re-examined the double driver idea. As most woofer builders have surely discovered huge box requirements are the number one roadblock to systems that go below 30Hz.

This is why the notion of V_{AS} reduction is so appealing. After examining both letters I returned to the test bench for more experimentation. This time I used two KEF B139s of similar characteristics. And when coupled as Mr. Meraner suggested initially through a sealed space, I obtained the same results. That is, the Q_T's were doubled.

However when connected as Mr. D'Appolito suggests, electrically in parallel, the original Q values can be approximated. The combined f_S was increased somewhat. So where does that leave the woofer designer? Well we are back to good news regarding Q and V_{AS}, but now we have to contend with new impedances.

Combining the two 8Ω KEFs gives us 4Ω, and eliminates the bridged Hafler arrangement I had been using. This is also true with my 18-inch drivers, but theoretically I should be back to the smaller box proposition.

The double driver definitely causes ripple exaggeration when only one driver is being driven. When driven in parallel there is still an exacerbation of the peak using the composite. Perhaps this is caused by the drivers being dissimilar in some parameters as Mr. D'Appolito suggests. I originally ordered one 18-inch driver, which turned out to have a Q_{TS} of 0.6. I replaced the original with a better one. Unfortunately, it also had a high Q. Because the price was exceptionally good in the first place, I decided to go ahead with the project. Initial design projections indicated my major problems would be response peaks at 30Hz or so (everybody should have such problems too much response where most have no response at all), and I could still attain my design goal of 16Hz.

In summary, I conclude that the composite driver idea does have merit in situations where the efficiency penalty can be tolerated. Often however, the place where efficiency is needed most is at low frequencies. In my case using the two driver technique still requires substantial system equalization, and the impedance/efficiency penalties are too high. But, I stand corrected on the penalty price list. This exchange of ideas is precisely the type of knowledge enhancing experience that I expect to gain from my SB subscription. My thanks to both authors for the ideas, examination and responses. My thanks to the Editor for providing the forum. I trust other enterprising woofer makers will benefit from these experiments.

KEF B139	Single	Double Undriven	Double Driven Parallel
Q_{TS}	.32	.72	.35
F_s	23Hz		26Hz

Mr. D'Appolito replies:

The discrepancy between Tom Nousaine's results and those of D. Meraner and myself is now clear. Mr. Nousaine did not drive the second driver in his composite. This does double Q_T and cause an additional factor of two reduction in efficiency for a total reduction of 4 or 6dB loss over a single driver. It makes little sense to leave the second driver motor idle.

The composite driver impedance problem can be handled by connecting the voice coils in series instead of parallel, or by driving each speaker from a separate amplifier, which is equivalent to the parallel voice coil connection. Unless the drivers are closely matched a parallel voice coil, or separate amplifier drive, is preferable to the series connection.

There is a third voice coil connection which is a curious cross between the one-driven and two-driven cases. In this last arrangement one voice coil is driven, and the second is shorted. The shorted voice coil provides damping, but no electrical input power. For this arrangement, Q_T is the same as that of a single driver, but the reference efficiency is down by a factor of four over that of a single driver.

I agree with Mr. Nousaine's comment that the composite driver configuration does have merit in selected applications. Both the advan-

tage (lower V_{AS}) and disadvantages (lower efficiency, higher cost) of this configuration must be understood before making the selection.

ISOBARIK INCEPTION?

This letter is in regard to the fine article by Mr. John Cockroft on "An Isobarik System" in *SB* 3/85, p. 7. Mr. Cockroft states that to the best of his knowledge the Isobarik system was invented by Mr. Igor Tiefenbrun of Linn Products. I've often wondered just where the idea came from, not that it matters a bit. I first heard the idea of two speakers in tandem within a sealed chamber to extend the bass from a gentleman who spent some time in Sweden.

I recalled seeing an advertisement for such a speaker and found a full page on Sinus Loudspeakers in *Audio* for January 1979, p. 99. It includes a drawing of their 55M series speaker, with the two woofers in a cast aluminum "accelerator tunnel." I cannot recall ever seeing another ad for these speakers.

Audio's directory issue for October 1979, lists the Linn SARA as well as the DMS which uses the same idea. Linn probably invented the name, "Isobarik" to describe the mid/bass idea.

