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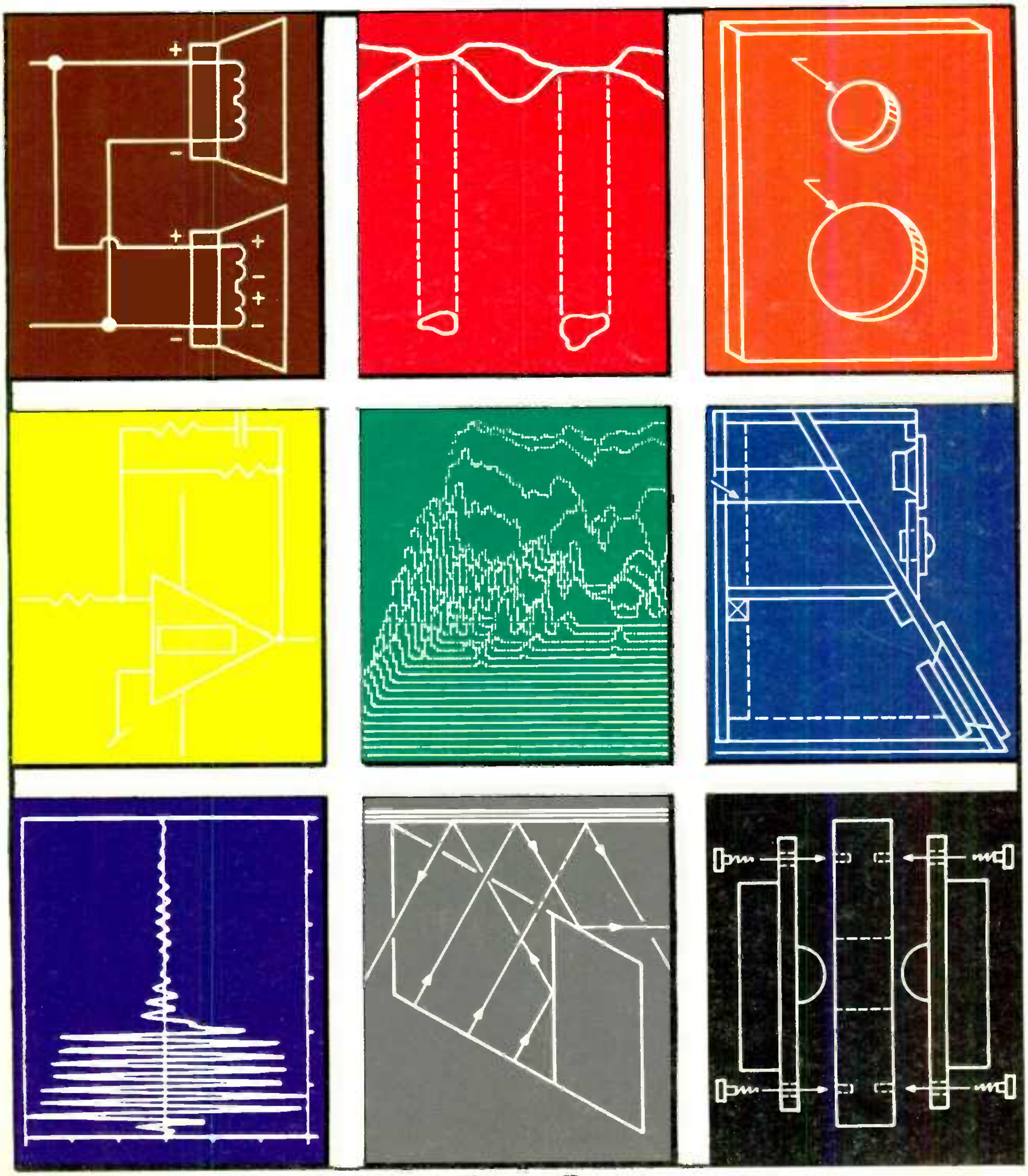
Speaker Builder

THE LOUDSPEAKER JOURNAL



SB Mailbox

CORRECTION

I found some errors in my Minimus-7 Super Mod article (*SB* 1/90). While the layout and values assigned to the capacitors in *Fig. 3* are correct, the text relating to it is not—the text on p. 43, column 3, paragraph 3 should read: C1 = 4μF, C2 = 8μF.

Figure 4's "Tweeter #2" sign should be positive (+), not negative (−).

Angel Rivera
Brooklyn, NY 11204

WHOSE CONCLUSIONS ARE CORRECT?

This is an "oops" letter, because if I had read Mr. Oliveira's letter (*SB* 2/89) sooner, I would have responded sooner. Have other readers also been delinquent, or are there other "oops" letters on their way to "Mailbox"?

In any event, if Mr. Oliveira had read far enough into back issues of *SB* he might have come across Mr. D'Appolito's analysis of the compound woofer configuration in the "Mailbox" section of issue 4/85. This analysis is in serious conflict with Mr. Oliveira's. I believe that Mr. D'Appolito's is the correct one, not only because he has shown remarkable expertise in the design of speaker systems, but because his conclusions are experimentally verifiable, as I have personally confirmed.

David J. Meraner
Scotia, NY 12302

DRIVER PAIRS

My question pertains to the formulas to determine values for impedance equalization and values for series notch filters. Using the formulas for single drivers seems straightforward enough. However, when like drivers are combined in series or parallel I am a little uncertain. For series notch filters, are the Q_{ES} and Q_{MS} values the same whether drivers are placed in series or parallel or must they be halved or doubled?

For impedance equalization, must the driver inductance L_E be doubled or halved depending on whether the drivers are placed in a series or parallel configuration?

My other question pertains to the rather elaborate crossover Dynaudio uses for the Myrage system utilizing paralleled 24-100 woofers, parallel D76 drivers and an Esotar tweeter. What is the mathematical basis for determining the *phase correcting portion* of the crossover used on the D76? In other words, how were the values of 50μF and 0.8mH determined?

Herbert Meyers
Longmeadow, MA 01106

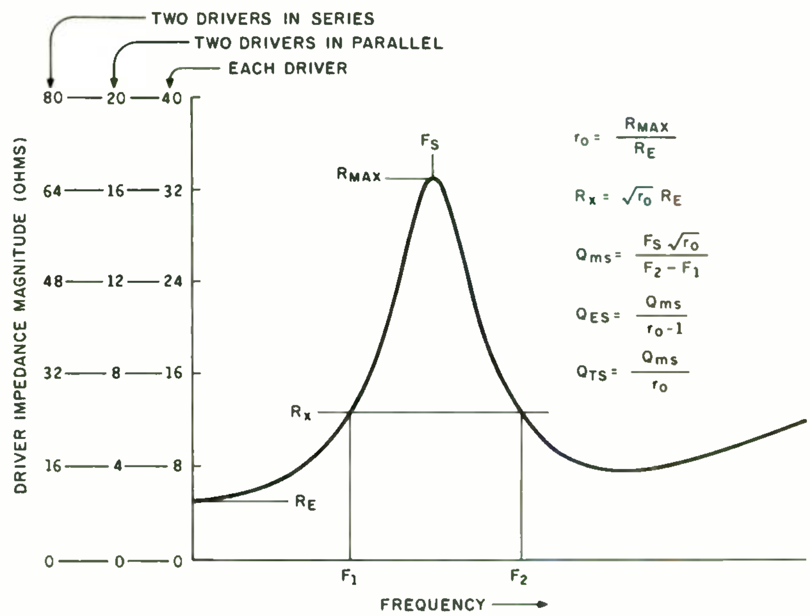


FIGURE 1: Demonstrating driver Q remains unchanged.

G. R. Koonce replies:

The basic question you ask is the effect on driver parameters when two identical drivers are used together. This was well covered by Bullock (*SB* 2/87, p.60), but is worth reviewing. When two identical drivers are mounted on a baffle in free air and driven with the same polarity, the approximate equivalent driver has the same electrical and mechanical Q_S, the same F_S and a V_{AS} equal to twice the V_{AS} of an individual driver. The limitations in this definition are because you can do things to make these results invalid, for example driving the two drivers out of phase or using them in a compound (Isobarik) configuration (where V_{AS} is halved). Generally, however, two identical drivers wired in either series or parallel produce a single equivalent driver with T/S parameters of Q_{TS}, F_S and 2 × V_{AS}, relative an individual driver.

The fact Q is unchanged may seem unlikely at first, but can be easily visualized. *Figure 1* shows the impedance magnitude curve of a baffle-mounted driver with the various Q computation points marked and the Q computation equations shown. Now, since hooking identical drivers in series simply doubles the impedance magnitude, you get the same curve with the vertical scale multiplied by two. Two identical drivers in parallel simply halves the vertical impedance magnitude axis. Thus the Q computations are unchanged for two identical drivers in series or parallel relative to a single driver.

You can also visualize the effect on V_{AS}. Let's design identical enclosures for our identical drivers and stack them on top of each other. Since identical things happen in both boxes, you can remove the wall common to both enclosures with no change in performance. Since the two drivers, for identical performance, require twice the enclosure volume as a pair, they must have a V_{AS} twice that of a single driver.

Table 1 shows how the various parameters for an equivalent driver composed of two identical drivers wired with the same polarity can be obtained from the original parameters for series and parallel connection. In practice, your drivers are not identical. I have often used parallel woofers using the following approach. Try to obtain matched drivers. I match the pairs in F_S and Q_{TS} as best I can. I then design using the average F_S, the average Q_{TS}, and V_{AS} equal to the sum of the individual V_{AS} values. This has worked out quite well. I have insufficient experience with dual-woofer closed-box enclosures to comment, but with vented-box enclosures I highly recommend using the drivers in parallel as I have found this consistently better than the series connection even though many times you would prefer the higher impedance offered by the series connection.

Turning now to your question about impedance correction (Zobel) computation for the driver pair. First, I must say I find the equations presented to compute the Zobel network are incorrect. I recommend finding the Zobel values by trial and error impedance testing. You can do this by testing the two drivers connected as they are to be used (series or parallel) or by testing with one driver and correcting for the connection. Remember the basic rules: Two identical resistors or inductors in series have double the individual value while capacitors in series give half the value. In parallel, the capacitor doubles and the resistor and inductor values halve.

For example, suppose you arrive at the Zobel values for one driver, by testing or equation, of 8Ω in series with 20μF. If you placed the two drivers with their individual Zobels in parallel the resultant Zobel would be 4Ω and 40μF. If you place the two drivers in series the resultant Zobel would be 16Ω and 10μF. This agrees with *Table I* which shows driver resistance and inductance double for series connection and halve for parallel connection.

TABLE I

PARAMETERS FOR TWO IDENTICAL DRIVERS

Parameter		Parallel	Series
Resonance	F_S	Same	Same
Electrical Q	Q_{ES}	Same	Same
Mechanical Q	Q_{MS}	Same	Same
Total Q	Q_{TS}	Same	Same
Compliance Volume	V_{AS}	Doubles	Doubles
DC Resistance	R_E	Halves	Doubles
Voice coil inductance		Halves	Doubles
Input impedance magnitude		Halves	Doubles
Electrical power limit		Doubles	Doubles
Maximum cone displacement		Same	Same
Effective piston area		Doubles	Doubles

Note: Shows how equivalent parameter relates to individual parameter

Regarding the question about series notch filters, I am not sure to which equations you refer. You should obtain the correct results by remembering that Q values for the driver are unchanged and the driver impedance is corrected by the basic rules of series and parallel connection as discussed above and indicated in *Table I*.

I am not familiar with the crossover used by Dynaudio on the Myrage system. I can only comment that the reverse engineering of a crossover is a difficult task. I have been involved in this many times, repairing systems that have failed, a driver that is not available or is simply too expensive to replace. To fully understand the crossover supplied with the system can require detailed testing of each individual driver, tough to do if the driver is not in good working order, and you don't have the same optimization software used in the original design. Many times it is easier to do a completely new crossover design. I know this is no help to your specific problem; perhaps someone else can provide a more specific answer.

PANACEA?

I would first like to add my support to the advantages of using driver impedance correction (Zobels) expressed by Mr. Cox in his article. Unless you use some optimization program requiring detailed testing of the driver to design the crossover, I believe Zobels the only practical approach. I found the imaging improved on three-way systems if I added a Zobel to the tweeter. I am a believer.

I infer from his article that Mr. Cox believes obtaining a flat input impedance via Zobels is something for which we should strive. Others may not have read this into the article, but if you did, some clarification is needed. Assuming a cross-

Continued on page 74

World Radio History

Speaker Builder

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About This Issue

If you think this issue is fatter than usual, you're absolutely right. Weighing in at 104 pages, it's the largest *Speaker Builder* yet, and we've made good use of the extra editorial room, as you'll soon see.

$500 was the total budget **Bill Schwefel** had to work with, but that didn't stop him from building an impressive pair of speakers for his friend —a friend with champagne taste, but a beer budget. Bill's story of austerity begins on page 10. And speaking of class acts, gold is the best metal for speaker contacts, right? **Marc Bacon** debunks the myths surrounding optimum connection material and tells us why pure gold doesn't always pan out.

Upgrading the in-law's faithful record player to a state-of-the-art stereo system could be a dicey assignment, but **Robbie Tucker** pulled it off handily (p. 26), even though function had to follow form. Next up, a few recycled parts, a little research and some modestly priced drivers are all part of **Mill Johnson**'s formula for fidelity, starting on page 34. And don't worry, even though Mill's a professional cabinetmaker, he's kept the construction simple. Those of you who have been following Roger Sanders' construction series, "A Compact Integrated Electrostatic/Transmission Line," can rev up your power tools for the final installment which begins on page 38.

As **Barbara and Kenneth Keller** found out, modifying a speaker design for your own application can be quite rewarding and, contrary to the title of this issue's "Craftsman's Corner" (p. 62), their swan song marks the *beginning* of a great performance.

And finally, **Dick Pierce** signs off with "Pox Humana" (p.102) wherein he recounts his quest the Holy Bass. For a while, it was his.

Speaker Builder

THE LOUDSPEAKER JOURNAL

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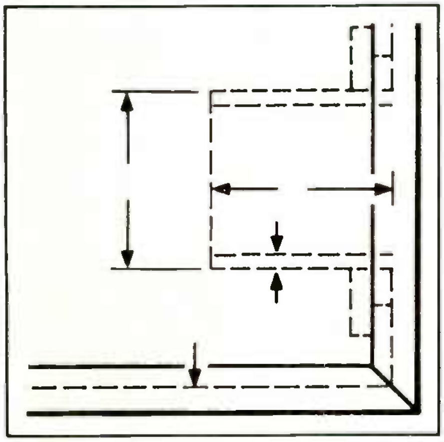

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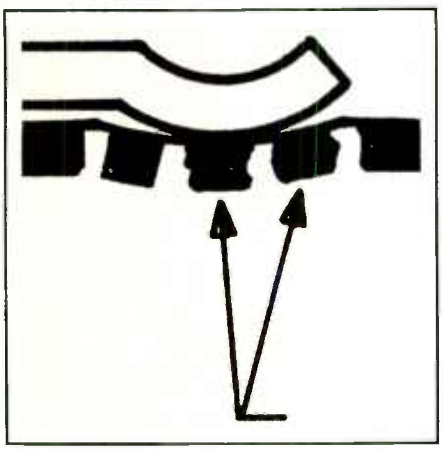

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FEATURES

DEPARTMENTS

Editorial

Speaker Checking, BBC Style

I greatly admire a small handful of genuine audio experts. Barry Fox is one of them. Fox writes a monthly column for *Hi-Fi News & Record Review* which by itself is almost worth the price of a subscription to the British journal, despite the absurdly high postage one pays to get copies to this side of the water.

The magazine's February 1990 issue included a sidelight on loudspeaker evaluation from within the hallowed precincts of the British Broadcasting Corporation, a nirvana of high standards for audio reproduction. I thought it interesting enough to repeat a portion of Fox's report here, along with an equally interesting response from a BBC executive. I probably need not belabor the significance of the facts presented, except to say that the legendary LS3/5A loudspeaker is widely regarded as not only a superior design, executed by the BBC for monitoring purposes, but a consistent, uniform product. In the world of loudspeakers, few products of fewer companies earn anything close to such a reputation. But I should let Fox tell the story in this excerpt, used here with Editor Harris' and *HFN&RR*'s kind permission.

Barry Fox writes:

Broadcasters such as the BBC obviously need an accurate loudspeaker for monitoring. Nearly twenty years ago the BBC designed its 'LS' range of speakers for in-house use. Since then several manufacturers have been licensed to make and sell LS speakers to the public. The BBC also buys its units from these firms.

But there is a carefully controlled system of cherry picking.

Why, you may ask, is this cherry picking necessary? Because even the most strictly controlled factory production process is at the mercy of the firms supplying the raw materials. If for instance the plastics from which the loudspeaker cones are moulded changes, then the glue for the surround may have to be changed too. And this can completely alter the sound unless the manufacturer tweaks other parameters to compensate.

To stay within the terms of the BBC licence, the manufacturers must do their best to keep the final sound stable. But, as the BBC has found out over the years, even different speakers from the same batch can end up sounding slightly different. As long as speakers are matched in pairs, the difference is unlikely to be of any consequence to the public. But it does matter to the BBC because engineers mixing and balancing radio and TV sound for transmission are relying on the fact that all speakers in all studios, and at all outside broadcasts all around the country sound the same.

The BBC checks batches before purchase for in-house use by a simple, but well-tried test. Pairs of the original first batch reference loudspeakers are held in store for testing. When a new batch of speakers arrives, they are first checked by engineers who weed out any with obvious audible differences. Then BBC sound engineers are invited, one by one, to sit in a room and listen to a standard tape of a BBC announcer reading prose. The sound is switched between an old reference speaker and a new and supposedly identical unit alongside it. If the two sound the same, the speaker under test is okayed and accepted by the BBC.

If there are audible differences, the speaker is rejected—it goes back to the maker. A dozen or so speakers are brought in during each test session. Sometimes the new and reference speakers sound virtually identical; other times differences stick out like a sore thumb. None of this makes reassuring reading for anyone who is planning to buy a speaker on the strength of an ageing review.

The Fox report elicited this reply from D. J. A. Walker, chairman of the BBC's Loudspeaker Liaison Committee:

"I have long been an admirer of Barry Fox's writings but I am afraid that his piece in *Hi-Fi News & Record Review*'s February issue ... has misconceptions that should be corrected.

When the BBC designs a loudspeaker, standard assemblies are selected which are judged to represent the median of the acoustic performance required. A standard assembly of this type is lodged with manufacturers who are licensed to produce that design, and is used by them to ensure that their production meets the required performance.

As part of the license agreement, the BBC takes sample production units for quality assessment. These may be selected from the factory with the manufacturer's knowledge or purchased 'off the shelf' from a supplier. Additionally the BBC buys speakers for its own use. These speakers are examined for any obvious defects and then auditioned by an expert listener against the standard to ensure that the production is within tolerance. This work is carried out by the BBC in a specially designed room with a carefully controlled acoustic and temperature.

In practice, the manufacturing process is well controlled and it is unusual for a unit to sound significantly different from the reference. When a problem is identified, this is discussed with the manufacturer and corrective action taken. This quality control system ensures that the public gets a high quality product. There is certainly no intention for the BBC to 'cream off' the best loudspeakers for itself."

We may be permitted to note here for all the meter readers of the world, that the final question of acceptability for a loudspeaker within the BBC is settled by a listening test, and not by a committee—but by one, presumably well-trained listener.—E.T.D.

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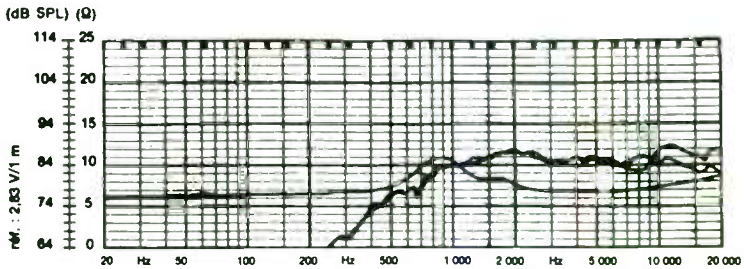

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THE BEER BUDGET WINDOW RATTLER

BY BILL SCHWEFEL

Recently a co-worker, Tom, asked me for speaker system advice. "What speaker would you purchase for roughly $500 a pair?" he asked. I responded that all speakers, regardless of price, involve compromises, and I would much rather build my own compromises than purchase them from someone else.

As we discussed this over the next two weeks, I agreed to design and build the system, and Tom agreed to pay for all the parts. The speaker essentially became my guinea pig.

BASIC DESIGN. I started with a standard three-way design: a 1" dome tweeter, a 2" dome midrange and a 12" woofer. After discussing the system with Tom, I rejected the idea. The cost was low, but it offered no advantage over most commercially available three-way systems in his price range.

Power was the major problem. Tom would be using the system exclusively with compact discs (no turntable) driven by a 60–100W integrated amplifier. He wanted to play the system at fairly high levels with good low-frequency extension and power.

After thinking it over, I settled on a double 12" woofer arrangement. With two Madisound 12204 DVCs in a large, vented cabinet, the BOXRESPONSE program[1] showed that 113dB was possible at 25Hz (*Fig. 1*). The only drawback was size. I roughed out the cabinet, and Tom took the drawing home to show his wife. She seemed to have no problem with an 11-cubic-foot cabinet, as long as it looked nice and could be placed alongside their large oak entertainment center.

PHOTO 1: The finished speakers with the left channel grilles removed. Note the grille frame details and cone doping.

Going over the plan, I noticed that, in terms of baffle board speaker placement, a D'Appolito configuration[2] was only an additional midrange away. I therefore raised the cabinet height to accommodate driver placement and cleared the plans with Tom and his wife.

Since Tom lived in a relatively old house with single-pane windows, I named the system the Beer Budget Window Rattler. I advised him to do a little caulking prior to initial power-up.

DRIVER SELECTION. I selected the tweeter and midrange drivers based on cost, effective sensitivity and sound quality. I preferred the sound of soft fabric domes as opposed to hard domes or cone units. I steered clear of 4–6" cone midrange units because of my previous ex-

ABOUT THE AUTHOR

Bill Schwefel, an economist with the United States Department of Labor, graduated from the University of Wisconsin in 1979. He has been an audio electronics hobbyist since the early '70s.