I think John Cockroft did a remarkably nice job, especially under the restraints of his apartment kitchen. He should be congratulated.

L. B. Dalzell
El Cajon, CA 92020

ISOBARIK ICEBERG

Mr. Cockroft's article on Isobarik Systems (*SB* 3/85, p. 7) was very interesting reading. However, I hardly think Mr. Igor Tiefenbrun "invented" the Isobarik principle, any more than he invented the principle in his Linn Sondek. The British publication *Hi-Fi For Pleasure* published an article on this subject by Stan Curtis in its October 1984 issue. Mr. Curtis tells us that the French firm P. E. Leon also claims a patent on the principle, using a ported enclosure. Mr. Curtis came across the system some 15 years ago in a church organ speaker.

Ingar Berg
1640 Rade, Norway

Mr. Cockroft replies:

When I wrote the article I had no idea that anyone else had looked into the constant pressure principle other than Linn (at least publicly). My foremost idea in writing the article was to stir-up some interest in this type of speaker system, as I no longer had the time or the facilities to delve into it to my satisfaction. To my surprise I find that I'm actually a Johnny-come-lately (no pun intended).

The Stan Curtis article, "Hi-Fi For Pleasure," October 1984, sounds interesting. I'm sorry I missed it. Several people have inquired about using the constant pressure idea with a ported enclosure. One person is planning to use 20-inch speakers. And since I live only 75 miles from him, I'll probably know soon if his project is successful.

Other letters mentioned that Linn wasn't the first company to use this idea. Dynaco and Goodmans were mentioned. In the February 1985 issue of Stereo Review, *a test report mentions that the Jamo PP3000 speaker system has a compound push-pull woofer in a ported enclosure. Reference is*

SB Mailbox

made of its "unusually powerful bass. . . . At reasonably high levels the speaker induced mistracking of a compact disk player elsewhere in the room!". A recent Focal catalog implies a similar system. It is indeed nice to know that mine is not the only interest.

ISOBARIK INITIATIVE

I am surprised John Cockroft, in his article on Isobarik speaker design *SB* 3/85, p. 7, did not mention the commercially available Sontek Subwoofer (*SB* 2/85, p. 20). Nor did he mention David Meraner's note on using two tandem woofers to reduce V_{AS} by a factor of two (*SB* 2/84, p. 32). In addition, I believe two woofers mounted in the Isobarik, or "compound," configuration will double their individual Q_T as well. This would explain how the bass goes so deep for a sealed system of modest volume.

I too have looked closely at the Linn SARA cut-away picture that Mr. Cockroft refers to in his article. The two eight-inch drivers have small voice coils and large magnets, inferring low Q_T magnetic circuits. A quick calculation based on similar drivers made by Focal (8N401 DBE) indicates that a fully stuffed enclosure of 0.85 foot cubed would achieve a Q_{TC} of 1.0, and an F_3 of 36Hz. This volume and cutoff coincides with Linn's claim for its SARA loudspeaker.

Matthew Honnert
Carol Stream, IL

Mr. Cockroft replies:

My article was written by the time David Meraner's letter appeared. The same with the Sontek. Besides, I was writing of my own personal experiences.

I do not see how Q_T could double in the case of the compound configuration. The static mass, and the motor power, increase by a factor of two. The air load, however remains the same as for a single cone, as one cone is occulting the other. I feel that because of this removal of air load mass, slight as it may be, Q_T would actually be lowered slightly rather than raised.

Jeffrey N. White, in his paper, "Speaker Athletics," JAES *11/79, p.894, states that doubling the mass of a moving system will lower the resonant frequency by a factor of 0.707, and raise the Q_T by 1.414. For the speaker to yield the original Q_T, one must also double the compliance, which will cause the resonant frequency to go down by a factor of 0.707, and V_{AS} to double. Thus we have a speaker with a resonant frequency of half the value and V_{AS} with twice the value of the original speaker. Q_T remains the same. Note that here White is speaking of a single speaker, with a single motor structure. With the compound speaker you have twice the mass, with two motor structures, so the relation of motor to mass remains the same (except for the loss of half the air load). Doubling the motor is equivalent to doubling the compliance, as far as Q_T is concerned, but since the compliance actually remains unchanged V_{AS} is not doubled. On the other hand I don't see why it should be halved, as Meraner states.*

Linn states in its literature, that the mechanical and electrical coupling between the two drivers allows the inner driver to correct errors produced by the external driver (and I suppose, vice versa). Apparently the compound speaker has a more complex function than merely a speaker with "double the mass."