FREQ. IN HZ	RELATIVE RESPONSE IN DB	MAXIMUM POWER INPUT IN WATTS	MAXIMUM INFINITE BAFFLE RESPONSE IN DB
5	-55.23	10.29	47.66
10	-32.82	19.26	72.79
15	-20.15	43.17	88.96
20	-11.31	143.01	103.01
25	-5.36	400.00	113.43
30	-2.45	400.00	116.34
35	-1.46	327.45	116.45
40	-1.15	323.17	116.71
50	-.92	400.00	117.86
60	-.77	400.00	118.02
80	-.53	400.00	118.26
100	-.38	400.00	118.41
150	-.19	400.00	118.60
200	-.11	400.00	118.68

```
PARAMETER LISTING AS FOLLOWS:

Fs: 22          Qes: .36          Qms: 2.12
Vas measured in cubic feet:          14.5
Driver DC resistance:                 3.4
Driver Power rating in watts:       400.00
X Max measured in inches:              .24
Piston diameter in inches:           14.8
Box leakage loss (QL):                7
Box tuning ratio (H) (Fb/Fs):         1.18
Alpha (Vas/Vb):                       1.81
System order: 4 (4th order, vented box)
```

FIGURE 1: Projected BOXRESPONSE output. Note that the parameters are for a pair of Madisound 12204 DVCs wired in series/parallel.

perience with upper midrange glare problems.[3]

I settled on a 1″ soft dome tweeter from Peerless, the SR-10 4Ω version. I didn't like the small amount of horn loading, but I needed a few extra decibels for sensitivity matching. For the midrange I chose a pair of Philips 02110/SQ8 2″ soft dome units. I had listened to these speakers in other systems, and I liked the sound. At roughly $40 per pair, the cost was right, too.

I selected the woofers on the basis of BOXRESPONSE tests and Thiele/Small parameter runs on my "antique" Radio Shack TRS-80 Model I computer. I used the BASIC computer program written by Robert L. Caudle and published as an appendix in David Weems's *Designing, Building, & Testing Your Own Speaker System With Projects*.[4] The frequency response graph generated by this program is shown in *Fig. 2*.

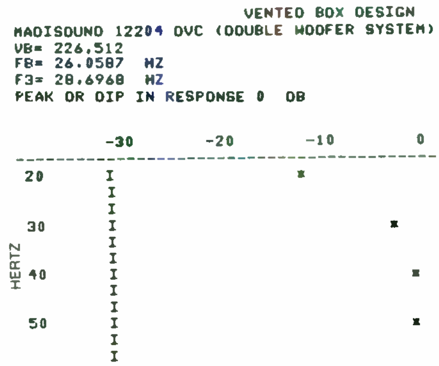

FIGURE 2: Caudle low-frequency response graph. The −3dB point is reached at 28Hz.

CROSSOVER NETWORK. I designed the crossover using Robert Bullock's equations[5] and then modified the values and sensitivities slightly using Ralph Gonzalez' LMP program.[6] The final crossover is shown in *Fig. 3*. The LMP output and parameter listing are shown in *Figs. 4* and 5. The parameter listing shows all the assumptions I made regarding driver sensitivities and rolloff rates.

I chose Linkwitz-Riley second-order APCs for the entire system, with turnover frequencies of 700Hz and 2.7kHz. The crossover spread is on the low side, roughly 4, but acceptable. I set the upper crossover at 2.7kHz because I could not reduce driver spacing below 9 inches (center-to-center distance between the midrange pair), and I did not want to cut the midrange or tweeter flanges. I set the lower crossover at 700Hz because my tests indicated that the Philips drivers began running out of steam at approximately 400Hz.

HEAVY STUFF. I realize proper implementation of a D'Appolito array requires odd-order acoustical slopes (electrical

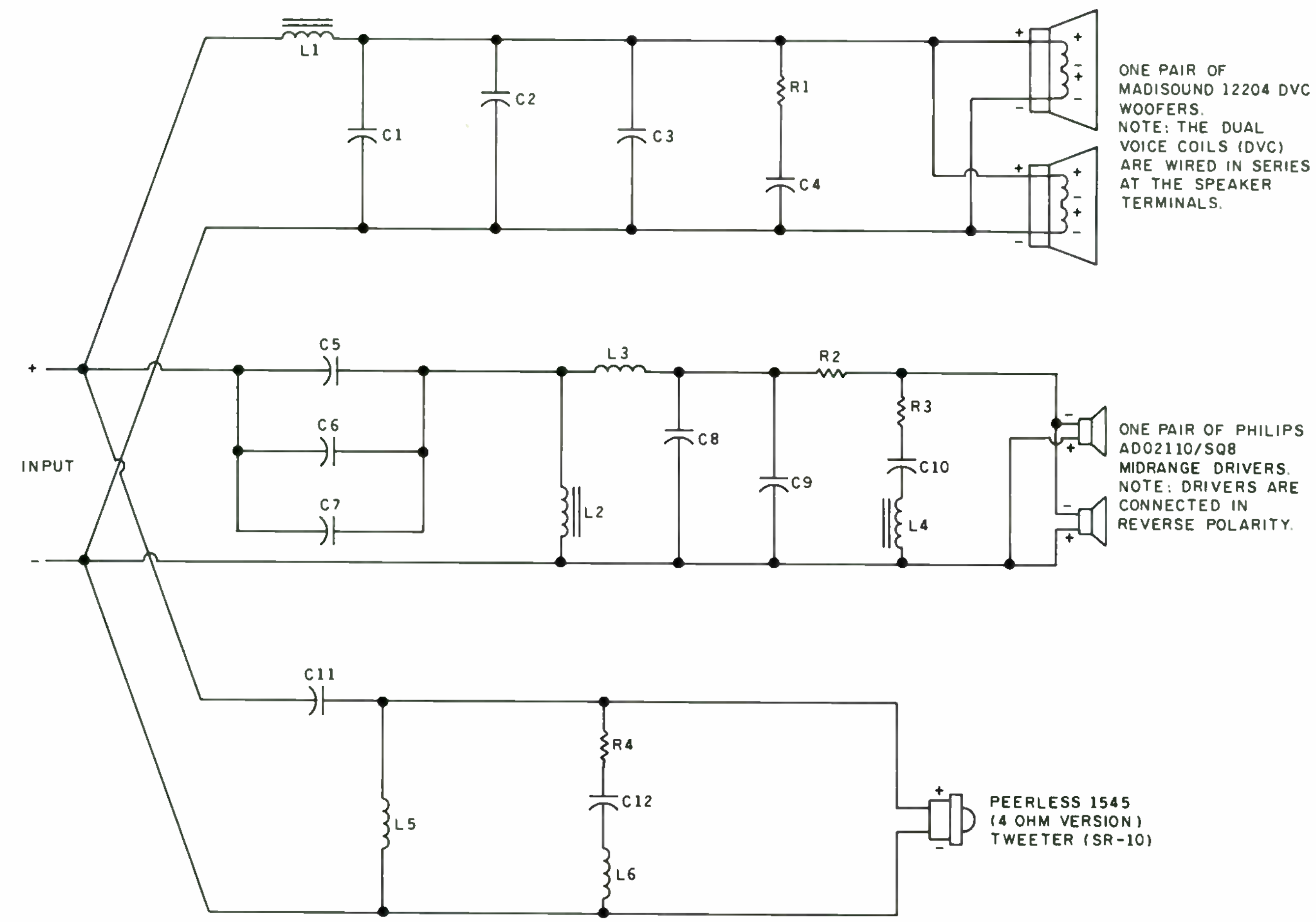

FIGURE 3: Crossover schematic diagram (one channel shown).

plus driver rolloffs), but my total cost so far was more than $500, and I needed to cut corners somewhere. Moreover, I could not produce an acceptable LMP model using 18dB/octave electrical components.

The drivers in my design are acoustically flat for approximately one octave

Continued on page 14

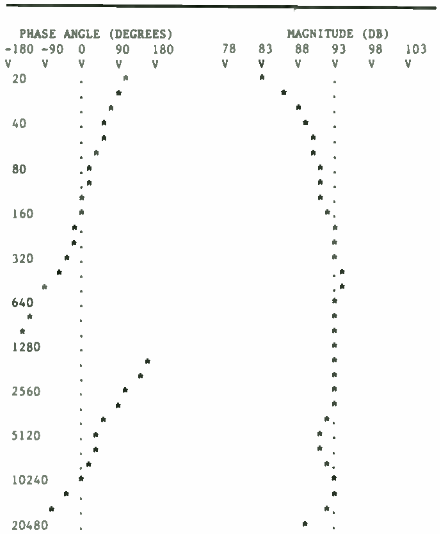

FIGURE 4: LMP output.

CROSSOVER PARTS LIST (ONE CHANNEL ONLY)

PART	DESCRIPTION	SOURCE
Resistors		
R1	6.7Ω, 20W [50Ω, 10W (#271-133) and 8Ω, 20W (#271-120) in parallel]	Radio Shack
R2	2Ω, 30W (two 4Ω, 15W in parallel)	Madisound
R3	8Ω, 20W (#271-120) **	Radio Shack
R4	5Ω, 20W [two 10Ω, 10W (#271-132) in parallel]	Radio Shack
Capacitors		
C1, 5	22.00μF NP (100V)*	Madisound
C2	3.30μF CPP (250V)	Madisound
C3, 9	1.00μF CPP (250V)	Madisound
C4	52.00μF NP (100V)* (22μF and 31μF in parallel)	Madisound
C6	6.80μF Mylar (100V)	Madisound
C7	4.00μF CPP (250V)	Madisound
C8	2.70μF Mylar (100V)	Madisound
C10	70.00μF NP (100V)* (40μF and 31μF in parallel)	Madisound
C11	6.00μF CPP (250V)	Madisound
C12	42.00μF NP (100V)* (12μF and 31μF in parallel)	Madisound
Inductors		
L1	2.00mH Sledgehammer (DCR 0.16)	Madisound
L2	3.00mH Sledgehammer (DCR 0.20)	Madisound
L3	0.47mH Perfect Lay (DCR 0.13)	Madisound
L4	2.50mH iron core (DCR 0.30) **	Junk Box
L5	0.68mH Perfect Lay (DCR 0.17)	Madisound
L6	0.80mH air core (DCR 0.45)	Madisound

CPP = Chateauroux polypropylene
* Electrolytic
** See text

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LOW FREQ ROLLOFF DAMPING RATIO:  .7
CORNER FREQ (HZ) OF DRIVER HIGH FREQ ROLLOFF:  1600
HIGH FREQ ROLLOFF DAMPING RATIO:  .5
ORDER OF HIGH FREQ ROLLOFF:  2
POLARITY INVERSION (Y OR N): N
SENSITIVITY (DB):  90
DEPTH DISPLACEMENT (INCHES): -2
FREQUENCY OF RESPONSE STEP:  950
HEIGHT OF RESPONSE STEP:  6

IDENTIFICATION NUMBER OF CROSSOVER:  5
VALUE OF COMPONENT K 0 :  5.5
VALUE OF COMPONENT K 1 :  .0000263
VALUE OF COMPONENT K 2 :  .002
VALUE OF COMPONENT K 3 : -1

                    DRIVER NUMBER:  2

CORNER FREQ (HZ) OF DRIVER LOW FREQ ROLLOFF:  450
LOW FREQ ROLLOFF DAMPING RATIO:  .7
CORNER FREQ (HZ) OF DRIVER HIGH FREQ ROLLOFF:  5000
HIGH FREQ ROLLOFF DAMPING RATIO:  .5
ORDER OF HIGH FREQ ROLLOFF:  2
POLARITY INVERSION (Y OR N): Y
SENSITIVITY (DB):  86
DEPTH DISPLACEMENT (INCHES):  0
FREQUENCY OF RESPONSE STEP:  2600
HEIGHT OF RESPONSE STEP:  6

IDENTIFICATION NUMBER OF CROSSOVER:  7
VALUE OF COMPONENT K 0 :  5
VALUE OF COMPONENT K 1 :  .0000037
VALUE OF COMPONENT K 2 :  .00047
VALUE OF COMPONENT K 3 :  .003
VALUE OF COMPONENT K 4 :  .0000328
VALUE OF COMPONENT K 5 : -1

                    DRIVER NUMBER:  3

CORNER FREQ (HZ) OF DRIVER LOW FREQ ROLLOFF:  1100
LOW FREQ ROLLOFF DAMPING RATIO:  .5
CORNER FREQ (HZ) OF DRIVER HIGH FREQ ROLLOFF:  15000
HIGH FREQ ROLLOFF DAMPING RATIO:  .5
ORDER OF HIGH FREQ ROLLOFF:  2
POLARITY INVERSION (Y OR N): N
SENSITIVITY (DB):  88
DEPTH DISPLACEMENT (INCHES):  0
FREQUENCY OF RESPONSE STEP:  3400
HEIGHT OF RESPONSE STEP:  6

IDENTIFICATION NUMBER OF CROSSOVER:  6
VALUE OF COMPONENT K 0 :  3
VALUE OF COMPONENT K 1 :  .00068
VALUE OF COMPONENT K 2 :  .000006
VALUE OF COMPONENT K 3 : -1
```

FIGURE 5: LMP parameter listing.

Continued from page 12

on either side of my turnover frequencies. Driver rolloffs then begin at a rate of approximately 12dB/octave. The actual acoustical rolloffs, with the crossover and impedance compensation networks in place, are roughly 12dB/octave for the first octave, changing rapidly to 24dB/octave thereafter.

My LMP modeling is not entirely accurate, since the program does not account for cancellation between driver pairs. In addition, the main vertical response lobe is probably narrower than that of a system with conventional driver placement using the same crossover. But my listening tests and crude frequency response measurements (the *Stereo Review* warble tone test record and the original Radio Shack sound level meter) showed that, with the speakers and listener placed in a 9′ equilateral triangle, a change in ear level from 30 to 40″ produced no change in sound. When I moved farther up or down, such as standing or sitting on the floor, I noticed a change in sound. Most of the change appeared to be due to the falling off-axis response of the tweeters (above 10kHz) rather than to lobing around the crossover frequencies, but I am not sure if I was hearing room response irregularities or changes resulting from lobing.

IMPEDANCE COMPENSATION. Without impedance compensation the crossover frequencies and acoustical rolloff rates will not follow theory. To determine the appropriate compensation, I used the equations published in Vance Dickason's *Loudspeaker Design Cookbook*.[8] I then used the constant-current method to measure impedance and, by trial and error, developed the networks outlined below.

For the woofers I used a standard Zobel network shunted across the woofer pair. The Zobel is shunted across four voice coils; I did not treat the voice coils separately. I made my measurements with the woofers wired exactly as they are connected in the final system but without the crossover components. The final values of 6.7Ω and 52μF result in a fairly constant impedance of 5.5Ω from 100Hz to 5kHz.

For the midranges (again, wired exactly as in the final system but without the crossover components) I used a series notch filter shunted across the pair. This network flattens the impedance peak at driver resonance. I measured a resonance (F_S) of 400Hz, not 340Hz as the manufacturer states. This peak is quite broad, and I adjusted the Q of my notch filter to match the peak. Final values are 8Ω, 70μF, and 2.5μH. I used an iron-core inductor because I happened to have a pair in my junk box. It would probably be better to substitute a standard air-core inductor here and then reduce the value of the 8Ω resistor to approximately 7Ω.

The midrange drivers did not show a rising impedance as a result of voice coil inductance but remained fairly flat approximately two octaves beyond my crossover point of 2.7kHz. For this reason I eliminated the usual Zobel network across them.

FREQ. IN HZ	RELATIVE RESPONSE IN DB	MAXIMUM POWER INPUT IN WATTS	MAXIMUM INFINITE BAFFLE RESPONSE IN DB
5	-54.86	8.5	48.36
10	-32.21	15.46	73.60
15	-19.19	34.09	90.06
20	-9.93	128.24	105.07
25	-4.04	400.00	115.90
30	-1.85	335.61	117.33
35	-1.40	218.91	115.93
40	-1.29	236.15	116.36
50	-1.15	368.72	118.44
60	-.98	400.00	118.96
80	-.68	400.00	119.26
100	-.48	400.00	119.46
150	-.24	400.00	119.70
200	-.14	400.00	119.80

```
PARAMETER LISTING AS FOLLOWS:

Fs: 22.5        Qes: .314        Qms: 7.615
Vas measured in cubic feet:       15.429
Driver DC resistance:              3.6
Driver Power rating in watts:   400.00
X Max measured in inches:           .24
Piston diameter in inches:        14.8
Box leakage loss (QL):            96.8
Box tuning ratio (H) (Fb/Fs):      1.11
Alpha (Vas/Vb):                    1.928
System order: 4 (4th order, vented box)
```

FIGURE 6: Actual BOXRESPONSE output. Parameters were measured after cone doping. Data is the average for two pairs of Madisound 12204 DVCs.

I gave the tweeter a series notch filter shunted across its terminals. This filter knocks out a rather sharp impedance peak at 1kHz (the manufacturer shows an F_S of 1.1kHz). Final values are 5Ω, 42μF, and 0.8μH. If you use a different tweeter, this filter should be either modified or removed.

GENERAL IMPEDANCE. Since my speaker is a 4Ω system, I took a little extra time to analyze the general impedance, as seen by the amplifier terminals, of the final system (with the crossover). The input impedance is similar to that shown in *Fig. 6* of Robert Bullock's article in *SB* 4/87,[9] which analyzes the input impedance of various network topologies. Simply take the C-bandpass topology curve and move the minimums down from 8Ω to 3.5Ω. This is how my system measured.

In terms of actual performance, the output stage of my amplifiers (a pair of Southwest Technical Products 207As) became very warm after about two hours of very loud music (an average of 102dB at the listening position in a 9,000-cubic-foot room). When I pushed the system to 106dB, the output stage

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TEST EQUIPMENT

Generator	Heathkit IG-72 tube-type audio generator
Voltmeters	Radio Shack Digital VOM (#22-185) and Radio Shack analog multitester (#22-201)
SPL Meter	The original Radio Shack sound level meter
Record	The *Stereo Review* warble tone test record purchased at Radio Shack 15 years ago
Test Amp	Realistic STA-45B stereo receiver

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Fast Reply #GE283

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became hot and the tweeters sounded compressed. You shouldn't play the system this high, or you risk losing your hearing, the tweeter voice coils and your power amplifier output stage.

LMP MODELING. In listening tests and crude frequency response measurements, the speakers seemed to follow the model except below approximately 500Hz, where I heard a slight heavy sound and my measurements indicated the woofers were about 3dB higher in output. I suspect room reflections were causing the increased output, or my assumption about the characteristic sensitivity of the Madisound woofer pair was incorrect (I had assumed 96dB with 2.83V at 1M). My assumption of a 6dB response step at 950Hz also might have been in error.

In any case, I needed to correct the problem. I chose the cone-doping technique as a solution. Let me explain.

When I took the Madisound woofers out of the shipping container, they had a free-air resonance (F_S) of 28Hz and a Q_{TS} of roughly 0.45. I made this measurement with the voice coils connected in series to form an 8Ω woofer. I then broke in each woofer by applying a 22Hz sine wave at a moderate power level (cone excursion of ½" peak to peak) for about four hours each. F_S remained at 28Hz for all four woofers after this test. I then increased the power level to produce a 1" peak-to-peak cone excursion and drove the woofers for another four hours each. F_S then dropped to 21-23Hz for the woofers, and Q_{TS} dropped to 0.27-0.29.

When I returned to the test bench two hours later, all four woofers had an F_S of 26Hz. I connected the woofers as pairs, wired exactly as shown in the schematic diagram (without the crossover components), and measured the same F_S and Q_{TS} parameters.

Apparently the cooling of the voice coils and spiders was causing a shift in my measurements. In any case, the manufacturer specified an F_S of 22Hz and a Q_{TS} of 0.316, so I decided to play the speakers in my system for a while before making any adjustments.

When it was time to finish the speakers, I pulled all the drivers and placed the woofers on my test bench again. I had played the woofers daily at fairly high levels for about one month. I applied a 22Hz sine wave to all the woofers with the power level set at a ½" peak-to-peak excursion. This served as a warm-up period to simulate actual use. I then measured an F_S of 26Hz and a Q_{TS} of 0.27-0.29.

SILICONE RESCUE. Since I needed to drop the sensitivity of the woofers anyway, I decided to dope each one with 100% silicone sealer. I applied a ¼" bead of silicone at the junction of the dust cap and the cone and then smoothed the bead with my finger until the inverted dust cap formed a continuous line with the cone. With the speakers still connected to the test equipment, I slowly applied about ½" of silicone to the center of the cones and watched F_S drop to 22Hz for each woofer. I smoothed the silicone with my finger to prevent high-frequency response aberrations.

After doping, I measured the woofers as pairs. F_S was now 22-23Hz and Q_{TS} averaged 0.301. I was expecting a higher Q_{TS} measurement, but for some reason the electrical portion (Q_{ES}) remained low (0.314) after the doping. The mechanical portion (Q_{MS}) skyrocketed to 7.615. See *Fig. 6* for the new BOXRESPONSE output.

As it turns out, my slightly high F_S measurements were a blessing in disguise. The cone doping dropped the characteristic sensitivity of the woofer pair by about 3dB, resulting in a much better blend with the midrange drivers. Moreover, low-frequency extension and power response seemed greatly improved.

CONSTRUCTION. These speakers are big (*Photo 1*) and building them was a challenge. Not since the early 1970s, when my brother and I put together a pair of Altec-Lansing A-7s, had I attempted anything this large. As I recall, the Altec-Lansing speakers were roughly 14 cubic feet with a large 500Hz horn on top. The Beer Budget speakers are roughly 9 cubic feet internally and 11 cubic feet externally—not quite the size of the Altecs but pretty close.

Don't be intimidated by the size, and don't expect to get the system up and running immediately. Break the project down into several steps. Once the cabinets are constructed, try to keep them in one spot; moving them around is not fun.

I used ¾" oak veneer plywood for the sides, top and bottom. I purchased two

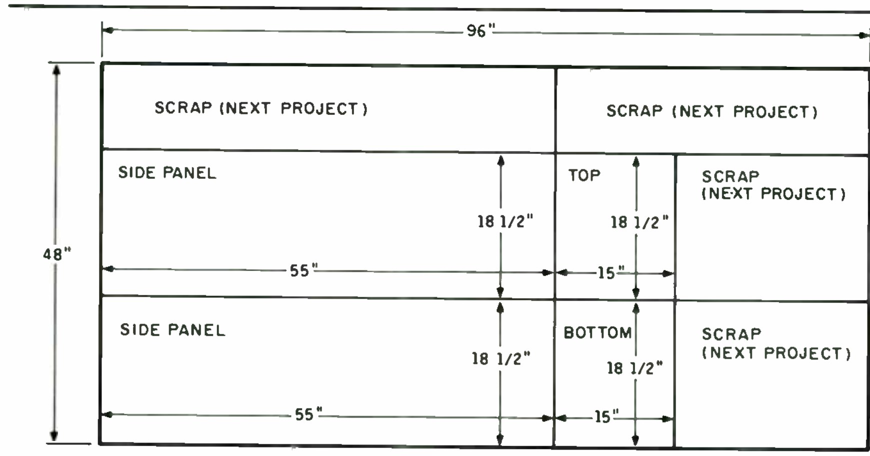

FIGURE 7: Cutting guide for 4 by 8' sheet of ¾" oak plywood (all dimensions in inches).

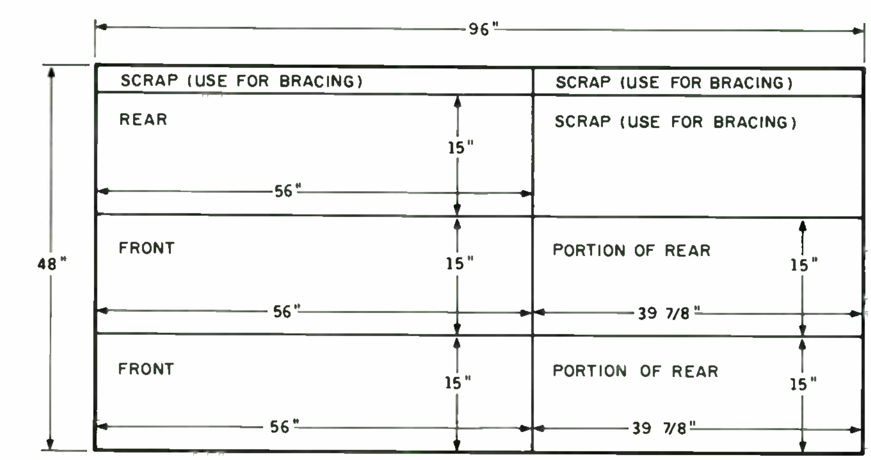

FIGURE 8: Cutting guide for 4 by 8' sheet of ¾" high-density particle board (all dimensions in inches).

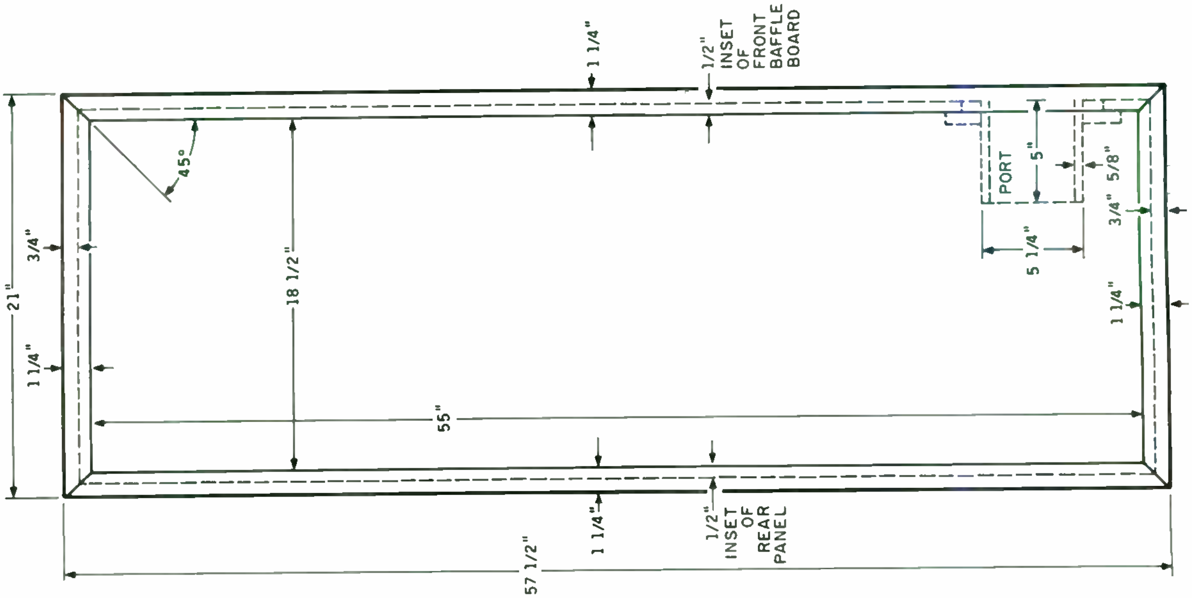

FIGURE 9: Side view (all dimensions in inches).

4 by 8′ sheets ($45 each) at my local lumberyard, where they cut the sides, tops and bottoms on an easel (a large industrial saw used for breaking down 4 by 8′ sheets of plywood or particle board—my lumberyard did the job for about 50 cents a cut). The cutting guide is shown in *Fig. 7*. I had the operator cut the panels slightly oversize and then ripped them to their exact size on my table saw.

I purchased one sheet of ¾″ high-density particle board ($16) for the front and back panels. These also were cut on an easel by an experienced operator. The cutting guide is shown in *Fig. 8*. Note that one back panel must be assembled by gluing two shorter pieces together. If you don't want to do this, you must purchase an extra 4 by 8′ sheet of ¾″ high-density particle board.

I also purchased approximately 75 feet of ¾ by 1¼″ oak facing. You will need eight pieces at least 60″ long, eight pieces at least 22″ long and eight pieces at least 16″ long. You will also need several 1′ long pieces as scrap during the mitering process. Take careful note of the wood grain, consistency and warpage.

MATERIALS LIST (BOTH SPEAKERS)

QTY	DESCRIPTION	SOURCE
Speakers		
4	Madisound 12204 DVC woofers	Madisound
4	Philips AD02110/SQ8 midrange drivers	Madisound
2	Peerless 1545 (4Ω version) (SR-10) tweeters	Madisound
Lumber		
2	4 by 8′ sheets of ¾″ oak plywood	
1	4 by 8′ sheet of ¾″ particle board (the highest density you can find)	
8	¾ by 1¼ by 60″ oak facing	
8	¾ by 1¼ by 22″ oak facing	
8	¾ by 1¼ by 16″ oak facing	
2	½ by ¾ by 16″ oak facing	
Note: The actual length of the oak facing is trimmed to size during construction.		
3	1 by 12 by 36″ high-density particle board stair treads (rear panel battens)	
3	2 by 4′ sheets of ¼″ Masonite (grilles)	
Miscellaneous		
2	Madisound D-Cups (gold-plated binding posts)	Madisound
1	Quart of borosilicate ceramic coating	Audio Concepts
1	Quart of flat black paint (front and back panels)	Hardware store
1	Quart of linseed oil (finishing)	Hardware store
1	Gallon of yellow carpenter's glue	Hardware store
1	Tube of black 100% silicone sealer (cone doping)	Hardware store
1	Tube of clear 100% silicone sealer (crossover mounts)	Hardware store
4	Five-lug tie points (#274-688)	Radio Shack
1	Yard of black felt (grille damping)	Fabric store
2	Yards of open-weave black grille cloth	Fabric store
24	½″ round Velcro™ fasteners (grilles)	Hardware store
44	#8, 2″ wood screws (back panels)	Hardware store
48	#8, 1½″ sheet metal screws (low/mid mounts)	Hardware store
8	#6, 1½″ sheet metal screws (tweeter mounts)	Hardware store
1	Bag of ¾ by ⅜″ closed-cell foam weather stripping (woofer mounting seals)	Hardware store
2	Bags of ⅜ by ⅜″ closed-cell foam weather stripping (rear panel and port seals)	Hardware store
1	50′ roll of #16 zip cord	Hardware store

MITER THAT JOINT. You can do the miter cuts on the facing for the large side panels easily but not quickly. Because the large panels are not perfectly square, you will need to follow a very slow procedure for getting the miters precise. Use the scrap oak facing to set up the table saw, then cut the long pieces. A power miter box is probably the best tool for this operation, but I used my table saw.

If the miter cuts are too much of a problem, cut the oak facing using simple butt joints. A butt joint results in a small amount of exposed end grain, but it probably looks better than the gaps that can sometimes ruin the appearance of a miter joint.

Using yellow carpenter's glue and six edge clamps, glue the oak facing to the side panels (*Fig. 9*). Then glue the facing to the top and bottom (*Fig. 10*). The facing will tend to squiggle unpredictably as you tighten the edge clamps. It should be flush with or stick out a little from the

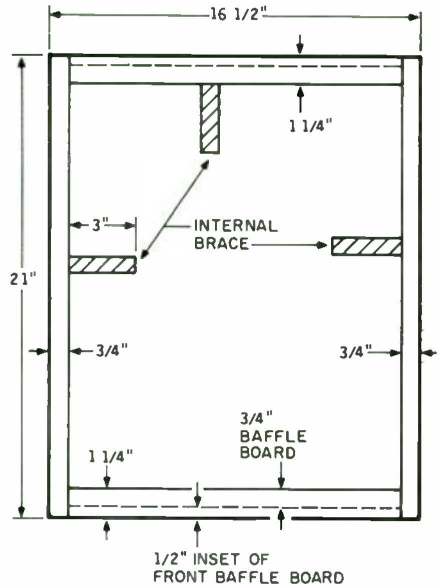

FIGURE 10: Top view (all dimensions in inches).

veneer so you don't sand through the veneer during the finishing process.

Keep at least two very wet, clean rags handy during the gluing process. Wipe excess glue off the oak immediately, before it has a chance to soak into the veneer. If the glue soaks in, it will interfere with the staining or oiling process.

Use small blocks of wood, glued to the end of the edge clamps, to avoid denting the veneer or oak facing. You will find it much easier to finish the project if there are no large dents. Remove small scratches with a wet clean rag.

BOX ASSEMBLY. Use two picture frame clamps to set up a perfect 90° angle, then bar-clamp the panels together with yellow carpenter's glue. This method provides perfect alignment of panels, ensures a 90° angle at each corner, and most importantly, breaks the task into several easy-to-complete steps.

Trim the front and back panels to the exact size using your router and a ⅜" carbide notching bit. Clamp a straight piece of oak facing near the end of the panel to serve as a guide for the router. Make several passes with the router, cutting a little deeper each time. Do not cross-cut this large panel on your table saw unless you have a special panel cutter like the one used by Norm Abram in his book *The New Yankee Workshop.*[10]

BAFFLE AND GRILLES. Cut the driver holes with a jigsaw (*Fig. 11*). Use these cutouts to trace and then cut the initial line-up holes for the grille cloth frames. Cut these frames from ¼" Masonite with exterior dimensions slightly smaller than the front panel.

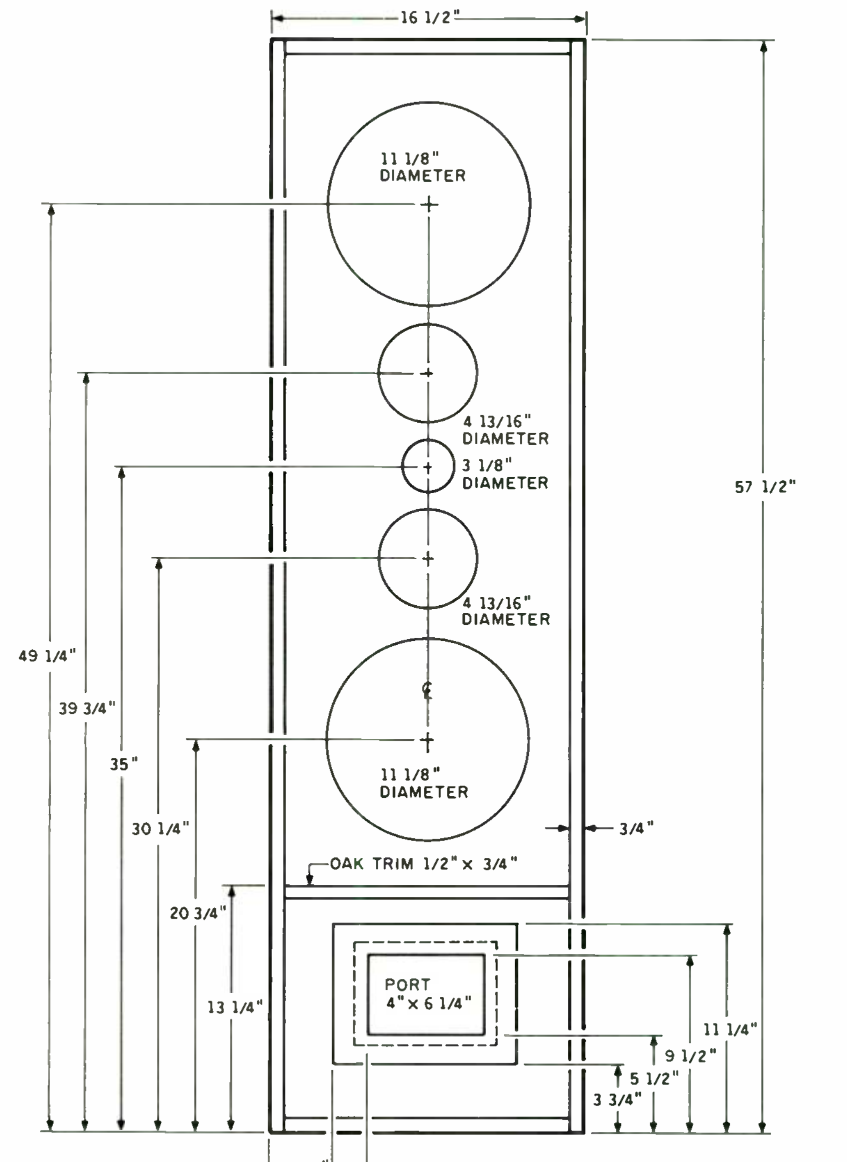

FIGURE 11: Front view (all dimensions in inches).

I have broken the grille into two parts. The upper portion covers the speakers, and the lower part covers the port. The grilles are separated by a small piece of oak trim. Not only did I think the speaker would look better with two grilles, but also using a second, smaller grille on the port allows the fabric to be stretched loosely, thus avoiding buzzing.

Mark the upper grille frame again by setting the speakers into the line-up holes and tracing the perimeter of each onto the frame. Then cut the holes again with your jigsaw, and cut a straight line between the midrange driver cutouts. For the lower grille, simply cut the hole a little larger than the port.

Finish the grilles by gluing a thin layer of black felt to the face of each one and then stretching and gluing the grille cloth over the felt. This is important because my LMP modeling assumes that the step response relates to the size of the driver flanges and not to the size of the baffle board. If you do not want to use my grilles, you must cover the entire face of the baffle board with some acoustically absorbent material to keep the step response near my target values. I think the speaker sounds better when damped in this manner, but my suggestion of no grilles was rejected by Tom and his wife.

CLEATS AND BRACING. With the box shells formed, glue a total of sixteen evenly spaced ¾ by 1½" oak cleats 1¼" deep into the front of each box (this results in a ½" inset of the front baffle board). Apply a liberal amount of yellow glue to all appropriate surfaces and drop

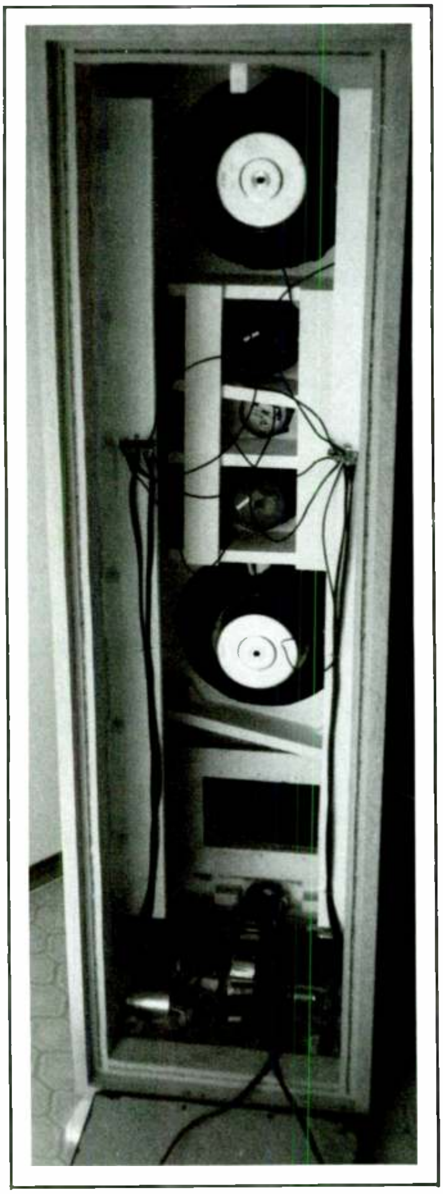

PHOTO 2: Rear view of speaker with the back panel removed. Note the double run of weather stripping used on the rear battens.

the front panel in place. Bar clamps and weights will hold the panel firmly until the glue is set. I added another sixteen ¾ by 1½″ oak cleats so a total of 32 cleats hold the front and side panels together. I did not use a continuous strip of oak facing here because of the cost.

Then install a 3 by 48″ brace on each side panel, cut from ⅝″ high-density particle board. I made special clamps for this operation with jaws that extend 12″ past the adjustment. This allowed me to use carpenter's glue instead of screws or epoxy.

Put another 3 by 15″ brace on the top, then install the 1 by 2″ rear battens 1¼″ deep into the cabinet (this results in a ½″ inset of the rear panel). Use several 3 by 12″ braces to support the weak spots on the baffle board. Then install two more braces across the original braces to keep the entire assembly from ringing when thumped (*Photo 2*).

Install a double run of ⅜ by ⅜″ weather stripping in the rear battens. Space the double run so the wood screws used to secure the rear panel fall in between the weather stripping. This provides a double seal and helps cut down on air leaks.

CROSSOVER ASSEMBLY. Install the crossover parts on a piece of scrap wood and glue it to the bottom of the box. Wire all parts point to point, with solder lugs placed as needed (*Photo 3*). Keep the inductors as far apart as possible and group the other parts so as to minimize interconnect distances. My brother and an audiophile friend stopped by during my construction and noted they didn't approve of "all that 16-gauge zip cord" I was using for connections. I see it as one compromise among many.