SARA speakers, according to the literature, use "highly modified" KEF 8-inch speakers. They further imply that the modification has to do with treating the baskets to reduce the effects of vibration. Linn does not mention altering the acoustic specs, (but of course it is possible that they do). I assumed that they used the KEF B200 (doesn't everyone?), for which KEF supplies the following data: Q_T 0.45, F_{SA} 25Hz$\pm$5Hz, V_{AS} 7.930 cubic feet. After long consideration, looking at the cut-away photo of the SARA, I arrived at about 940 cubic inches (0.54 cubic feet). Mr. Honnert did not take into consideration the set-back front baffle, the cleats, the doubled stiffening boards, the tunnel, the rear speaker and the effects of the acoustic value of the stuffing, (I arbitrarily assigned 15 percent to it), when he arrived at 0.85 cubic feet. This gives the SARA a Q_{TC} of 1.776 and an F_C = 98.6Hz. This is what it would be if a single speaker were used. F_3 would be 0.68s F_C, or 67Hz with a 5.3dB hump at about 107Hz. Linn claim the SARA is "essentially flat" to 40Hz. To meet that with the same parameters, F_C would have to be about 58.9Hz, And then what about the hump?

On the other hand, if V_{AS} was indeed halved, it would be 3.965 cubic feet. Q_{TC} would be about 1.295 and F_C about 7.95Hz. F_3 would be about 0.72F_C or 51.8Hz. This comes a bit closer to essentially flat to 40Hz.

I think there is more to the compound speaker than is currently evident.

(Note: The Sontek system is in a "close-out" phase, and when current stocks are exhausted it will no longer be marketed—Ed.)

MORE ON THE ISOBARIK

Mr. Cockroft's interesting and enlightening article on Isobarik woofer systems in *SB* 3/85 was most welcome. I have built four similar systems, and what I heard was essentially the same as what he heard and measured, with one difference: while the Isobarik is capable of extending the bass considerably deeper than an acoustic suspension box, with better impact and control, it can have a rather poor midrange performance. I believe the cause is the midrange's rear woofer blaring away into the back of the main woofer. In the bass the wavelengths are so long that the distance between the two woofers is not a significant portion of a wavelength. But as the wavelengths become shorter the rear woofer ceases to work harmoniously with its partner, because by the time the wavefront from the rear woofer hits the cone of the front woofer, the front woofer is already working in a different part of the waveform. Thus a somewhat garbled version of the original waveform is radiated. Whatever the exact explanation for the coloration I heard rolling off the response of the inner woofer, somewhere not too far above 100Hz, it cleans up the midrange problem. A large inductor in series with the inner woofer works well, but the rest of the crossover would need to be modified unless you have a bi-amplified system.

Francis Le Jeune
New Orleans, LA 70118

CALLING ALL TL BUFFS

I am probably one of *Speaker Builder's* youngest readers at age 19, and enjoy the magazine. I especially liked Craig Cushing's "A Compact Transmission-Line Subwoofer" article in *SB* 1/85, p. 6, and plan to build a pair. I'm new at building speakers, and also hope to build a pair of TL satellites to go with the subwoofers. Perhaps readers interested in the TL design could give me some advice. If you've built them, or have plans for them, I would appreciate any help.

Danny Bowes
RR 2 Forester's Falls
Ontario, Canada KOJ 1VO

Back issues are your best resource.—Ed.

MORE PASSIVE CROSSOVER QUESTIONS

I have read and enjoyed Bob Bullock's series of articles about passive crossovers. I started to play around with the first-order, three-way equations on my computer, and found a problem: with a CPC type crossover, the value for RA turns out to be negative. I worked out the equations myself, and found that the APC type crossover had a problem too.