After the crossover and wiring is done, cut a 3″ hole in the back panel for the Madisound D-cups. I cut this hole 16″ from the floor, the same height as the wall outlets in my house. Glue another 3″ brace onto the inside of the back panel. This brace should be roughly 36″ long, extending from the D-cup to the top of the speaker.

REFERENCE AND ASSOCIATED PLAYBACK EQUIPMENT

Cartridge	Ortofon Digi-Track (My Grado units have a better sound but I broke the needles.)
Turntable	Kenwood KD-500 (modified 3 times)
Tonearm	Formula 4 (modified 4 times)
CD Player	Sony CDP 350 (stock)
Preamp	LAST-PAS (with the Vorhis phono and line stages, heaters, and power supply)
Power Amp I	Dynaco ST-70 (modified 3 times; triode output stage; drives a pair of Dynaudio D-28af tweeters)
Power Amp II	Dynaco ST-70 (modified 3 times; triode output stage; drives a pair of Dynaudio 17M75 midrange drivers)
Power Amp IIIa	Two SWTP Tiger 0.01 amps (60W each) with bass equalization circuits (These amps drive a pair of Peerless 10″ woofers mounted in 60-liter closed boxes.)
Power Amp IIIb	The same SWTP amps with the bass circuit removed (These amps were used to drive the Beer Budget system.)

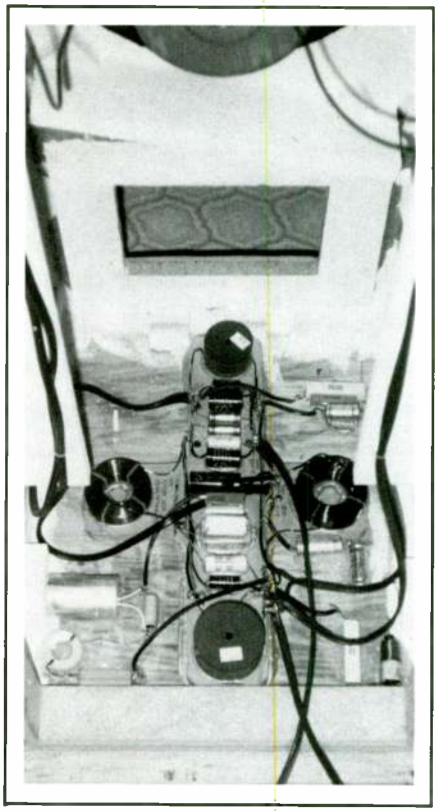

PHOTO 3: Crossover parts placement. Note that all wiring has been arranged to keep inductor spacing to a maximum.

Solder all internal connections (no crimp-type connectors). I used a 25W pencil and heatsinks to solder the driver lugs and D-cup terminals. Then I used an 80W pencil to solder the other connections, using a heatsink in places where the joint was close to a component.

PORT PROBLEMS. I calculated the port length and area using equations published in *The Loudspeaker Design Cookbook*.[11] I then compared my results against the charts published by David Weems[12] and the equations used by Richard Brush.[13] All these sources indicate a vent length of approximately 8″ for a box with a net internal volume of 8 cubic feet, a port of 25 square inches, and an F_B target of 25Hz. I ended up trimming the port down to a length of 5½″ to meet this target. (The actual port length measures 5″ but is effectively 5½″ with the grille cloth in place.)

I constructed the port so it could be taken in and out of the box, just like a driver. I then made a closed-box plug which could be substituted for the port. I wanted to experiment with closed-box versus ported-box sound.

The experiment was a failure. The closed-box system sounded bass shy below 50Hz without the power-handling ability of the vented system. I spent a

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great deal of time constructing and tuning this removable port, and I would advise simply substituting a pair of 4″ (inside diameter) round ports, both cut to a 5″ length. This equals the same 25-square-inch area of my single removable port.

DAMPING COMPOUND. Coat the driver mounting holes and all internal braces with two coats of borosilicate ceramic coating. Paint about 1″ around each mounting hole, front and rear of the baffle board. This way, the drivers are mounted in a bath of coating. Line the inside of the box with 1 to 2″ of fiberglass, then screw the back into place (after predrilling new holes) with #8 2″ wood screws spaced about 6″ apart.

FINISHING. I began construction in May, and by the middle of August I was suffering from a severe case of speaker building burnout. I couldn't lift the boxes anymore, so I had Tom stop by to help with the finishing. We carried the speakers into the basement and removed all the drivers. After sanding the sides smooth with a power sander loaded with #100 grit sandpaper, I rounded all the

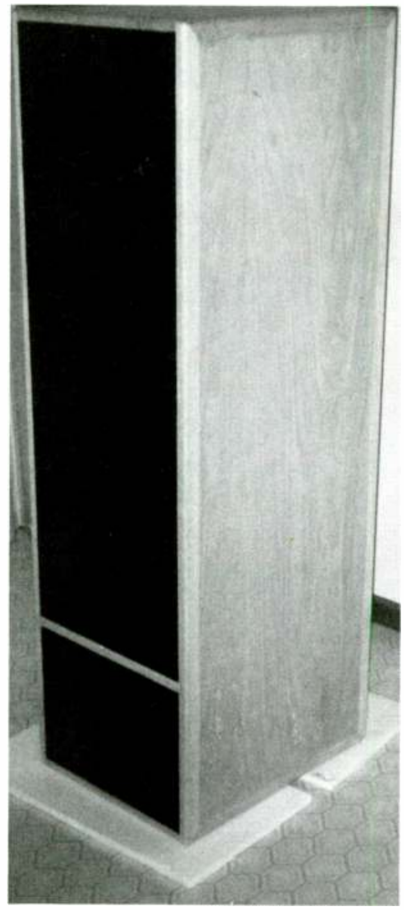

PHOTO 4: The finished speaker prior to staining. Note that the box is almost 2′ deep.

edges with a router and a carbide-tipped ⅜″ round-over bit with a ball bearing guide. Do not use an inexpensive high-speed steel round-over bit, as it will burn the oak facing and ruin the finish.

After routing, we power sanded the cabinet with #150 grit paper and then again with #220 grit paper. The result was a fine piece of furniture ready for stain or oil (*Photo 4*).

SOUND. Sonically, the system has two weaknesses. The first occurs in the frequency range from 100Hz to 1kHz. I refer to this problem as a slight grey fog. The lower end of the human voice tends to be less crisp and detailed than it is with my Dynaudio 17M75 drivers (see Reference and Associated Playback Equipment). I accepted this design compromise when I decided to use dome midrange units and a crossover point of 700Hz. My Dynaudio system uses a first-order crossover at 100Hz.

The other weakness involves the tweeter. Compared to my Dynaudio D-28af's, the Peerless tweeters lack some of the "air" on the top end, resulting probably from the small amount of horn loading, which causes the response to fall above 15kHz. Also, when the D-28af's are played at high levels, they provide a better sense of dynamics.

On the positive side, the Beer Budget system images very well. It locks on target and tells you exactly where the vocalist or instrument is located (at least on good recordings). This speaker does a much better job in this regard than my Dynaudio system. This same imaging quality also seems to make the Beer Budget speakers extremely transparent. In comparison, my Dynaudio system sounds cold and analytical.

In low-frequency extension and power (below 100Hz), the Beer Budget system is awesome. It goes right down to 25Hz with authority and sets almost everything in my house into sympathetic vibration. I had to place my turntable on a 4″ thick foam slab to keep the entire stereo system from oscillating.

CONCLUSION. If you want a labor intensive yet cost effective speaker, perhaps the Beer Budget Window Rattler is for you. I estimate the do-it-yourself construction cost at about $650. This can be dropped to about $550 if you use particle board and omit the grilles.

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CONTACT BASICS

BY MARC BACON

As most *Speaker Builder* readers know, gold-plated contacts are often portrayed as sonically superior, as are esoteric audio cables. You may consider spending extra dollars for connectors just as you do for spikes, large-gauge inductors, and polypropylene capacitors, yet you don't know why, other than the fact gold "doesn't corrode and conducts electricity well." What follows (some of which is taken from an article in *Machine Design*, April 6, 1989) is intended to demystify the situation.

Contact surface interfaces, while macroscopically smooth, typically have microscopic peaks and valleys, with only the peaks touching each other (*Fig. 1*). Pressure at the contact areas flattens the peaks according to Hertz' relationship,[1] assuming approximately spherical contact points:

$a = 0.721(P \times K_D \times C_E)^{1/3}$, where

a = contact area width/2

P = applied pressure to each contact point

K_D = geometric constant relating to the geometry of the contact area

C_E = material constant related to the modulus of elasticity and Poisson's ratio for the contacting bodies.

These contact areas often constitute as little as 1% of the apparent contact area. Two series resistances result from this in addition to the bulk resistance of the contacts, namely:

1. Constriction resistance due to a small contact area.

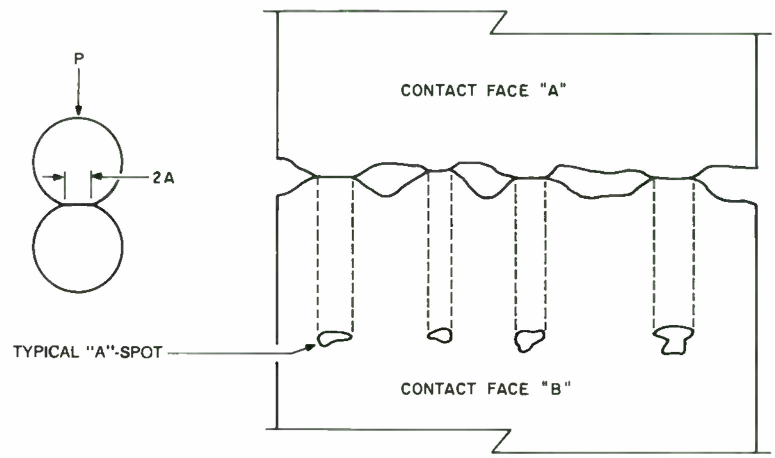

FIGURE 1: Typical geometry of "smooth" contact surfaces. Note: A-spots are far smaller than contact faces.

2. Contact resistance due to surface oxides or contaminants.

Also, contacts have a nonlinear term caused by capacitance of adjacent contact surfaces which don't touch due to surface irregularities and oxides. Normally, this element is small enough to be ignored, but corroded or poorly designed connectors may exhibit frequency-dependent impedance. The equivalent circuit for a simple contact is depicted in *Fig. 2*.

LOWERING RESISTANCE. High contact resistance at a speaker's input reduces overall system damping and results in power loss and contact heating. Poor internal contacts to a driver or crossover can cause selective degradation of performance with resulting frequency imbalance as well. This is typically caused by using tin crimp connectors instead of well-made solder joints.

To lower contact resistance, manufacturers design better contacts by:

1. Increasing true contact area by increasing the deformation per the above Hertzian equation by using:

a. Better finishes for more contact points,

b. More resilient alloys which deform readily, and

c. Greater contact pressures per unit area.

2. Using more noble metals which develop less surface oxides.

3. Using metals which have lower bulk resistance, i.e., greater conductivity.

The following is a list of most often used contact materials, from least to most suitable for loudspeakers, based on the above factors: nickel, brass, tin and tin/lead compounds, copper and gold. Typical contact resistances can range from 0.002Ω for a nearly perfect gold connector to 0.500Ω or more for a faulty, less noble contact. Note that while tin has a higher resistivity than brass, it is softer, giving it a larger contact area for a given pressure. Tin contacts are therefore the better choice.

OXIDES AND FRETTING. Tin is nat-

ABOUT THE AUTHOR

Marc Bacon, age 30, is married with two children. A US citizen with Canadian residency, he is bilingual and manager of factory operations for a pulp and paper industry equipment plant in Sherbrooke, Quebec, where he recently implemented CAD and FEA on PC workstations. He is a member of the American Welding Society and has dabbled in speaker building for eight years.

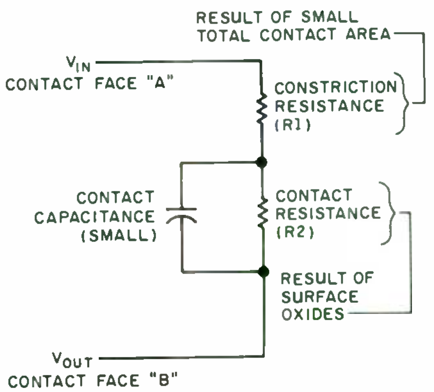

FIGURE 2: Equivalent circuit for a simple contact.

urally covered with a nonconductive oxide film, however, so connector design must provide for cracking off and displacing the oxide films to make a reliable contact.

Once mated, tin contacts remain reliable until opened and reoxidized. Reoxidation is the major reason tin contacts degrade. Vibrations of as little as 0.001" in amplitude (called "fretting") can form new oxide films on the newly exposed surfaces of the contact spots (*Fig. 3*). Differential thermal expansion caused by use of different materials in a contact may also cause fretting. Fretting causes insulating oxides to mix with the tin, building up in thickness as vibration persists and significantly increasing the total contact resistance. Black spots on tin contacts are a definite sign that such fretting has occurred. You can avoid fretting corrosion by applying a protective lubricant, designing more rigid connections, and using more noble, softer metals.

While rocking and twisting micromovements will build up oxides, long sliding movements may scrape them off and help delay the increase of contact resistance. Hence, if you can't afford to change your tin connectors immediately, unplug and replug them at regular intervals, and use a fine emery paper to remove any apparent deposits.

Loudspeakers, by nature, will induce movement, either through cable motion or cabinet vibrations. Thus, you should solder internal wiring to individual drivers and crossovers. Binding posts and lugs are similarly much better than coaxial connectors or spring clips due to their higher clamping pressures, larger contact areas and integrity in the presence of vibrations.

Contact lubricants either reduce friction or seal the oxygen from the contact area, or both. Friction-reducing lubricants are more often used on gold contacts, while sealing compounds are better for tin.

Gold is often considered the *ne plus ultra* of contact materials. Don't use pure gold for sliding contacts, however, because it sticks, galls and smears, although harder gold alloys may work quite well. Also, for high-pressure, semi-permanent connections outside corrosion environments, the performance of gold may be no better than that of cheaper materials.

SUBSTRATES. Gold plating contacts doesn't guarantee a film-free contact surface, because corrosion products may migrate from other surfaces to the contact and because base metal diffusion from the substrate may contaminate the contact face. Nickel substrates are helpful in reducing both effects. Porosity of gold plate which penetrates to the substrate will allow the substrate to corrode. Eventually corrosion products build up on the plated surfaces, increasing contact resistance. Copper substrates thus build up copper-sulfur products, while nickel substrates inactivate the pore by producing a thin oxide film at the pore's base. Porosity occurs in films less than 15 microinches thick, while films thicker than 50 microinches provide no benefit at increased cost. Another benefit of a nickel substrate is to provide a relatively hard base for the soft gold plate.

What is the practicality of all of this? Is the effect of poor connections audible?

Consider, for example, a woofer fed by a very poor connector with a 0.8Ω resistance. The woofer parameters are:

R_E	= 6.0Ω	
F_S	= 30Hz	
Q_{ES}	= 0.4	
Q_{MS}	= 4.5	
Q_{TS}	= 0.367	
V_{AS}	= 40 liters	
R_G	= Cable	0.05Ω
	+ Inductor loss	0.2Ω
	Total	0.25Ω

Resulting total woofer Q_{TS} values:

With perfect connector	Q_{TS} = 0.381
With poor connector	Q_{TS} = 0.426

In a closed-box system of 15 liters, this yields the following differences:

With perfect connector	system Q = 0.729
With poor connector	system Q = 0.815

The same woofer in a ported box of 30 liters tuned to 40Hz acts as follows:

With perfect connector	F_3	= 52.4Hz
	Response hump	= 0.36dB
With poor connector	F_3	= 48.1Hz
	Response hump	= 1.01dB

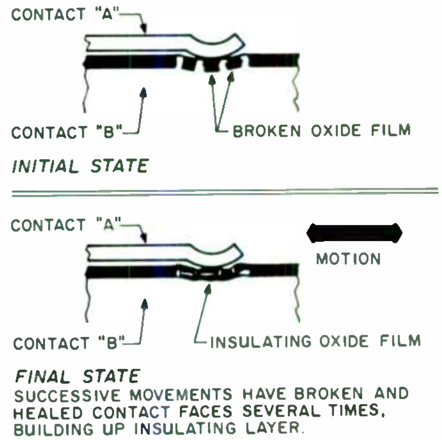

FIGURE 3: Contact fretting.

Although subtle, the degradation of bass transients is quite apparent from the above example. Plus, power loss is 11% across the connector, with a resulting 1.05dB lower sensitivity. This can substantially affect the subjective quality of a stereo pair. Thus, the extra dollars you spent for high-quality matched drivers can be marred by the poor connection quality.

In summary, remember these points when selecting esoteric connectors:

1. Choose connectors which provide high clamping pressures, freedom from vibration-induced movement, and relatively large overall contact areas.
2. The best known metallurgy at present for loudspeakers is a nickel substrate with a 15-50-microinch plate of gold or a gold alloy.
3. Use a contact lubricant compatible with the contact metallurgy.
4. Keep contacts clean and free from contaminants.

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If it's warranted, we will forward your query to the author or a Contributing Editor for a prompt reply.

THE MDT MINI-MONITOR

BY ROBBIE TUCKER

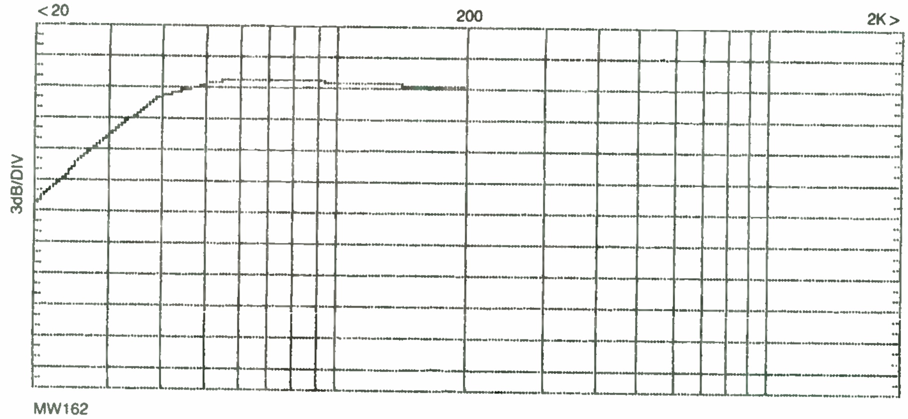
As a custom speaker builder, I design mostly for specific applications. The musical design technologies™ Mini-Monitor is no exception. For years I had been trying to convince my in-laws to replace their old console record player with a new stereo system. Both have a great appreciation for classical music and really seemed to enjoy listening to my system.

The problem was simple—space. My mother-in-law has packed her house with more antiques and knick-knacks than you can imagine. It's a gorgeous home, and I really don't blame her for not wanting electronic components scattered about. After much deliberation, she agreed to buy an integrated amp and CD player for my father-in-law's Christmas present, and I would build him a pair of speakers.

The electronics would go into an armoire with speakers on top. Although this was not a perfect spot for speakers (I argued to no avail for speaker stands), we had the start of a new system.

DESIGN. I had several drivers lying around from previous designs and decided to use one for this speaker. I wanted to keep the speaker small, have great midrange, and satisfy my father-in-law's liking for bass. My personal preference for sealed-box speaker sound didn't make the task any easier. I remembered the good performance I had obtained from the Morel MW-162 in an earlier

PHOTO 1: Front and back views of the MDT Mini-Monitor.



A
CLOSED BOX FOR MW-162
With box filling

F_S	= 39Hz
V_{AS}	= 16.5 liters
Q_{TS}	= 0.87
Q_{TC}	= 0.9
Volume of box (V_B)	= 23.2442331 liters
−3dB downpoint (F_3)	= 33.4647658Hz
Box resonance (F_C)	= 40.3448276Hz

B
CLOSED BOX FOR MW-162
With box filling

F_S	= 39Hz
V_{AS}	= 16.5 liters
Q_{TS}	= 0.87
Q_{TC}	= 0.95
Volume of box (V_B)	= 16.8226509 liters
−3dB downpoint (F_3)	= 34.3066215Hz
Box resonance (F_C)	= 42.586207Hz

FIGURE 1: a) 23-liter box with a Q of 0.9.: b) 16-liter box with a Q of 0.95.

ABOUT THE AUTHOR

Robbie Tucker has a degree in Education from Texas A&M University. A music lover, he is a better-than-average trumpet and guitar player. He has been a serious audiophile since 1973 and enjoys jazz, classical and rock, in that order. He is business manager and designer for Musical Design Technologies.

TABLE I

SPECIFICATIONS

Bandwidth (−3dB)	49Hz–20kHz
Amplitude Response	54Hz–20kHz ±3dB
	62Hz–10kHz ±1.5dB
Sensitivity	87dB 1W/1M
Impedance	8Ω nominal
Minimum Impedance	4Ω @ 4kHz
Recommended Power	50–200W
Size	10 × 15 × 15″
Weight	29 lbs. each

design, so I proceeded to the computer to design a small box and keep the Q as low as possible using that driver.

Q is a composite term which describes resonant magnification in speaker boxes. It represents the degree to which the electrical, mechanical, and pneumatic circuits of the woofer/box combination interact to control resonance.[1] The computer estimated a box of 16 liters with filling for a Q of 0.95, and 23 liters for a Q of 0.9 (*Figs. 1* and *2*.) The MW-162 is a 160mm treated paper cone driver with rubber surround and a 75mm voice coil.

I went to the scrap pile to round up something to build a prototype. I had several pieces of 1″ MDF (medium density fiberboard) on hand. I can't recommend the MDF too highly. In final application, these speakers would rest on their sides, so I knew I could build them deeper than I normally would for speaker stands. If you are planning to use stands, adjust your dimensions accordingly. External dimensions were 10″W × 15″H × 15″D, giving an internal volume of 22 liters (*Fig. 3*). I used silicone and wall board screws to put the prototype together.

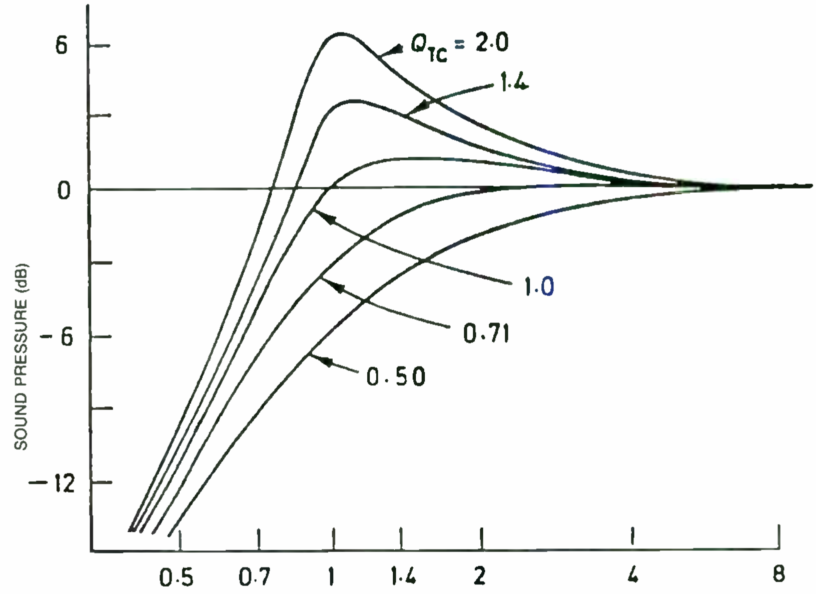


FIGURE 2: Sound pressure versus normalized frequency.

CROSSOVER. Next, I tested the drivers on Robert Caudle's fast Fourier transform processor (FFT) and started designing the crossover. First I ran the bass and tweeter separately in a sealed box on the FFT analyzer without a crossover. The tweeter was the Morel MDT-30 (no relation to the MDT Mini-Monitor). Morel makes several other tweeters such as the 28 and 29, but the 30 is my favorite. It is a 28mm, chemically treated soft dome. The magnetic system is cooled and damped with ferrofluid and capable of handling 200W of power. I could have used a Dynaudio D28AF, but the Morel is more competitively priced. Since this project I have experimented with the new Morel MDT 33 tweeter, which I highly recommend if you have room in your budget. Upon analysis, I found the MDT-30 and the MW-162 very close to the manufacturer's frequency charts (*Figs. 4* and *5*). The bass had smooth response out to 5kHz and the tweeter performed to around 1kHz.

I decided to use a second-order crossover to keep costs low. The target crossover point was 3kHz. I started out with the values suggested by the computer and worked out the final values by (much) trial and error. I ran each driver separately on the FFT with crossover, and the results are shown in *Figs. 6* and *7*. The tweeter exhibited a resonance peak which was easily controlled with an impedance compensation network.

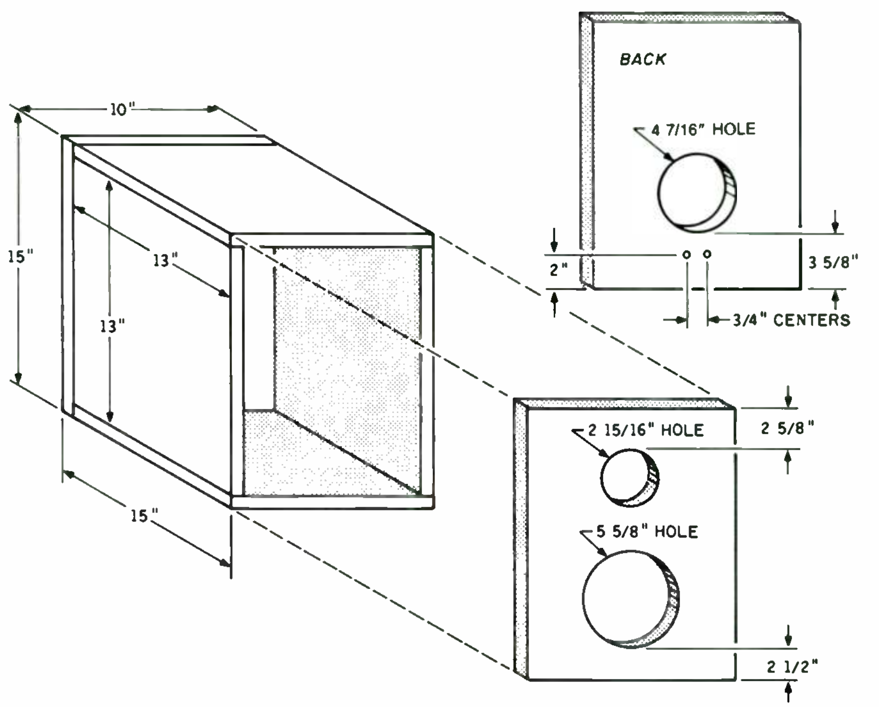


FIGURE 3: Construction details.

The frequency response exhibited some serious suck-outs initially at around 2kHz. I decided to use impedance compensation on the bass driver as well which eliminated the suck-out problem.

The results of the final crossover used in the Mini-Monitor are shown in *Fig. 8*.

TESTING. I can't tell you how excited I was to hook this speaker up to my

TABLE II

MATERIALS LIST

Qty	Item
1	4′ × 4′ sheet of 1″ MDF
1	3′ × 8′ natural veneer
2	Morel MDT-30 tweeters
2	Dynaudio variovents
2	Morel MW-162 bass drivers
2	Crossover boards
6	Feet of Kimber Kable 4TC speaker wire or equivalent
2	Pairs of Music Post binding posts or equivalent
1	Sheet of dense foam
1	Tube of silicone sealant
60	2.5″ black wall board screws
14	1⅝″ #6 black wood trim screws
4	16 gauge 0.4mH air-cored inductors
4	Solen 6μF capacitors
2	Solen 1.5μF capacitors
2	Solen 7μF capacitors
4	8.2Ω 5% 25W resistors
2	3.3Ω 5% 25W resistors
2	15Ω 5% 25W resistors
3	Feet of 62Sn solder
1	Quart of contact cement (with solvent)
1	Pint of fine wood stain
1	Pint of Formby's Tung oil
10	Sheets of 220 mesh (fine) sandpaper
6	Sheets of 100 mesh (medium) sandpaper
2	Pads of fine steel wool

reference system which consists of: SOTA Series III turntable with acrylic mat, Simply Physics linear tracking/air bearing arm, Electrocompaniet Pre-la, and Quicksilver mono amplifiers. Charts and phase linearity can often tell a lot about a speaker, but listening is the real test. The midrange was wonderful and vocals sounded as good as any speaker I've built. However, the bass just didn't sound real.

Back I went to the FFT to run the lower end on the 2k program. This program reads the low frequency driver from 20Hz to 2kHz. The problem became clear immediately. The Q of the box was not 1 as the computer-aided design estimated but was instead a very

TABLE III

TEST EQUIPMENT

FFT Analyzer by Bob Caudle
Formula "Loudspeaker Designing Aides" by Kelly D. Cunningham
Apple IIe 128K with "Transwarp"
Technics microphone RP-3800E
Quicksilver mono amplifier
MIT 330 interconnects
Kimber Kable 4TC speaker wire
Micronta digital multimeter 22-195
Heathkit sine-square audio generator IG-5218
Heathkit RLC bridge IB-5281
Radio Shack sound level meter 33-2050

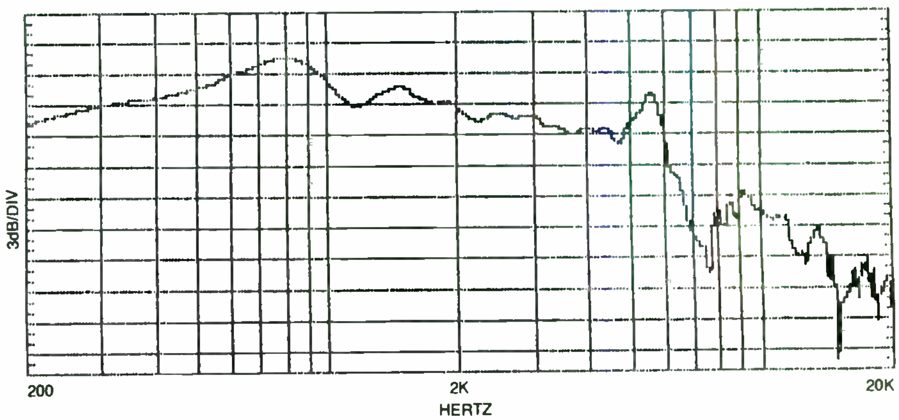


FIGURE 4: Bass driver without crossover.

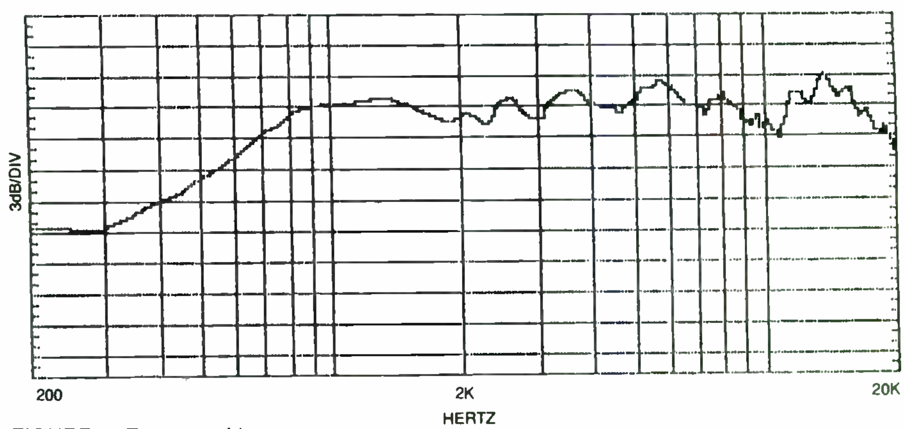


FIGURE 5: Tweeter without crossover.

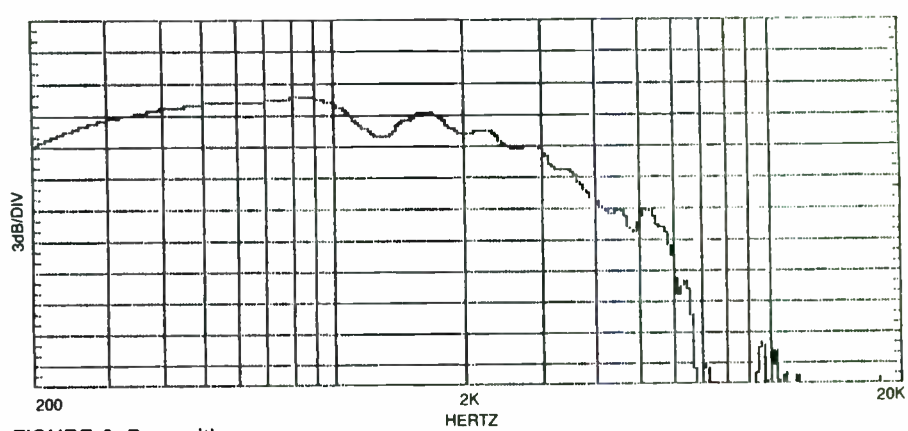


FIGURE 6: Bass with crossover.

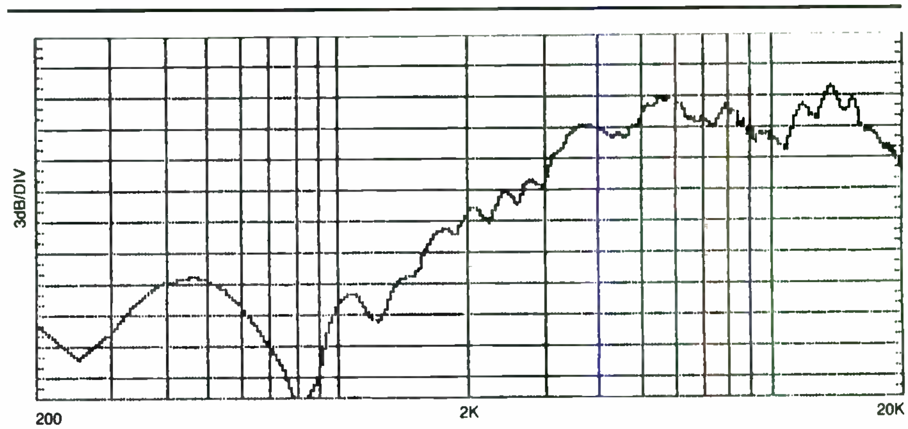


FIGURE 7: Tweeter with crossover.

Alternative to the Caudle FFT

Bob Caudle's FFT analyzer is not commercially available. As an alternative, we suggest the DRA MLSSA FFT analyzer (DRA, 607 W. Nettletree Rd., Sterling, VA 22170, (703) 430-2761). All you need is an IBM or compatible computer, a microphone and a microphone preamp. Bob has designed the preamp shown here.

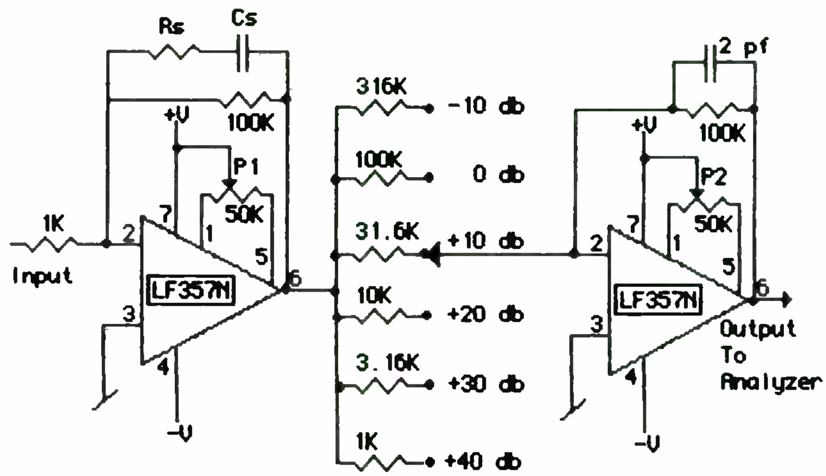


FIGURE B: Microphone preamp with frequency response compensation.

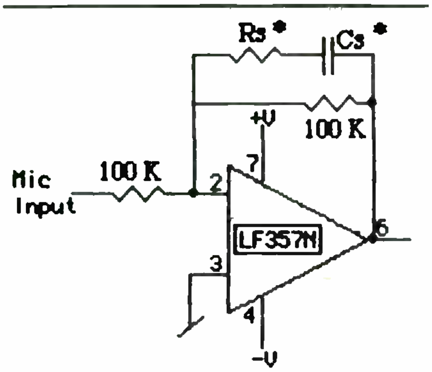


FIGURE A: Microphone preamp with shelf equalization components, R_S and C_S.

*These values for R_S and C_S will be close to 68kΩ and 220pF. These values were determined to be the best choice when a sample of six RP-3800E microphones were tested. However, due to changes in manufacturer's specifications, these values may require modification for current production units. For the most accurate results, your microphone should be compared to a B&K 4133 and final component selection made based on this comparison.

unsatisfactory 1.4. I was disappointed since I really didn't want to make this design any larger. With a floor standing speaker, I could have used the same drivers and crossover with a 30-liter box and eliminated the problem. Those of you at liberty to work with a floor standing speaker may want to do that. It was not an option for me.

I immediately looked at other possibilities. I had used foam for filling which, with other designs, I had found acceptable and cheaper than wool. Still, I tried replacing the foam with wool. Another analysis showed no improvement in the Q. I experimented with various amounts of wool, without satisfactory results. By this time I would have settled for 1.2. The Q problem shows you cannot always count on box volume formulas to be any more than a good starting point.

I let the design sit on the back burner for a while. *[Sounds incendiary to me.—Ed]* During my trip to the Chicago summer CES, I discussed my problem with

Continued on page 32

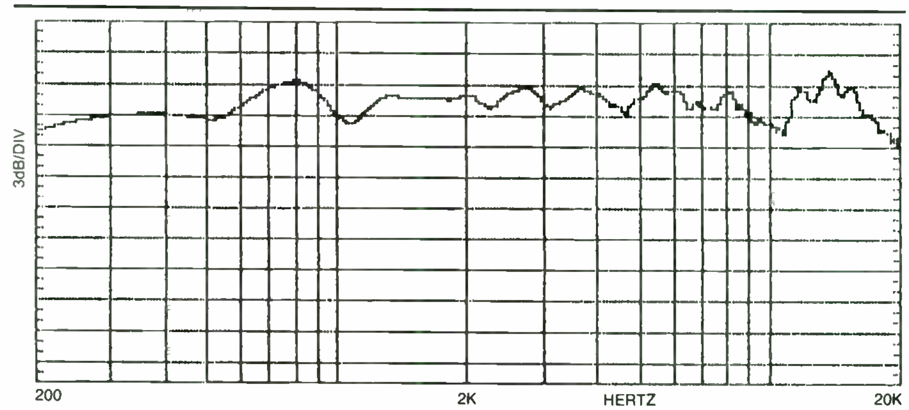


FIGURE 8: The MDT Mini-Monitor.

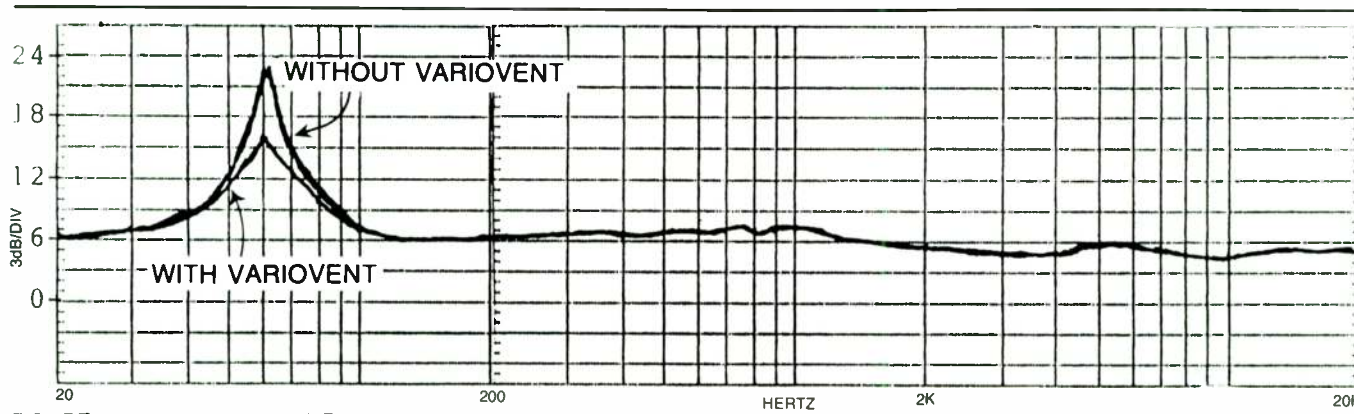


FIGURE 9: Impedance of the MDT Mini-Monitor.

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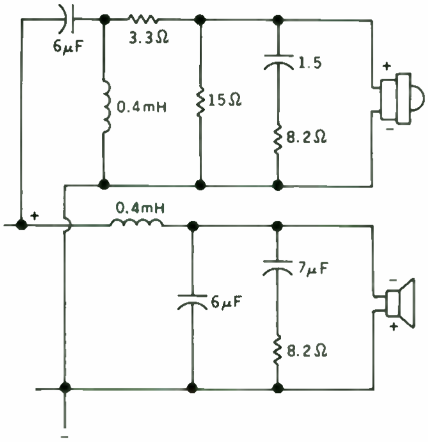

FIGURE 10: Crossover schematic.

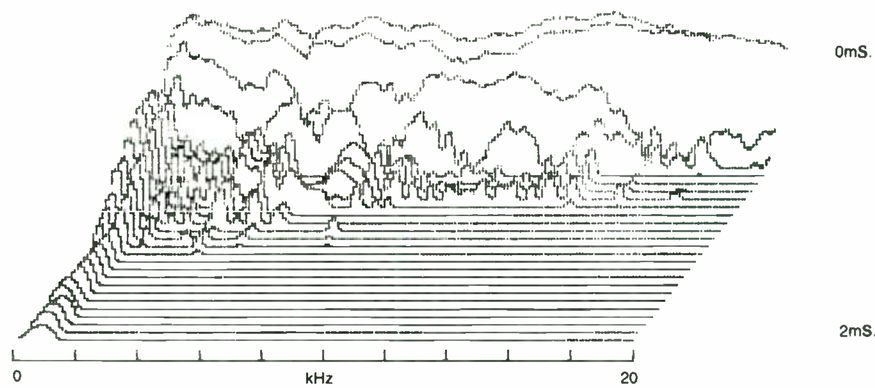

FIGURE 11: Three-dimensional decay.

Continued from page 30

a Dynaudio rep. He asked if I had considered using one of their "varioventS." I had not. He went on to discuss their design. One of the attributes was the lowering of the impedance at resonance which also lowered the Q of the box. Dynaudio's literature states that "the variovent is a flow resistance, damping the resonance like a DC-resistance in the oscillating circuit which results in a more precise bass response and better woofer quality." They go on to claim the impedance maximum at the resonance point will be reduced by at least 50% compared to a sealed cabinet. I have to admit I was skeptical, but the idea made sense.

When I got back to Houston, I ordered some and gave them a try. I was pleased with the results. Although the impedance was not reduced by 50%, it was reduced by 25% (*Fig. 9*). More importantly, the Q was reduced to a livable figure of 1. The resonance was 59Hz and the −3dB downpoint was 49Hz.

CONSTRUCTION. Now I was ready to build the finished product. Normally, I would cut my sides at 45° angles and use heavy bracing, but because of the speakers' small size and the MDF thickness, I found it unnecessary. Thus, if you do not have a table or radial arm saw you could probably use a saber saw, a steady hand and a power sander. Alternatively, you can have the lumberyard cut out the parts.

Cut your boards according to *Fig. 3*. You will need two each of 13″ × 13″, 10″ × 15″, and 10″ × 13″ for each enclosure. Make sure you install your binding posts and the speaker cable that goes to the crossover prior to assembling the boxes. You will probably have a hard time finding binding posts long enough to go through the 1″ board so routing an indention on the inside surface may be necessary. I used Music Posts™ which are five-way binding posts made of high purity tellurium copper alloy with a tightly bonded Lexan mounting plate. Many other good posts are available if you don't want to spend $50 on these. Once you are sure your posts will easily fit and can be tightened, remove them for box assembly and veneering. Once the box is veneered you can reinstall them through the bass driver hole.

Make sure to use a good quality silicone adhesive and long wallboard screws for box assembly. MDF is so hard you must predrill holes to avoid twisting off screws. Take your time and get some help when lining up your sides and tops or you'll spend a great deal of time sanding. Countersink your screws. Once all six sides are together, place a dense foam or wool filling in the top half of the box. Cut small strips for the bottom and sides of the lower half but be sure not to get foam directly behind the bass unit. You will need a free air passage to the variovent, and I also believe filling directly behind the bass driver affects imaging. If you use wool you'll have to use a screen to keep the wool in place. Foam can be glued to the sides with a hot glue gun.

Place your finished crossover (*Fig. 10*) in the box and secure it to an accessible place on the bottom or side. A loose crossover can create unwanted resonances. Also, as a precaution, keep it away from direct contact with the foam filling. You may find it easier to glue the foam and crossover to the box prior to installation of the last side panel (*Photo 2*). Be sure to use good quality capacitors (like Solens) and air-cored inductors with sufficient diameter wire to keep resistance

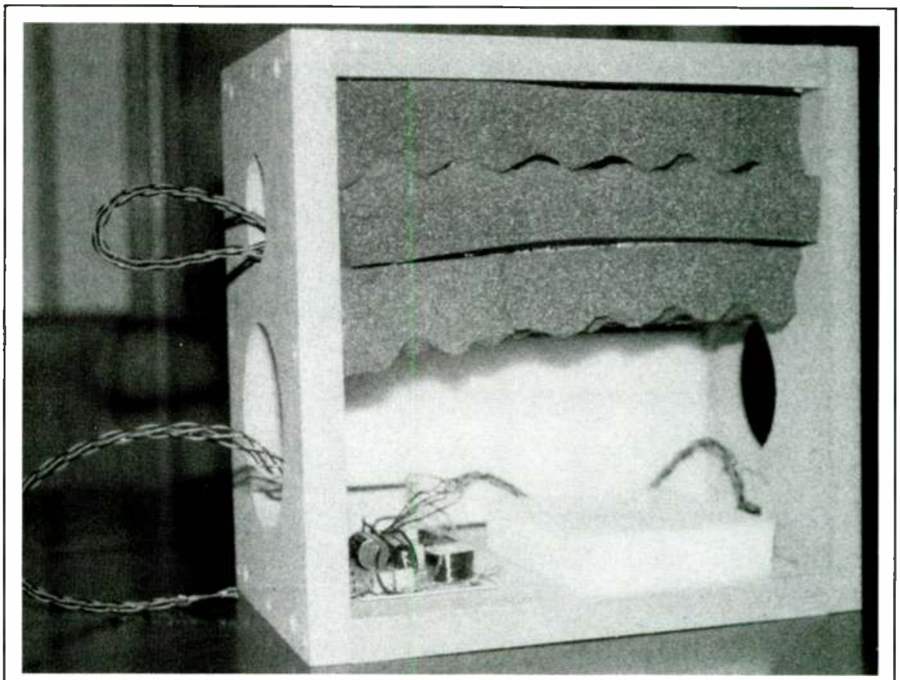

PHOTO 2: Inside view of foam and crossover placement.

PHOTO 3: Subjective listening at the "Esoteric Ear."

to a minimum. I found 16 gauge to be adequate.

Now you're ready to fill the countersink holes. Use a filling that will set up hard but is sandable and to which glue will adhere. Most fillings will sink a little after drying so two applications may be needed. As far as finish goes, I like natural veneers. Sand the box as smooth as possible. Most indentations or ridges will show through veneer. I finished my speakers in dark walnut to match the armoire. Be sure to give the contact cement plenty of time to dry or you will be redoing the job in a couple of years. If you have one, use a router to cut the edges. Otherwise, a very sharp utility knife will work.

Once the veneer is applied, sand very lightly by hand with fine sandpaper. Do not use a power sander on veneer if you wish to have any veneer left. Stain the veneer the color of your choice. Lightly sand again when the stain is dry and repeat the process if necessary. I used tung oil for the finishing touch. Many other finishes are acceptable, i.e., lacquer and polyurethane, but tung oil is fairly easy to apply, leaves a good protective coating and looks beautiful. It will take three to five coats. Lightly sand with fine steel wool after each coat. Be sure to remove all steel wool fibers before you apply the next coat of tung oil. Be patient. You should not assemble the drivers to the boxes until they are completely finished.

ASSEMBLY. Mark and predrill holes for driver placement. You can now solder the drivers to the crossover. Use good quality solder and internal wire. I used 62Sn silver solder and Kimber Kable 4TC. You'll need something to seal the drivers to the boxes. Silicone works well, but if you use too much, you can smear and ruin the finish. You may feel more comfortable with a clay-based seal such as Mortite. Once the units are screwed to the front panel, you're ready for listening.

I built grilles for these speakers out of necessity. The grille material can have a considerable effect on sound and must be carefully selected. If a covering is not acoustically transparent, it will not only absorb sound energy (particularly in the treble range) but will also provide a partial reflecting surface adjacent to the drivers, thus producing further coloration. Light machine-knit stretch polyester fabrics are suitable.[2] If you don't have to use grilles, don't.

RESULTS. I can't tell you how much I enjoy listening to these speakers. I performed subjective listening tests at home and at one of Houston's high-end studios, the Esoteric Ear (*Photo 3*). I found myself listening to the music more than the speakers and electronics. That pretty much says it. The cost of the project was low, especially for the quality sound produced.

I also designed a vented version using Morel's MW-164 instead of the 162. The 164 has a low Q_{TS} (0.41) and a dual magnet for improved sensitivity. Details of this design are available upon request.

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1. Dickason, Vance, *The Loudspeaker Design Cookbook*, The Marshall Jones Co., 1987, available from Old Colony Sound, PO Box 243, Peterborough, NH 03458.

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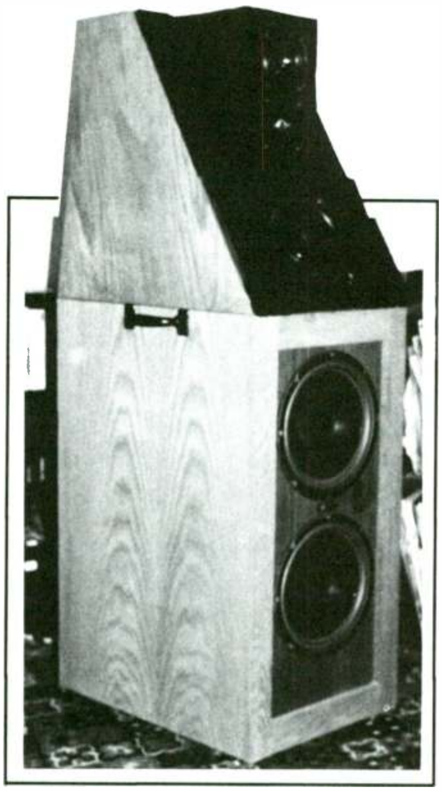
TITANIUM + TPX + POLYPROPYLENE = FIDELITY