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It turns out that both of these problems are caused by minor typo's in equations 9 and 10.

$$A = \frac{R+1}{R} \quad \text{should be} \quad A = \frac{S+1}{R}$$

$$H = \frac{R-1}{R} \quad \text{should be} \quad H = \frac{S-1}{R}$$

With working equations, I experimented and found something which Bob did not mention: his technique for three-way networks can easily be expanded for four-way or larger networks (at least for first-order networks). To do this, design the high-pass and low-pass sections normally, then design each band-pass section the way Bob has shown for a single band-pass.

Allan Flippin
San Jose, CA 95131

Contributing Editor Bullock replies:

Mr. Flippin's versions of formulas 9 and 10 are indeed the correct ones. It seems that every occurrence of the form

$$R \pm \frac{1}{R}$$

wound up as

$$\frac{R \pm 1}{R}$$

Thus, formula 16 should also be changed to read

$$A = a\left(R + \frac{1}{R}\right)$$

Thank you for bringing these errors to my attention.

MAIL ORDER ADVICE

In our mail order business, every week we receive two or three catalog requests lacking addresses, or with illegible addresses. We even get orders that don't include the customer's return address. Since we have no face-to-face contact with customers, this makes them impossible to track. Some recommendations for the best mail order service are:

- include your name and address on all correspondance. Just using the name and address on a check or an envelope is an easy way for it to get lost or torn-up
- write legibly. As one of the world's sloppiest writers I know it's difficult, but if an order can't be read how can it be filled correctly and shipped to the proper address? Most mail order companies want to serve you well, help them out by giving complete information on all your correspondence.

Mike Dzurko
Audio Concepts
La Crosse, WI 54603

PARALLELING AND THIELE/SMALL

When parallel drivers are connected and assumed to be one, what exactly happens to Thiele/Small parameters: particularly Q_{TS} and V_{AS}? I read that Q_T and F_S remain the same as either one of the identical pair. I didn't find out what happened to V_{AS}. I assumed that it doubled. Through common formulae I derived a box volume for this "driver" made of two identical drivers. The box volume was incredibly small. What did I do wrong?

Single Driver	Double Driver
$Q_{TS} = 0.18$	$Q_{TS} = 0.18$
$f_S = 40\text{Hz}$	$f_S = 40\text{Hz}$
$V_{AS} = 0.019^3$	$V_{AS} = 0.938\text{m}^3$

$V_B = 15Q^{2.87}$ $V_{AS} = 253$ cubic inches or 0.00414 cubic meter.

I then assumed to derive V_B using parameters of a single driver and simply doubled it. But then I considered that maybe V_B would be unnecessarily large. What is the truth behind all these assumptions?

Carmen Gitto
Thornhill, Ontario Canada L4J 1A5

Contributing Editor Bullock replies:

Your conclusions are correct. For two identical drivers in parallel, the equivalent single driver V_{AS} doubles, and f_S, Q_{TS} remain the same.

The box size you obtain in your example is due to a small Q_{TS}, and has nothing to do with the use of double driver parameters. You did nothing wrong.

RIBBON SPEAKER MODE MATTERS

In the Spangler and McKenzie article "Modified Strathearn Ribbon Speaker", *SB* 3/85, p. 22, no mention is made of the effect diffraction has on the frequency (and impulse) response of the unmodified Strathearn ribbon. It has been shown (H. F. Olson "Direct Radiator Loudspeaker Enclosures, *JAES* 1969, Vol. 17, No. 1, p. 22) that 10dB response irregularities can result from the worst case of a moving-coil driver mounted in the center of a flat, round surface (where the distance from the driver to the enclosure edges is the same in all directions, with no staggering of the time delays between the direct driver radiation and the radiation diffracting at the enclosure edges). Unfortunately, this case is analogous to that of a line-source driver on a long rectangular face with sharp edges. I believe with a 2½ inch distance from the ribbon element to the Strathearn edge, diffraction will contribute a 180 degree out-of-phase component at 2.6kHz, and an in-phase component at 5.2kHz, etc. . . . This will result in a dip and a peak at these respective frequencies, and at a sequence of higher frequencies.

I wonder how far this—in combination with the slightly delayed and 180 degree out-of-phase rear radiation—goes toward explaining the jaggedness of the free-standing unmodified Strathearn's frequency response. What happens when the Strathearn is flush-mounted in a wall, in a sonotube ("Tools, Tips and Techniques," *SB* 2/85), or on a foam-fronted baffle?