BY MILLARD JOHNSON



Speaker builder fans, take a careful look at this system that features:

- Dual 10-inch woofer system (will work with many systems);
- Polydax 8-inch TPX lower midrange, MHD 2025 TDSN;
- Polydax 4½-inch TPX midrange, TX 1125 JSN;
- MCD-25M 1-inch titanium dome tweeter;
- Simple construction; no need for a computer or cabinet shop;
- No driver costs more than $40.

I built the upper part of my system from a design described in a Polydax bulletin, *Audax TPX System II.*[1] Excerpts from this bulletin are:

"A six-month research project, in conjunction with a major university in Paris, France, has resulted in a system which utilizes the full benefit of advanced development techniques in order to optimize the performance of a loudspeaker system. Excellent horizontal dispersion and vertical directivity characteristics have been achieved in a new loudspeaker design which has been introduced by Audax engineers.

"A comprehensive array of testing has been performed to ensure that the loudspeaker's performance excelled technically. Previous attempts to create a truly state-of-the-art system had resulted in an accurate soundstage, but only over a limited dispersion area. Exhaustive, blind test listening comparisons conclusively revealed that a three dimensional image was present, over a wide listening domain. It is now possible to obtain the localization of separate voices and instruments, while keeping the stereo imaging stationary within an extended listening field."

The bulletin documents the excellent frequency, phase and transient characteristics of this new design and includes enclosure construction plans and the crossover schematic. I modified the high-pass section because I substituted the MCD tweeter for the Polydax HD12X9D25G.

ADDING A SUBWOOFER. The Audax design uses the 8-inch woofer for the lower midrange and bass, yielding good bass, similar to Dick Olsher's Dahlia design. However, it lacks the powerful foundation this spectacular upper three-way demands, so I decided to add a subwoofer system.

I selected Madisound's new 10-inch model 10208, designed for a sealed cabinet. I used two Dynaudio Variovents per enclosure, which act as pressure relief valves. They are *not* bass reflex ports. They lower impedance at resonance and make the woofer system easier to equalize—yes, I said equalize. I had banished my equalizer to the storeroom after I found it added a layer of "grunge" to the midrange and treble. But in my new setup the equalizer does *not* affect the bass sound quality and you can tailor the sound to the acoustics of the room and your personal taste.

CONSTRUCTION. The details are fairly simple and this project can be built without owning a cabinet shop. I won't repeat common construction practices. I prefer wall bond or Liquid Nail adhesive to glue; it comes in tubes and is ap-

PHOTO 1: Notice ribs on woofer and exposed crossovers.

ABOUT THE AUTHOR

Mill Johnson, age 52, is a cabinetmaker by profession. He is an Extra class ham radio operator (call KU7D) and has been interested in speaker building since the late '50s. He has built several tube amps. Mill is also president of his local historical society.

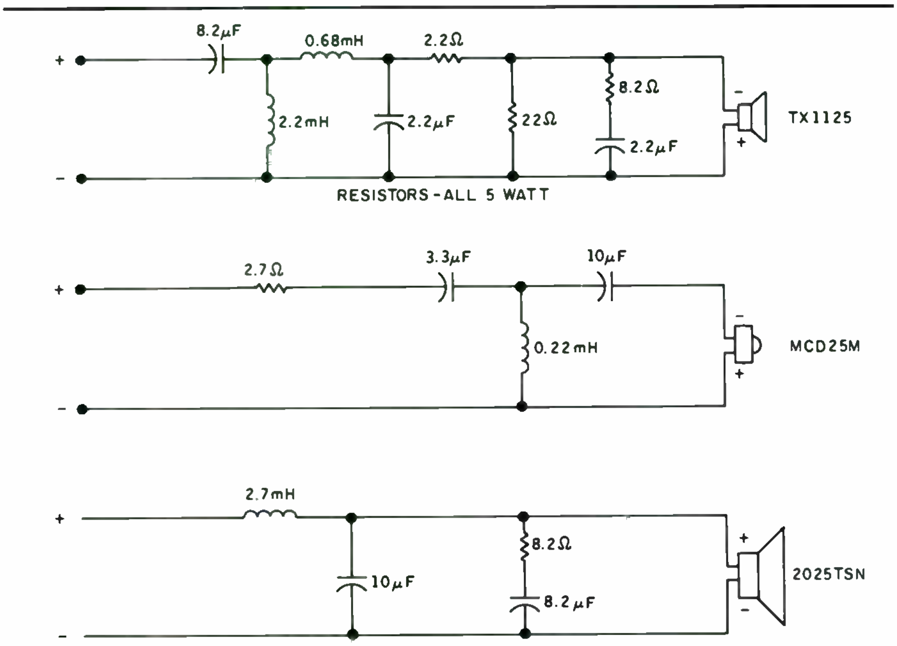


FIGURE 1: Crossover schematic. Inductors from Meniscus. Single run of 18 gauge solid core wire to each driver and a double run of 18 gauge (Radio Shack) to the 2025, 8″ speaker. 10 or 12 gauge high quality wire to the woofers.

plied with a caulking gun. The material is heavy bodied, fills cracks and sets up incredibly strongly.

I built the main boxes using ¾-inch novaply, with 2 by 2s in the corners and 1 by 4s as front-to-back braces. I also glued novaply scraps to the spaces between the corner blocks and braces to damp resonances.

After completing the basic boxes I used a belt sander to smooth the sides and then glued ¼-inch finish hardwood plywood to the sides and top. I covered the front of the upper speaker with ½-inch acoustic foam and, using cardboard templates, carefully cut holes to expose the drivers.

RECYCLING. In the lower speaker I used a piece of ¾-inch walnut plywood for the speaker baffle, left over from a cabinet I built in the late fifties using 30-inch woofers. It is only appropriate that

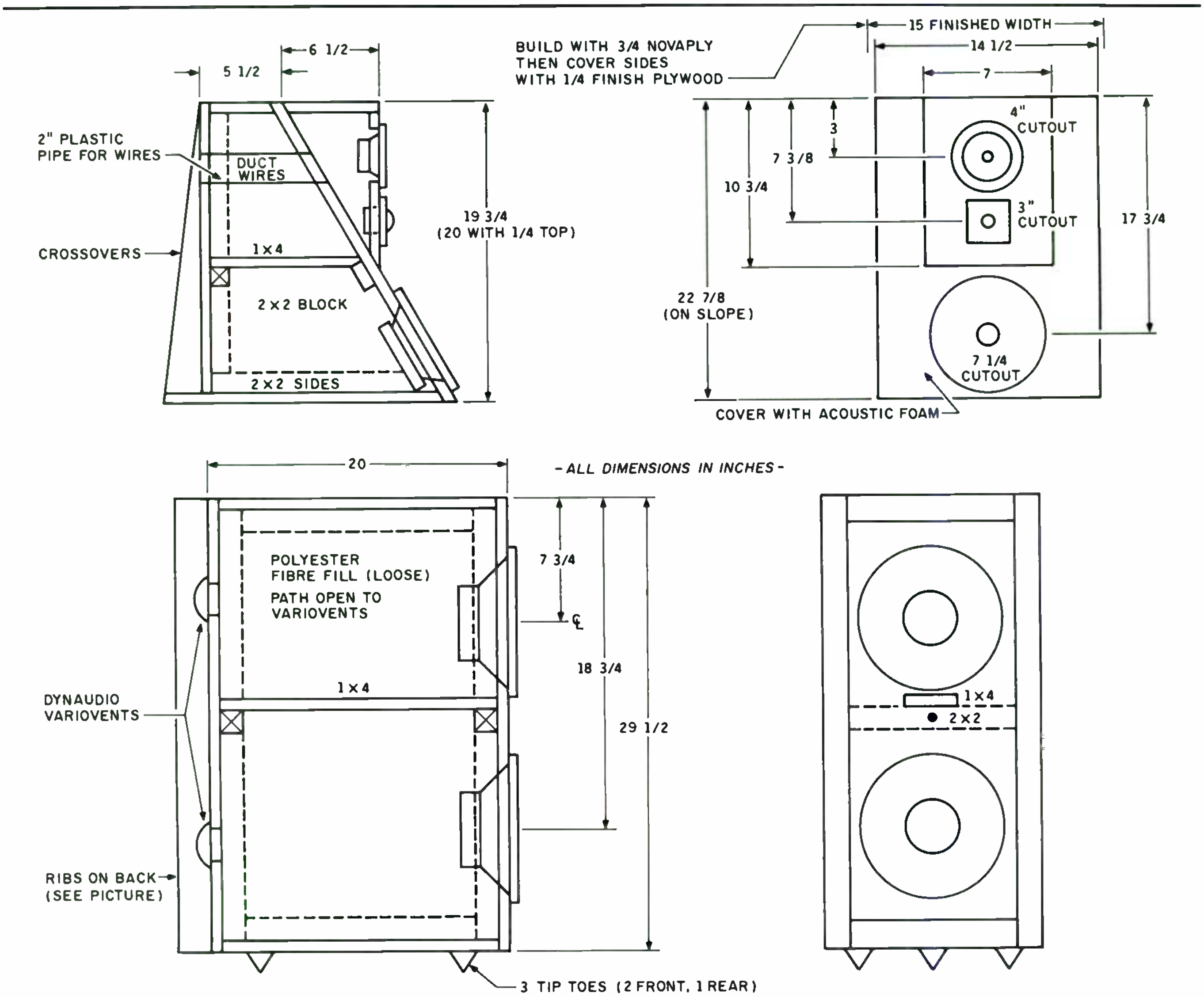


FIGURE 2: Construction details.

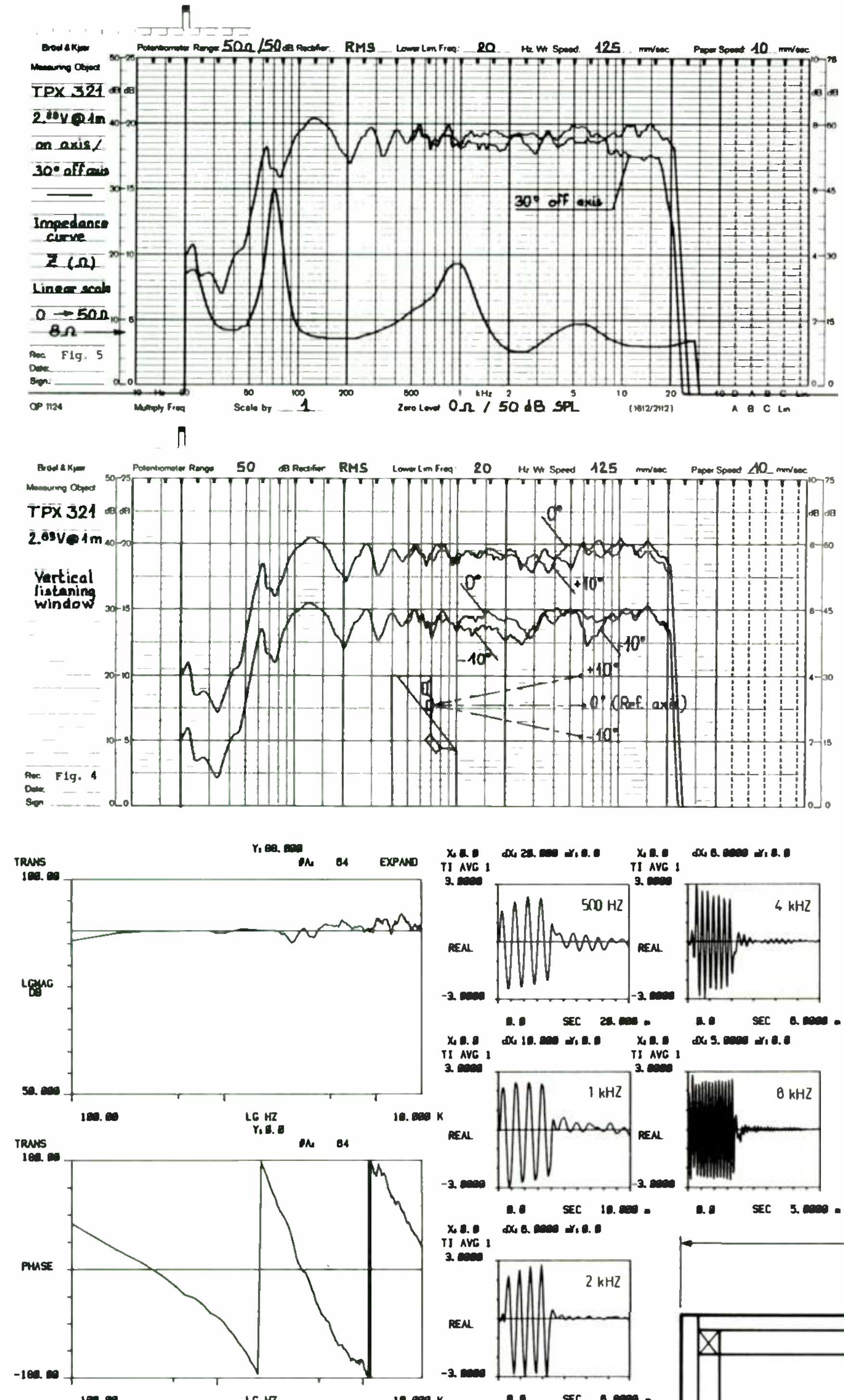


FIGURE 3: TPX System II performance specs. Top: horizontal dispersion, measured at 0, 30 and 45° off axis. Center: vertical directivity, measured at 0, 5 and 10° off axis. Bottom: transient and phase response.

I used a piece of plywood from my largest woofer for my latest project—the smallest and best woofers I ever built.

This system uses a unique crossover (*Fig. 1*). I firmly believe extra layers of electronics must be avoided. The electronic crossovers I tried veiled the sound. My PS Audio 4.6 preamp has two sets of outputs. I ran one set to my tube monoblocks, and the other to my Audio Control Richter Scale Series III, which is connected to an Adcom 545 bass amplifier.

The tube amp has a 0.01μF capacitor at the input which gives the effect of a 6dB high-pass filter. The bass starts rolling off at 140Hz, and I set the Richter Scale Series III crossover frequency at 125Hz (with plug-in module).

REVISED WOOFER. A new couch and lower listening position necessitated lowering the height of the speaker system in my room. I decided to try an Isobarik configuration using the same drivers and cabinet minus seven inches (*Fig. 4*). The results are very interesting. The original woofer design had excellent bass, and you could equalize it to have flat response to 30Hz with 6dB of boost. Below 30Hz the response dropped like a rock, and even at high SPL the cone movement was minimal.

With the Isobarik version, I had hoped to duplicate the performance of the larger enclosure. I was amazed with the results. The response is flat to 25Hz without equalization, with a 3dB down point of 23Hz.

Because of increased cone excursion I wondered if the Isobarik could play

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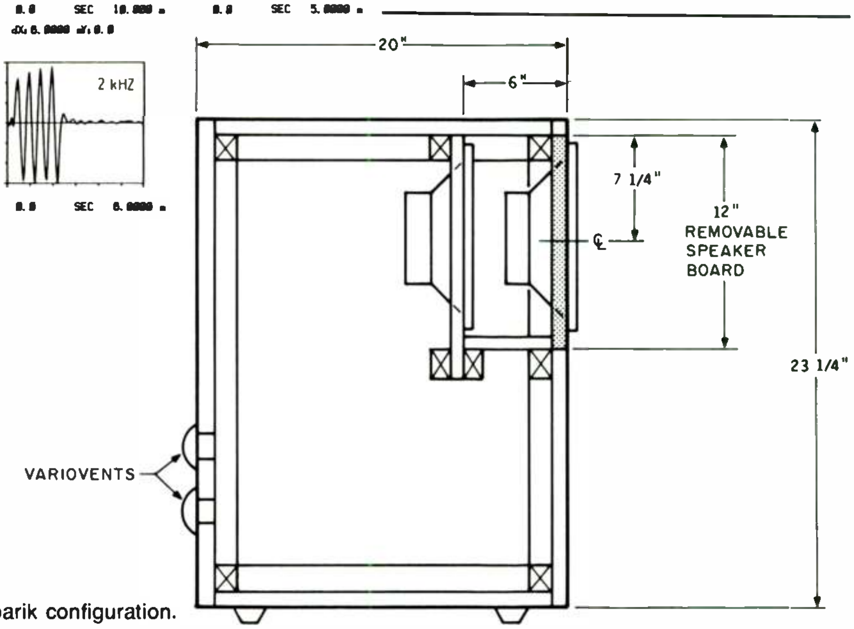

FIGURE 4: Revised woofer with Isobarik configuration.

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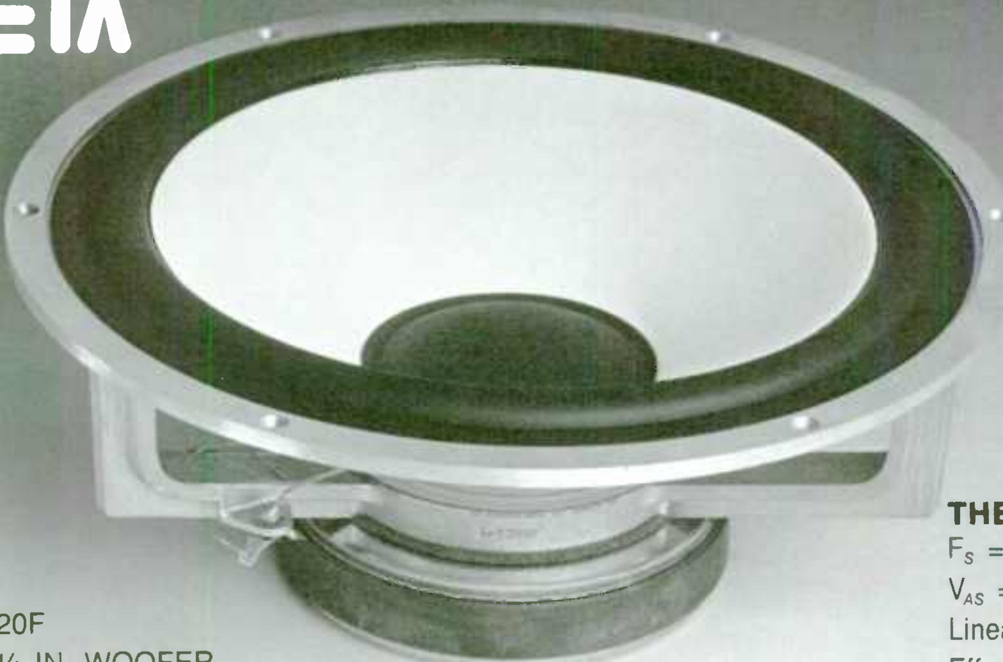

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Part III

A COMPACT INTEGRATED ELECTROSTATIC/ TRANSMISSION LINE

BY ROGER R. SANDERS

This transmission line (TL) has a strange shape and looks difficult to build but is no more difficult than other TLs, all of which are more complex than your basic box. I'm no carpenter, but I built these without much trouble. You need no special tools, as most of the cuts can be made with an ordinary circular saw and a long straightedge. Typical speaker enclosure construction is used, consisting of ¾″ particle board screwed and glued together. I constructed mine in one weekend. Because I wanted them to be attractive, I had a carpenter apply Formica to the cabinets.

The TL is tapered both front to back and side to side for minimum resonance. Most TLs are a constant width, that produces one significant resonance. Probably the most unusual aspect of this TL is that it is a parallelogram rather than a rectangle in cross section. I did this for performance and aesthetics. A planar ESL is laser beam directional and must be aimed toward the listener. It must be angled inward at 15 to 30° for optimum soundstage presentation.

If you place the ESL at the front of a rectangular enclosure, you must angle the entire enclosure inward. Most people find this unacceptable. The problem could be solved by setting the ESL back from the front of a rectangular enclosure so it could be angled but hidden by a surrounding grille cloth. Then you could place the rectangular enclosure against the wall in the normal fashion, the woofer would fire perpendicular to the wall, and the ESL would be angled inward. The audible problem with this is the ESL would be out of the plane of the woofer and would not have free dipole radiation around the back of the TL. Aesthetically, it is unattractive because the surrounding grille cloth makes the speaker appear as a large box.

I decided to leave the enclosure sides perpendicular to the wall and angle the entire face of the speaker. Not only does this make an attractive enclosure, but it is the key to the rear-wave beam splitter. By picking the right width to depth ratio on the vertical part of the TL and putting the ESL inside, the TL will intersect about two-thirds of the rear beam. Different surfaces of the TL are then used to reflect parts of the rear wave in directions not usually covered by conventional dipoles, which produces the casual dispersion desired.

You may want to consider a curved ESL. Although this would have the disadvantage of wide dispersion, it would allow a rectangular enclosure with part of the ESL facing the listener and the basic enclosure perpendicular to the wall.

The drawings are somewhat difficult to visualize because of the angles (*Figs. 1–3*). To make them easier to interpret, the front and side views are drawn as though the enclosure were a rectangle rather than a parallelogram. The dimensions are essentially the same in either case. Just make the cuts at the required angle rather than the normal 90° angle, and you will automatically end up with a parallelogram when you assemble it.

IMAGING CONSIDERATIONS. Unlike magnetic speakers, ESLs sound the same no matter how close you are to them. This makes it possible to have different stage presentations based on the percentage of room acoustics in the image. If you sit far away, the performers will sound as though they are in your room. If you sit very close, you will think you are in the concert hall where the recording took place. Close seating has other advantages as well, including higher SPLs, improved detail resolution, more precise instrument location and greater intimacy with the performance. The effect is much like listening to good headphones but without their bizarre imaging.

Another consideration is image width. Since planar ESLs have such excellent imaging ability they may be more widely spaced than wide-dispersion magnetic speakers without developing a hole in the middle of the image. I have found they can present perfectly an image 60° wide. Thus, you can set them up to form an equilateral triangle with your listening location. I have set up a very small equilateral triangle only 5 feet on a side. The resulting image is astounding, but your eyes can play tricks on you until you get used to this position. Initially, visual clues tend to contradict and override what your ears are telling you, suggesting a compressed image. If you close your eyes, the image opens out into the concert hall.

After deciding your preferred listening distance, determine the angle required to have the speakers face your seat. This may be up to 30° for each speaker. Note that angles less than this will reduce not only the soundstage width but also the effectiveness of the rear beam splitter (*Fig. 3*). For optimum performance, your seating position should not be against a wall or the sound will be smeared by wall reflections immediately behind you. If you must sit near the wall, put some sound-absorbing material on it.

If you don't want a chair in the middle of your room, consider my solution. I have two tiny marks on the carpet for the front legs of my listening chair, which is normally near the wall. I place the chair on the marks for serious listening, but the rest of the time it is out of the way.

CONSTRUCTION. Remember to make

PARTS LIST

TL

2	Particle board 0.75" × 4' × 8'
2	Driver, Dynaudio 24W75
1	Grille cloth, Mellotone flameproof 30" × 8'
Misc.	Screws, glue, paint, Formica, connectors, wire, aluminum bracing, wool or polyester damping material

ELECTRONICS

2	Transformers, audio, Triad S-142A
2	Electronic crossover, assembled module, Biamp 650Hz 18dB/octave, DeCoursey #9078
2	Gain/equalizer, assembled module, DeCoursey #871
1	Power supply, 3kV, 0.01mA
Misc.	Chassis, switches, jacks, connecting cables, plugs

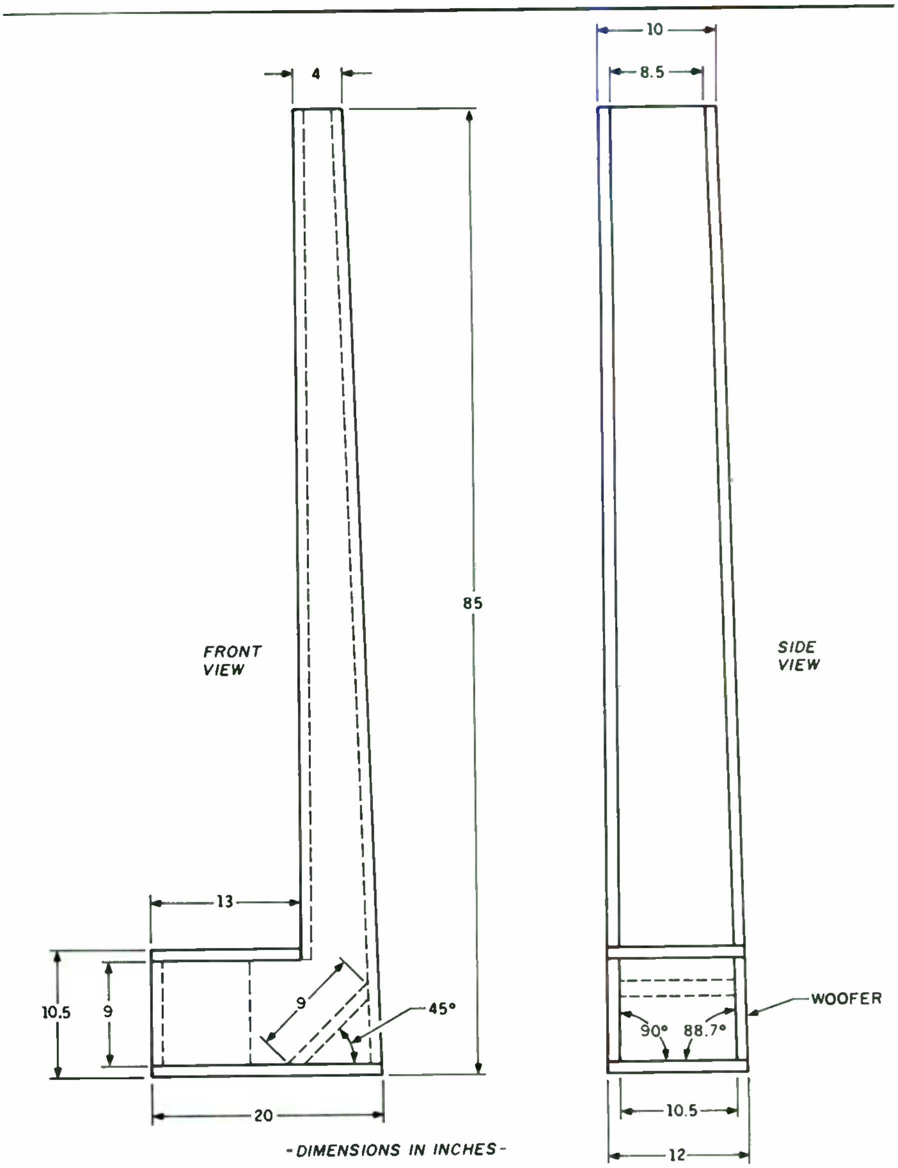

FIGURE 1: Front and side views of enclosure.

mirror-image parts for the left and right cabinets. All these angles make for some interesting cuts, but if you pay attention, it is not difficult. To make the long vertical cuts at the required angle, clamp an 8′ straightedge (aluminum bar stock 1½" by ¼") to the wood with C clamps along the required cut. Adjust the foot plate of the circular saw to the required angle. Run the saw along the straightedge to make the cut. Your saw's foot plate will probably not tilt the other way to make the mirror image cuts, so run the saw from the other direction. You cannot run the circular saw completely to the right-angle corner on one side of each front and rear piece without cutting into the face of the enclosure. Just get close to the corner and finish the cut with a handsaw. The power saw's kerf makes a good guide.

If you are careful, you can get the screws in at the appropriate angle freehand. I found it easier to drill one screw hole at each end of the enclosure and assemble the two parts temporarily using only those two screws. Be careful not to tear out the screws while you finish drilling a string of screw holes down the joint. I put screws about every 6 inches. An assistant is essential during this process. After the holes are drilled, disassemble the two parts, apply the glue and reassemble them using all the screws. With all the screws in place, the parts are stable, and you can use the same process on the next part.

Perfect joints are nearly impossible because the wood tends to slide, but this is not critical. Use a belt sander or plane to trim the overhangs after the glue is dry. Don't forget to insert the damping material before you put the last piece in place.

Note that the woofer goes on the tapered side of the enclosure. This helps balance the front-heavy speaker and aims the ESLs slightly upward so you are not listening at the joint between the two panels.

Virtually all woofer systems reflect the rear wave off the back wall of the enclosure and radiate through the woofer cone into the listening area. You can solve this problem by placing a 45° baffle directly behind the woofer to direct the sound waves down the line rather than allowing them to reflect back through the cone. Place a 45° baffle at the 90° turn in the line to direct the sound up the line rather than reflecting it back into the woofer. You can make these baffles out of scrap particle board.

DAMPING MATERIAL. This design has very tight dimensions, and you must be careful not to overstuff it. Too much damping material will wipe out the deep bass.

Natural long-fiber wool is the best damping material, but it is costly, hard to get, and must be mothproofed and supported. Expect to use about ¼ pound or a little less per cubic foot. I prefer constant-impedance stuffing, which must be packed more tightly near the woofer than at the port. Staple some nylon webbing into the line about every foot to support the wool and keep it from settling. Sprinkle moth crystals in with it and be sure to use a grille cloth over the port to prevent moth entry.

There is little audible difference between wool and synthetic materials, so polyester fluff is commonly used. If you have a choice, use fine rather than coarse polyester. Polyester is cheap and readily available, moths hate it, and it does not need support. Under a microscope, the fibers are smoother than wool.

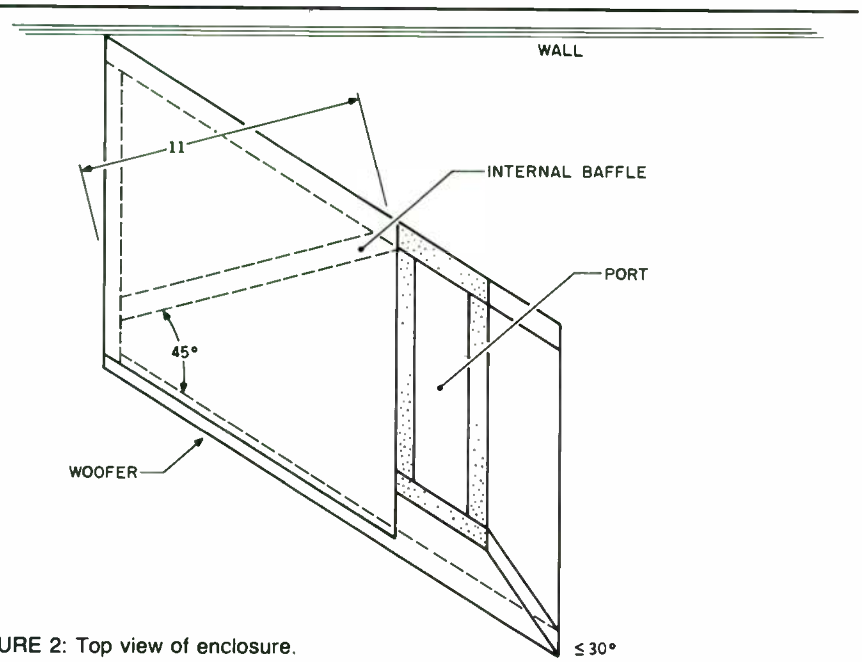

FIGURE 2: Top view of enclosure.

Hence it is not as good for impeding sound, so stuff it a little more tightly than you would wool.

Fill the line loosely; but put in a little extra near the woofer. Too little stuffing is better than too much. Do the finish work before you stuff the area behind around and install the woofer itself. It is easy to finish stuffing through the woofer opening. The wiring can also wait until the last minute.

DRIVERS. Which driver is best in a TL? Unlike ESLs, magnetic drivers are extremely complex and unpredictable. How do you pick a good one? I use a combination of logic and luck, which has served me well. My philosophy is simple: 1) use the largest driver possible consistent with design limitations; 2) buy the best quality, most advanced drivers available; and 3) spend whatever money it takes to achieve numbers 1 and 2. Drivers are inexpensive, so don't cut corners here.

The Dynaudio 24W75 best meets my criteria for this design. I originally planned to use an 8″ woofer, but this 9″ unit offers high quality with hexagonal voice coil wire, a plastic cone, a very large spider, superb frequency response, and excellent power-handling capacity. It also has a very shallow cone, which minimizes phase alignment problems. I did not test any others in this design, but I would be surprised if you can improve on this one. I expected clarity and linearity from this compact TL system, and I was not disappointed. But I was not prepared for the degree of deep bass extension and power handling that these speakers exhibit.

TL TESTS. I was concerned I had made so many compromises in the interest of compactness that performance would be unacceptable. With considerable anxiety I substituted them for the woofers in my big system, that uses the excellent 12″ Dynaudio 30W54 in a large cross-section 10′ TL stuffed with wool. Its performance is truly outstanding. To expect a compact system to approach this level of performance seemed unreasonable.

I was amazed when the little system matched the big one in almost every way. There were two differences. First, as expected, the small system was not as efficient, requiring that I turn up the bass amplifier to match the output of the ESL. This presented no problem, however, as I could not drive it into obvious distortion even though I was seeing in excess of 105dB on my SPL meter. The other difference was in the deep bass response, which was not quite as extended as in the big system. This I also expected, but the difference was remarkably small. Good woofer systems literally make the floor move without sounding strained. You feel the bass rather then hear it. This is the first woofer system under 10 inches that I have heard do this, and it does it with ease and authority.

MOUNTING THE ESLs. The method of mounting the ESLs to the TLs may vary depending on the ESLs you build. I attached some wood strips along the TL to form a slot for the ESLs. The opposite edge and unsupported top edge are braced with aluminum strips similar to those used for the cutting guide. I used 1 by ⅛″ aluminum, which is easy to bend without cracking and can be cut with wood tools. I also used 8/32 nylon bolts to maintain insulation.

Physical phase alignment between the ESL and TL is not critical in this design because the relatively low frequency crossover is below the region where the ear is sensitive to phase abnormalities, low-frequency wavelengths are long so errors are minimized, and the woofer cone is shallow. This is fortunate because there was no alternative but to drop the woofer from ear level to the floor, which results in a longer sound path for the woofer than for the ESL. A good rule of thumb is to place the ESL diaphragm in a plane about one-third the way down the woofer cone. In this design, that means the ESL diaphragm should be recessed only ¼ inch from the front of the TL cabinet. I don't think this speaker can be optimized for phase unless it is angled severely backward so the ESL and woofer are equidistant from your ears. Obviously, this would be asthetically unacceptable. I suggest you place the ESLs reasonably close to the front edge of the TL and don't worry about phase alignment. Listening tests have not revealed any serious phase problems.

GRILLE CLOTH. Grille cloth impairs sound quality. Close-weave fuzzy cloths and thick foam are the worst. The best are the open-weave smooth plastic cloths made by Mellotone. Flameproof Mellotone cloth is not cheap but is difficult to detect sonically. Other than cost, the only disadvantage is its sheerness, so you must paint your cells black lest they show. I do not use grille cloth, but omitting it is aesthetically unsatisfactory. Like reduced SPLs and deep bass extension, grille cloth is part of the compromise of an aesthetically pleasing speaker.

To test grille cloth, mount it on some type of frame and have someone alternately put it in front of the speaker and then take it away while you are listening to a wideband complex source. Use blind testing, otherwise you will be convinced the sound has changed just because you see an obstruction. You should readily and reliably be able to tell when the grille cloth is on.

ELECTRONICS. Audiophiles get all worked up over trivial differences in their sound systems while overlooking major areas of improvement. A good example is the listener who spends thousands of dollars repeatedly trading one amplifier for another while continuing to operate

Continued on page 42

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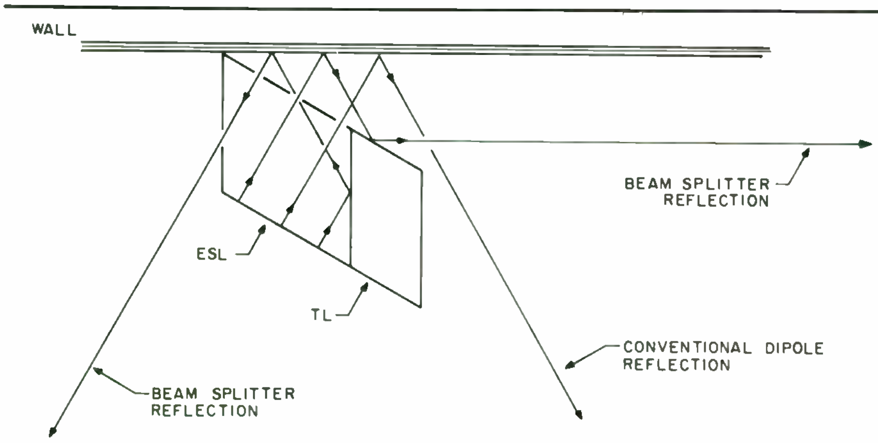

FIGURE 3: Beam splitter geometry (top view).

Continued from page 40
his speakers with passive high-level crossovers. The superior sound quality of low-level active (electronic) crossovers used with multiple amplifiers is obvious, but amplifier differences are subtle at best. All my speaker systems have electronic crossovers and multiple amplifiers. I consider this essential (*Fig. 10*).

Since no electronic component is as pure as one that isn't there, it doesn't make sense to have a preamp. We use preamps for RIAA equalization in analog disk systems, which I believe are obsolete. Digital audio's flaws are fewer than those of commercial analog systems. Analog tape has always been superior to analog disks, but manufacturers have not used tape to its full potential.

If you still have an analog disk system, I recommend you copy any music of interest to a quality tape system; discard your turntable, preamp and disks; and use a passive attenuator and switching network to adjust gain and select sources. Similarly, tone controls are unnecessary with a top quality speaker system. If you feel tone controls are essential, you need at least a 10-band equalizer, not tone controls on a preamp. If your attenuator tracks well, you don't need balance controls either. In short, there is no longer any need for a preamplifier.

It is easy to build a passive attenuator/switching unit. You can customize it to your specific needs; then incorporate it into your gain/equalization/crossover electronics, which I will describe shortly. I use the AR Remote Control because it offers power, gain, balance, muting and selection of two sources without any detectable influence on sound quality. It is cheap, convenient and has perfect gain tracking between channels. The AR has two shortcomings: its power switching is limited to 600W (a problem shared by virtually all preamps as well), and it switches between only two sources. You can solve the power problem by using the unit to turn on a large power relay that switches on the rest of the system. I have a switch in my gain/equalization chassis that allows me to select one of several other sources.

CROSSOVERS. I chose Butterworth filters because they are maximally flat in the passband and in odd-order designs they afford constant voltage and power levels through the crossover regions.

First-order Butterworth filters are low in phase shift and have constant output through the crossover point, but they roll off at only 6dB/octave, which requires a two-octave spread beyond the crossover point for the drivers. For example, for a 550Hz crossover, the woofers should be linear up to at least 2,200Hz and the ESLs should be linear down to at least 136Hz. This is not practical.

Second-order filters have 12dB/octave slopes, which are steep enough for most speakers and widely used in passive high-level crossovers. Unfortunately, there is a definite, audible discontinuity at the crossover point. You can make this "hole" less noticeable by reversing one speaker, but there is still an audible imperfection.

Third-order, or 18dB/octave, filters correct these problems. In addition to a maximally flat passband, they maintain a constant sound level through the crossover point. Driver cutoff is sharp, minimizing extended frequency response requirements. The smooth, gradual phase shift across the band is not objectionable.

You can use steeper sloped filters, but phase shift becomes a problem and it is difficult to obtain parts precise enough for proper performance. Therefore, I decided to use 18dB/octave slopes.

Select the crossover frequency carefully. The advantages of a low crossover frequency (less magnetic driver energy in the midrange, flatter frequency response, less critical phase performance and better driver blending) must be balanced against high output. I have chosen a 550Hz effective crossover point for optimum results. If you demand a lower crossover point, more equalization will be required, the ESL will have to produce more bass, voltage requirements will be higher, and driver excursion will be greater. All these conspire to reduce output. The ESL can be operated down to 150Hz, but the TL is so good that the subjective difference between a crossover at 150Hz and one at 550Hz is nil, while the difference in output is dramatic.

You can obtain crossovers from several sources, as well as build them yourself. *[Several kits are available from Old Colony, PO Box 243, Peterborough, NH 03458.]* You need precision components, however, and these can be difficult to obtain. Complete circuit boards are often cheaper than building your own. I use units built by DeCoursey Engineering Laboratories. They come in both hard-wired and plug-in versions, are about 2" square and are glass epoxy with quality components. They cost about $50 per channel. The part number for the plug-in version is 9078. The crossover point should be specified at 650Hz, which yields a 550Hz crossover point when mated with the necessary gain/equalization stage.

EQUALIZERS. As I mentioned, the speakers use a modest amount of equalization to compensate for phase cancellation. You can accomplish this equalization passively but with an insertion loss of around 18dB. Most systems don't have much extra gain, particularly when driving high-powered amps, which typ-

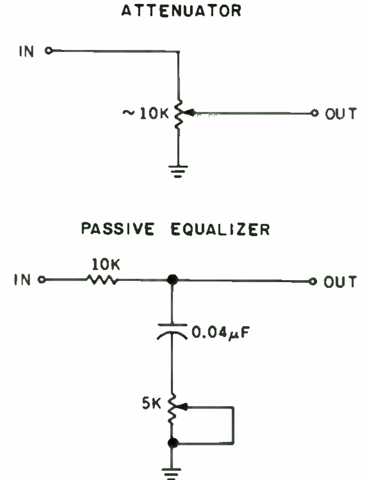

FIGURE 4: Passive and active circuits.

ically need high drive voltage. For this reason, I use an active circuit with a small amount of gain. Both passive and active circuits are shown (*Fig. 4*).

If you use the passive circuit, measure its response with an audio generator and voltmeter to adjust the response to match the curve (*Fig. 5*). Because it is influenced by your amp's input impedance, you must tailor the components to the amp. Be sure the amp is connected to the circuit when making adjustments. The active unit is buffered from the amplifier, so the components are precise and no measurements are required.

You can build the equalizers yourself, but DeCoursey offers them for about $50 per channel (part #871). The units are slightly smaller than their crossover boards, use the same power supply, plug into the same type of sockets and will fit into the same chassis.

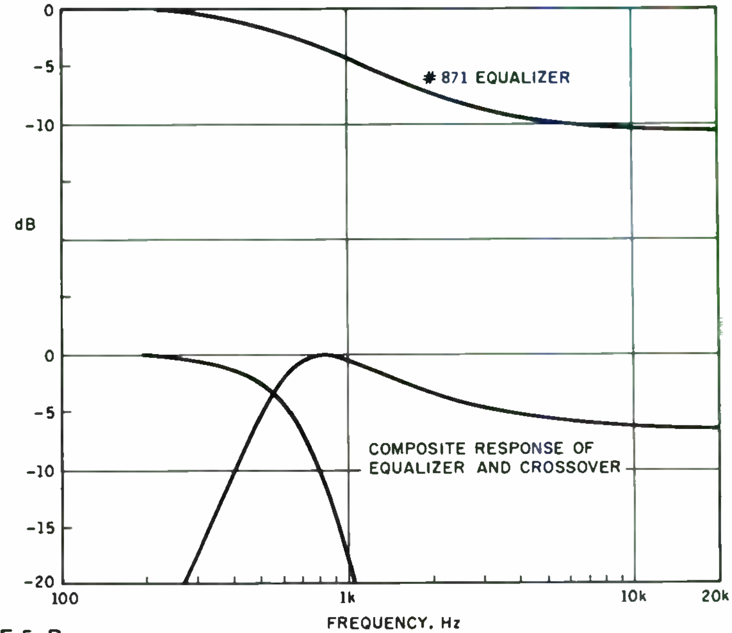

FIGURE 5: Response curve.

ELECTRONICS ASSEMBLY. Assemble the equalizers and crossovers in the same chassis with a common power supply. If you wish, add an attenuator (*Fig. 6*) to control overall system gain, a rotary selector switch for choosing different sources and a few RCA jacks on the back panel to provide a complete control center/gain/equalization/crossover unit in one small chassis. DeCoursey also sells the chassis with everything installed and ready to use.

VOLTAGE SURGES. Voltage surges occur when the unit is turned on or off. To avoid amplifier and speaker damage, these must be suppressed. Most amplifiers are AC coupled and will tolerate surges when first turned on, but DC-coupled amps may blow woofer cones right out of the cabinet. Leaving your electronic circuits on at all times prevent turn-on problems. They use practically no electricity and will probably last longer this way. If you must switch them on and off, use a delay relay in the output to protect your amps.

DC OFFSET VOLTAGES. Most low-level electronics have a trace of DC offset in their output. Most amplifiers are AC coupled, which blocks this DC voltage. Some modern amplifiers are DC coupled, however, and will amplify DC voltage. With these, there must be no DC component to the input signal. If there is, the DC will be amplified and the transformers or woofers can overheat or have their operating parameters reduced by the steady current. You can solve this problem by turning your DC amp into an AC amp by putting a capacitor between the crossover and the amplifier.

In double-blind A/B comparison tests, I found the effect of a good DC-blocking capacitor audibly undetectable. If you think otherwise, obtain the IC application notes used in your particular crossovers and build a DC offset adjust circuit to null the output. The same holds true if you use a differential tube or discrete transistor circuit. In that case, you must also use regulated power supplies, leave the electronics on all the time for stability and check the output for DC occasionally, particularly when the unit is new. Your ESL amplifier should run almost as cold as it would if it were not driving any speakers. With matching transformers, they should run cold. If your amp or transformers get hot, look for DC problems or supersonic oscillation.

LEVEL MATCHING. You will undoubtedly discover that the various amplifiers and drivers will not match in loudness. The woofer will be louder than the ESL. Therefore, you must put an attenuator in the woofer circuit to bring its level down to that of the ESL. Many basic amplifiers have input level controls that do this. If yours does not, you may add them or incorporate level controls in your equalization/crossover electronics. A suitable schematic is shown (*Fig. 6*).

AMPLIFIER CHOICES. You will need a very powerful amplifier for the ESLs and a modest one for the TLs. It may seem crazy to use a 500W stereo amp to drive tweeters, but that's what it takes to do it well. ESLs are extremely efficient (power dissipated vs. acoustic power generated), and they dissipate an insignificant amount of power, so at least you don't have to be concerned about burning them up. The TLs are reasonably efficient; an honest 60W amplifier should be adequate. The woofer amp quality standards are much more relaxed than those for the midrange amp. To save money, you might want to build a kit. I now use a Hafler 500 on the ESLs and a Hafler 220 on the woofers, but for years I was happy with a Williamson Twin 20 on my big woofers. *[The Twin 20 is no longer available from Old Colony. The 40-40 is being closed out.—Ed.]*

Direct drive amps capable of the outputs I consider adequate are not, in my view, practical. If you wish to design and use one, see my article, "The Sanders Electrostatic Amplifier," (*TAA* 1/76) or David Hermeyer's "An Electrostatic Speaker System," (*TAA* 4/72). *Audio Amateur Loudspeaker Projects*, available from Old Colony, also offers plans for two direct drive amps.