In reference to the authors' criticism of stacked ribbon elements, I wonder again whether some of the frequency response irregularities may be attributed to the driver baffle.

Also, a truncated line source like the Strathearn may act as a point source at low frequencies, but will certainly not at high frequencies (unless Strathearn are only energizing a part of the ribbon at high frequencies?). A pair of stacked ribbons will act like a single long ribbon, not like two point sources.

Ralph Gonzalez
Philadelphia, PA 19143

Mr. McKenzie replies:

In an attempt at brevity in the original article, Mr. Spangler and I decided to only discuss the relevant factors describing the sonic output of the Strathearn SLC2 midrange ribbon driver. Diffraction was one factor which was not relevant, but the raw data published in the article included the information needed to determine the contribution of diffraction in the total response.

Ralph Gonzalez seems to have missed the key point (which he even makes note of in his letter, when he refers to the lack of staggered time delays as the cause of the worst case response noted by Olson) needed to make use of the published data. A physical source of interference, located a set distance from the transducer, produces a second source of excitement at a fixed time delay relative to the original source. Factoring in a number of variables such as temperature, humidity, air pressure and the additional air path delay with the stated 2.5 inches to the edge of the Strathearn ribbon, we can cal-

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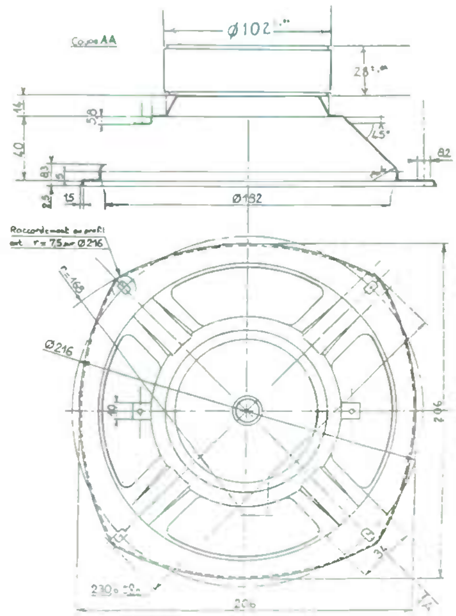
Fs = 33Hz
Qms = 1.8
Qes = 0.57
Qts = 0.43
Vas = 2.7 cubic feet
SPL = 91dB



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FAST REPLY #7

culate a fixed time delay of about 0.19 milliseconds. We can review the published data for the Strathearn in free air, and look for the effects caused by the sharp edge of the face of the driver.

Figure 1 is an oscilloscope presentation of the magnitude versus time response of the Strathearn, offset so that the maximum output occurs at the 0.2 millisecond output level and the 0.39 millisecond (0.2 milliseconds plus a fixed delay of 0.19 milliseconds) delay region. Most interesting about the data at the 0.39 millisecond point is the negative polarity of the output. A physical boundary, whether representing a point of reflection or separating half space to full space radiation, cannot change the basic polarity of a pressure zone. The other interesting feature of the data at the 0.39 millisecond region is a basic lack of magnitude.

Figure 3 is the FFT-derived frequency response of the magnitude/time data of Fig. 2 with all data beyond 0.42 milliseconds deleted. All data beyond the fixed time delay of 0.19 milliseconds must be produced by sources other than diffraction since we are now physically beyond the edge of the Strathearn faceplate. The response pattern of the Strathearn during the first 0.22 milliseconds is response up at about 4.3kHz, down at 6.5kHz and up again at 10.8kHz. These results do not quite agree with Gonzalez's predicted response.

Figure 4 is the oscilloscope presentation of a perfect transducer with one neat perfect boundary effect, and a delay of 0.19 milliseconds. This boundary effect has a magnitude of 99 percent of the value of the direct output of the perfect transducer, representing a worst case condition for any practical loudspeaker. Figure 5 is the FFT-derived frequency response of the data in Fig. 4. The major response deviation occurs at 2.47kHz, very close to Gonzalez's predicted frequency of cancellation with a magnitude of deviation to about 11.5dB, then smaller response dips at 7460Hz and again at 14.4kHz. There are no reinforcements evident: i.e., where the response rises above the base sum level represented by the low frequency values. Figure 6 is the perfect transducer again, but with less boundary effect. Figure 7 shows the much smaller frequency response deviations caused by a still significant boundary effect contribution to the summed signal. Even at a much larger value, compared to what is found during the 0.19 millisecond delay region in the free air Strathearn data, the maximum response variance is only 2.2dB.

In response to the question of flush mounting a Strathearn midrange ribbon, yes, any boundary effects will be minimized, but since the major problems are not caused by diffraction the result may not be satisfactory. As for boundary effects causing the response problems with stacked diaphragms, please note that the lowest frequency suck-out is over 3kHz. From the previous discussion of frequency and relative delay we must infer that the physical location of the boundary is less than 2.5 inches, and no changes were made to the physical dimensions of the faceplate during stacking.

I thank Mr. David K. Miyashiro, a math wizard of the highest order, who volunteered his time to analyze and solve Mr. Gonzalez's equations. Mr. Miyashiro found that the equation for the approximation is mathematically incorrect and gives the results of Table 1. Please note that as crazy as it may seem, when B1 and H are varied by equal amounts, such that the listening position to the line source is exactly the same, the pressure varies by an almost consistent 3dB. Once the equation was corrected, at least so the math was correct, the results in Table 2 were generated. The positions of H start at the middle, or an equal distance from the

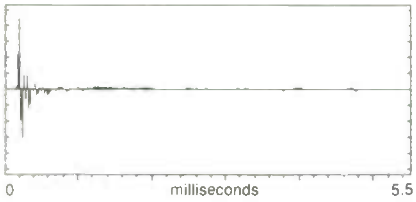

FIGURE 1

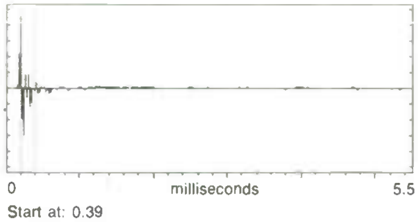

FIGURE 2

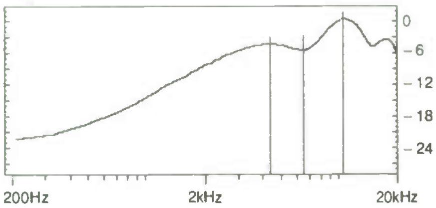

FIGURE 3

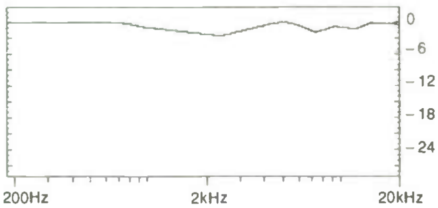

FIGURE 4

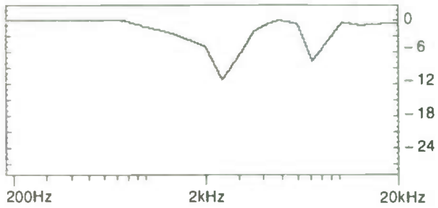

FIGURE 5

FIGURE 6

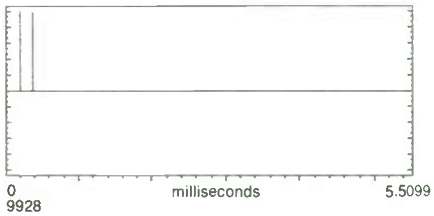

FIGURE 7

TABLE 1

	100Hz		1kHz		10kHz	
d	30	36	30	36	30	36
24	.03	3.04	0.00	3.02	-2.4	1.2
30	6.04	7.01	5.96	6.95	3.15	4.21
36	8.47	9.05	8.32	8.91	5.38	5.92

TABLE 2

h	100Hz	1kHz	10kHz
10	0	0	0
8	-0.0006	-0.0051	-0.4066
6	-0.0026	-0.0207	-1.587
4	-0.0058	-0.0466	-3.075
2	-0.0103	-0.0830	-3.593
0	-0.0160	-0.1297	-3.623
-2	-0.0231	-0.1868	-4.485
-4	-0.0313	-02542	-6.625
-6	-0.0408	-0.3318	-8.334
-8	-0.0516	-0.4195	-7.266
-10	-0.0635	-0.5175	-7.274

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top and bottom edge of the line source and move to an equal distance below the line source.

For what it may be worth, the results for the corrected equation seem to make some sense. But, I am unsure that the model of the line source, represented by the equation, is correct. Each of the infinite number of point sources making up the line source is considered to be working in free air, which in the real world is not the case. And the equation defines a boundary, the floor, which should not be considered if the object of analysis is the line source. Last, since a practical line source must be made of practical materials, which due to the mass and compliance of the diaphragm prevent the applied force from moving all areas of the diaphragm equally at higher frequencies, practical line sources move only small areas of their "line" and thus do not operate as true line sources.

Mr. Gonzalez responds:

As a postscript to my letter, it appears that I was misguided in my description of the exact frequencies at which diffraction-induced irregularities should occur.

The response irregularities are caused by radiation from the enclosure face, not from the enclosure edges as I stated. I suspect that diffraction may be responsible for the dip near 4kHz of *Fig. 13* (and hence for some of the irregularity of *Fig. 12*) in the Strathearn article. It would be interesting if a knowledgeable reader could produce theoretical frequency response curves for a line source in a rectangular enclosure, or in a baffle with the rear radiation partially absorbed as is the case of the Strathearn with its "dampers" intact.

I also neglected to mention the interesting practical discussion of diffraction effects in *SB* 1/80, p. 28.

Ralph Gonzalez
Philadelphia, PA 19143

CIRCULAR ESLs

Has anyone investigated round electrostatic loudspeakers? If you look at a "normal" ESL, and imagine the diaphragm being driven, assuming that the force applied to the diaphragm as uniform, the displacement of the driver will be uneven (ie., not a true, rigid piston) because the tension on the diaphragm is not even around the perimeter of the "cone." With a round diaphragm, and the driver being attached in a circle, it would seem the tension on the edges would be the same, and the motion more piston-like.

Also, has anyone graphed, or embodied, in equation(s), the following for electrostatics:

- frequency response versus stator/diaphragm spacing?
- overall driver distortion versus diaphragm?
- "beaming" versus driver size?
- passive crossovers between ES drivers?

As a not-so-quick, but relatively inexpensive replacement for zip cord style speaker cables, readers might want to try weaving Radio Shack 16 gauge cable as follows:

- buy six times as much 16 gauge cable as is needed to reach both speakers
- separate the paired cable
- weave three strands with a simple right-over-left, left-over-right pattern. Tape each end to keep the cable from unraveling, and secure the first end in a small vise to prevent it from rotating. Tape every two or three feet to hold the weave.

I've found this to be a simple, inexpensive and superior alternative to 16 gauge zip cord. Unlike some exotic woven cables in the past, this doesn't seem to cause any high-frequency oscillations in my NAD 3020, and it is clearly superior to zip cord, especially and noticeably in the high frequencies.

James M. Rice
Richmond, VA 23229

Round, no, curved yes. John Civitello of Paterson NJ produced a curved array (not a series of flat radiators) a few years ago and marketed it briefly. We've heard no news of the enterprise for some time. Two Audio Amateur *authors have done significant work on electrostatics: David P. Hermeyer (*TAA *72/3:11; 72/4:9; 73/3:8; 77/2:4; 77/3:8), and Roger R. Sanders (*TAA *75/4:18; 76/1:12; 76/3:39). All of these are reprinted in* Audio Amateur Loudspeaker Projects *(Old Colony AA-1, $20).*

The early work on electrostatics was done by Peter Walker in England and Arthur Janszen in the USA. Janszen's 1954 work is reprinted in the Audio Engineering Society Loudspeakers, *Vol. 1 collection. Walker's three landmark articles appeared in* Wireless World, *May, June and August 1955.—Ed.*

COMPUTER CORRECTED

My current system is mainly homebuilt: an Oracle Alexandria II with Nagaoka MP11B, Last PAS (*TAA* 4, 5/82), Audio Research Stereo 70C3, Ace 5000 (kit), and a Nikko Alpha 22. My speakers are LS3/5A replicas, with Falcon Acoustics Butterworth crossovers, and a common vented push-pull subwoofer like the one described by W.L. Ramsay in *SB* 4/84, p. 36. Most of what I know about speaker building came as a result of this disastrous subwoofer. Ramsay mentions only 8-inch Polydax drivers, but in fact Audax/Polydax manufacture 8-inch speakers with two different magnet sizes. The smaller "J" magnet was recommended in the old *Transcendental Audio* catalog where I first saw the design. The speakers are also marketed with two different voice coils: a two-layer and a four-layer version. This may have been the beginning of my problems.

The original design called for the two-layer version, but no one could tell me how many layers were in my 8-inch Audaxes. The completed system sounded terrible: muffled, boomy, and having only one note. I read Weems, and Bullock's *SB* articles, and measured the driver parameters. These were wildly different from Polydax's published specs. I considered using the Audaxes for something else, and putting some old 8-inch JBLs into the box. But I learned how to use a microcomputer, and using the program at the back of Weems' book, decided on optimum tuning for the system. It all sounds good now, excellent on deep bass, organ and Telarc drum recordings, but slightly slow compared to the LS3/5As or Mission 770s.

Fred Humphrey
Campden, Ontario Canada

ECLIPSE WATCHERS

A note to those interested in the Eclipse W1032R (sold by Meniscus). I recently purchased four of these fine ten-inch woofers, and after eight hours of break-in, tested them for Thiele parameters. I found them consistent, with the following spreads in measured values:

f_S	1 percent
V_{AS}	3 percent
Q_T	6 percent

however, f_S and Q_T measure approximately 20 percent higher than advertised, giving me doubts about their suitability for vented-box alignments. (Advertised as, $f_S = 24$, $Q_T = 0.40$.)

I called Gary Church, Carbonneau Industries' design engineer, and related that the rubber surround added initial stiffness that required parameters be tested "under operating conditions." The rubber is very lossy (an ideal cone termination), but has hysteresis at low signal levels. I usually check my drivers with approximately 100mV across them, by the constant current method. This is admittedly much below normal operating conditions. By raising the test signal above 0.5V the measured values come close to the advertised values, and are much better for a compact vented box.

Matthew Honnert
Carol Stream, IL 60188

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

NEW JERSEY AUDIO SOCIETY meets monthly with the emphasis on construction and modification of electronics and speakers. Individuals at any level of electronics expertise are invited to join. Contact Bill Donnally, (201) 334-9412 or Bob Young, (201) 381-6269, 116 Cleveland Ave., Colonia, NJ 07067.

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TORONTO AREA AUDIO SOCIETY formed. Serious audiophiles contact Neelam Makhija (416) 842-2606 or John Sloan (416) 532-4387.

THE ATLANTA AUDIO SOCIETY started in October 1983 and has regular meetings on the third Sunday of each month as well as special programs with leaders in the industry, such as Mr. William Conrad of Conrad-Johnson and Mr. William Johnson of Audio Research. We are currently looking for additional members in the Southeast. All members receive the minutes of each meeting and program, as well as other relevant announcements and correspondence. For full information and membership packet, write Atlanta Audio Society, PO Box 92130, Atlanta, GA 30314, or call Howard Royal in Newnan, GA at (404) 253-6419.

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Publication No. 01997920 Edward T Dell, Jr.

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Fried C/2 and O/2 drivers; Sony TAE-86 preamp; TAJ-88 tuner; Platter Matter: Orsonic 2 SDG clamp. All mint. Best offer. Also album collection. Send for list. Doak Wattigney, 51 Nassau, Kenner, LA 70065, (504) 443-1238.

I.M. Fried model H subwoofer, 2 KEF B200 drivers in a transmission line stereo enclosure, gray formica, $350. Located in Detroit area, not able to ship. Call Marc, (313) 546-4218.

WANTED

Information from owners of genuine Karlson 15″, Karlsonette, Karlson 8″ and Karlson Rocket. R.E. Fabregvettes, Lotissement Pre Vescal, RAM BAUD 05000 GAP France.

Two Sonotube enclosures to accommodate four Jordan modules per side. Also need four Jordan modules. Jack O'Dea, 22 Carlton Lane, Harrington Park, NJ 07640, (201) 767-3922.

JBL cabinet design/construction manual with black and white photo on front cover and red and gray graphics. Will buy your copy(s) or Zerox. Also need copies of Altec's manual. Tom Young, Box 436, Naugatuck, CT 06770.

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