One possibility for a new type of amplifier is one with a power supply or bias circuit that can vary voltages in response to the musical demands. Or perhaps a dual amp with a high-voltage/low-current section for the lower frequencies and a low-voltage/high-current section for the higher frequencies might work. This should greatly reduce the power requirements. I would be interested in hearing from anyone who develops a satisfactory direct drive design.

Continued on page 45

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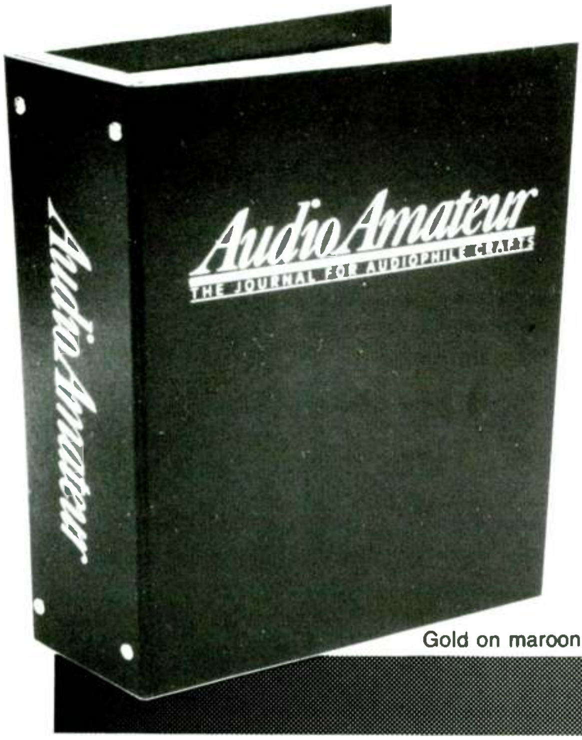

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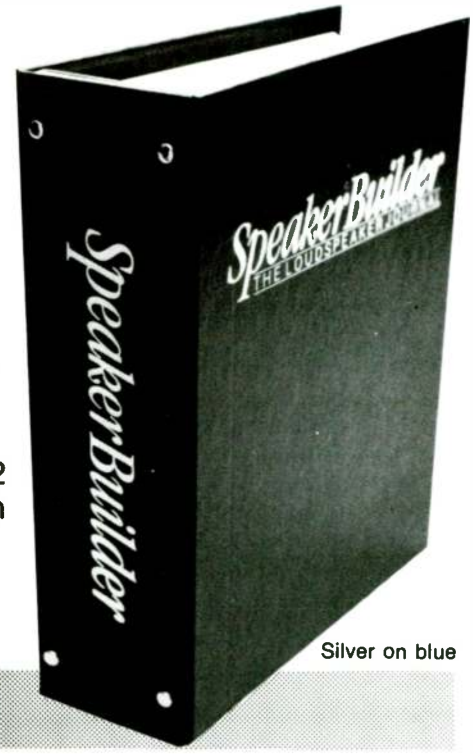

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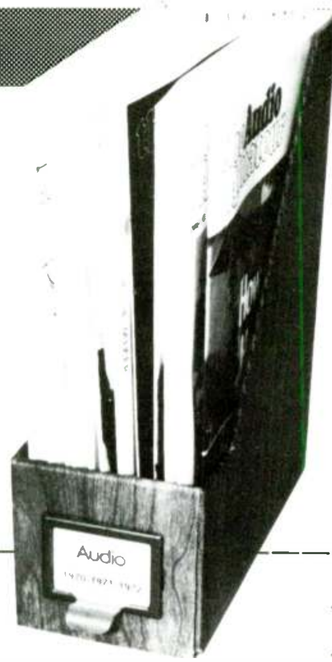

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ESL MATCHING TRANSFORMERS. As discussed earlier, when using conventional amplifiers, you must raise their output voltage drastically to drive the ESLs. This requires special transformers which, although available and reasonably priced, are difficult to find. Look for audio output transformers designed for small, high-quality tube amps. The transformer must have the following characteristics:

1) A high turns ratio (at least 40:1). The turns ratio is the square root of the secondary impedance divided by the square root of the primary impedance.

2) Adequate power handling. A conventional 15W audio transformer designed for wide bandwidth and good bass response is adequate for even the largest amplifiers when operated above 300Hz.

3) Flat frequency response when driving a capacitor of around 1,600pF.

4) Adequate insulation to handle the voltages developed. 1,500V RMS seems to be all that is readily available. Keep in mind, however, that we are working with peak voltages and 1.5kV RMS converts to 2.1kV peak-to-peak. These ratings must be very conservative because such transformers don't arc even when putting out more than 7kV. Transformers are normally used to drive essentially resistive loads, and are therefore tested into resistive loads. You cannot trust the manufacturer's specifications. When driving a 1,500 to 2,000pF capacitive load, a transformer's high-frequency response will be only about one-third of what the manufacturer specifies.

You must make a few compromises when evaluating transformers. First, to obtain an extended high-frequency response, you must compromise other parameters such as the turns ratio. The higher the turns ratio, the poorer the high-frequency response. Second, you must make a similar compromise with power handling in that large transformers tend to have a lower frequency response than small ones. Conveniently, large transformers are needed for bass performance, but we are not using our ESLs as woofers.

TRANSFORMER TESTING. Unless you buy transformers known to operate ESLs satisfactorily, test your potential selection. The engineering data and mathematics available will not accurately predict the behavior of a transformer driving a capacitor. All information I have found indicates the transformer will roll off at some high frequency, which is true. What isn't mentioned is the resonant peak somewhere below that.

Testing requires a sine-wave audio generator and vacuum-tube voltmeter (VTVM) or FET volt-ohmmeter (VOM) suitable for measuring audio frequencies. Connect your generator-driven amplifier to the low-impedance side of your transformer. You will probably have a choice of various input taps, typically 4, 8 and 16Ω. The lowest impedance taps will produce the highest turns ratio, and you will want to use the 0-4Ω taps.

A knowledgeable reader pointed out that you obtain the highest turns ratio by connecting between the 4 and 8Ω taps, which produces an 8dB increase in output over the 0-4Ω taps. However, my transformer's frequency response was not satisfactory at this higher turns ratio. Test the transformer at all the taps to determine the best compromise between frequency response and turns ratio. Your choice of secondary taps is simple: always choose the highest impedance ones to connect to your load. You may use your speakers for the load, but it is usually more convenient to use a small capacitor of equal value. Connect your meter across the load for measurements. Do not exceed about 300V at the output of the transformer, or you may arc the meter.

Sweep the frequency range of interest (400Hz to 15kHz) looking for a resonant peak. A rapid rolloff will follow the peak. You will almost certainly discover a resonant peak of 3-6dB somewhere between 4kHz for a poor transformer and more than 20kHz for a superb one. I have encountered transformers with no resonant peak, but they also rolled off well below 10kHz.

I have tested nearly a hundred transformers over the years and have found only three suitable. One set came out of an old Williamson 10W tube amp, and the others were designed as small high quality tube output transformers. One of these is made in the US, and the other is Japanese. The American one is still manufactured by Triad Corporation (part number S-142A) and is rated at 15W from 7Hz-50kHz. Using their 0-4Ω input taps, it has a 45:1 turns ratio, is flat to 10kHz, +2dB at 15kHz, +4dB at 20kHz, and +6dB at 24kHz, its resonant peak. They cost about $50 each and can be ordered from any Triad dealer.

When Triad transformers are used with a Hafler 500, the combination can produce the maximum voltages that these speakers can withstand. I have occasionally seen arcing on master tapes playing extremely loud passages with tremendous amounts of timpani and French horn. If you manage to obtain a higher voltage drive, you should increase the diaphragm-to-stator spacing of your cells by using 80-mil polycarbonate insulators and increase the polarizing voltage. Otherwise, the additional voltage will not be usable.

This combination performs as well as a high-voltage amplifier. You cannot audibly detect a smooth rise of 2dB between 10 and 15kHz, and even if you could, virtually all source material is deficient in this range and can benefit from the slight boost. While the Triad transformers are satisfactory, if anyone knows of a source of better performing transformers, I would appreciate knowing about them.

HV POWER SUPPLY. You must give the diaphragm an electrostatic charge of about 3kV. But for a small amount of leakage, we would have to charge them only once and would not need a power supply. The power supply need deliver only a tiny amount of current; 0.1mA is plenty. Power supply ripple will not cause hum in this application, so quality standards are very low. No filtration,

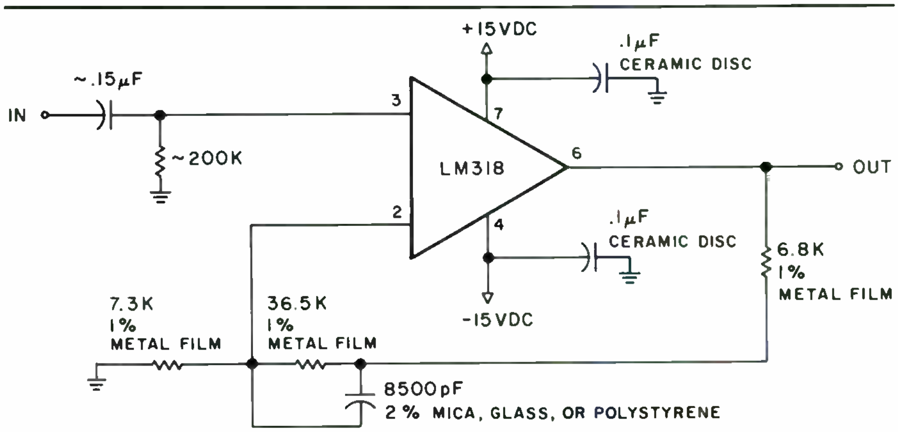

FIGURE 6: Schematic for one channel of an equalizer with gain for the electrostatic panels.

storage or full-wave diode bridges are required. Since a high polarizing voltage is critical to high SPLs, and because diaphragm tensions and building accuracy vary, you need some adjustability in this supply.

Unfortunately, there is no ready source for such supplies. Copy machine power supplies are commonly available from surplus electronics outlets for about $10. They usually develop around 7kV and will need to have their voltage reduced. You can accomplish this easily with a voltage divider at the input. Frequently you can simply add series resistance to reduce the output. Of course, the ultimate control would be a variable autotransformer, but resistance is much cheaper and more compact.

If you have some electronics background, it is easy to make a transformer/diode power supply. The catch is getting a small, high-voltage transformer rated at about 2,100V RMS, which when rectified will be in the required 3kV range. You can gang several smaller transformers, use voltage doubler, tripler, or quadrupler circuits, or use a combination of these to get the required voltage.

A well built set of cells will tolerate about 3kV of bias voltage. Cells with warped stators or a low or uneven diaphragm tension will handle only about half that. If you turn up the voltage excessively, the diaphragm will usually move over to the stator and stick there while hissing and possibly arcing. Sometimes it will move over to the stator, arc and pop back to its neutral position. It will repeat this indefinitely until the voltage is reduced. A few such arcs don't seem to harm anything, but arcing should not be allowed to persist.

If you have a bad spot, the problem will be either poor diaphragm tension, a warped stator, or a foreign object between the stator and diaphragm. Check the stator by laying a straightedge over the area. Adjust the bias voltage so the cells are always stable, but don't push it to the ragged edge, as the slight gain in output isn't worth the frustration of arcing or unstable cells.

You can mount the ESL transformers in a separate chassis along with the high-voltage power supply and keep them with your amplifiers, or you can mount them in each TL in the unused space behind the woofer baffle. The latter has the disadvantage of requiring two high-voltage power supplies, one in each speaker. You also will have to run rather large speaker wire from the amps to the transformers, and an AC power cord to a wall socket to energize the power supply. The advantage is that you will have one less chassis.

The advantages of having a separate chassis are that you need only one power supply, the wires running from the transformer to the ESL may be very small, you will not have AC power cords running all over the place, and the chassis may be specifically designed for high-voltage parts. I prefer the separate chassis. I built mine from ¼″ Plexiglas so I could mount high-voltage parts directly without having to worry about arcing to a metal chassis. Remember, when you deal with high-voltage parts, plenty of space between parts is the best insulation.

SET UP. Because of the parallelogram shape, you can place these speakers directly against a wall without compromising dipole radiation. With the exception of corner horn designs, however, it is always better to keep the speaker some distance away from the wall. To guarantee holographic quality images, you must be geometrically precise about speaker position relative to your seating location.

Begin by removing the grille cloth and squaring the speaker sides with the wall. Sit in your listening chair and look for the reflection of your face in the speakers. This is usually easy to see, but a flashlight just above your head will make it more obvious. Move your chair until your reflection is centered between the vertical borders of both ESLs, in the same location vertically on both speakers, and is centered between them left to right. If necessary, you can shim under the speakers or install adjustable feet.

Now measure from the center of the back of your chair to the reflection points. This must be the same distance for both speakers. If it isn't, then rotate at least one of the speakers so the distance is the same.

The front of the enclosure is angled slightly upward so that when you are seated, the junction of the upper and lower cells is not at ear level. You may need to shim or use a different height chair to get your reflection off this area. Failure to do so will compromise high-frequency performance and imaging.

Improper setup will prevent the speakers from fulfilling their potential. When set up correctly, the phasing/imaging is so good that moving your head to the left will not shift the image to the left as with conventional speakers, but rather to the right. In other words, your brain prefers phasing precision over loudness when determining source position.

For optimum beam splitter performance, you must have a hard surface behind the speakers. A bare wall or window is best. Heavy drapes, cork walls, or other sound-absorbing materials will reduce rear-wave output and hence dispersion. While the sound at the focal point (your listening chair) is always best, the speakers will produce adequate sound anywhere in the room because of the beam splitter.

ESL hookup wire must be able to handle high voltages, but the current requirements are very low. Therefore, the wire can be quite small. Test probe wire works well but is expensive and bulky, particularly since you need three wires to each ESL. A better choice is Teflon-coated wire, which typically uses silver-coated copper conductors. AC signals are carried on the surface of the wire, and silver is more conductive than copper. Teflon insulation is quite thin but effective. I have found 22-gauge wire adequate, and have never had arcing problems as long as the insulation has been intact, even when driving more than 7kV through the speakers.

If the wires are close together, they can become capacitively and inductively in-

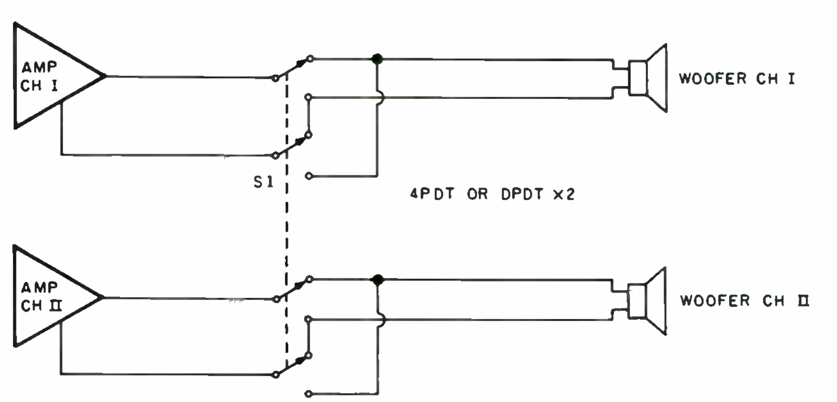

FIGURE 7: Woofer-to-ESL phase test circuit.

teractive, which results in increased stray capacitance and impedance. This is not a big problem, but you can avoid it by keeping the wires separated by ¼ inch or so.

The best high-voltage connectors I have found are plain old banana plugs. They are better insulated than other connectors, are very easy to use and have been completely reliable in my system.

Make sure the phasing between the two channels is correct. Determining the correct phasing between each ESL and its respective woofer is more difficult. You must do this by ear after the system is fully operational. The effect of ESL/woofer phasing is subtle, but generally you can detect a slight increase in fullness in the upper bass/lower midrange when the drivers are in phase. This is audible only if you have used high-quality odd-order Butterworth filters in the crossovers. It is somewhat difficult to evaluate this if there is a significant delay while you reverse the leads to your woofers. It is helpful to make an instant A-B tester (*Fig. 7*).

CRITICAL ADJUSTMENT. Matching the woofer level to the ESL level will make or break your system. I cannot overemphasize the importance of this adjustment. Without sophisticated instrumentation, you must achieve the correct frequency balance subjectively. I can offer some suggestions to help guide you.

Unlike most ESLs, these do not sound bright and thin; nor is the TL bassy and thin. Optimally, the system should have the full, rich sound of the best magnetic speakers, but with electrostatic detail, imaging and delicacy.

Adjust the bass level while listening to the midrange, which should be full but completely clean. A lack of definition in the midrange indicates the woofer level is too high. If the midrange is thin, the woofer level is too low.

All this assumes you have first-class source material. Be particularly careful if you are using a male voice as a reference. Good recordings of the male voice are rare because cardioid microphones exhibit a proximity effect when used at close range. This produces exaggerated bass and is largely responsible for the unnatural quality of male voices and guitars typically noted on commercial source material. I also assume you are using the crossover point and equalization I have specified. If not, you are on your own.

If the deep bass response is inadequate, either your source material lacks deep bass information or the damping material in your line is packed too tightly. Room acoustics also might affect the woofers, although the ESLs are immune to this problem. To determine if acoustics are a problem, try the speakers in different locations in the same room and in different rooms.

THE SOUND. It would be foolish to believe what an obviously biased designer has to say about his latest creation, so I will simply review the system's design parameters and point out what they are known to accomplish.

First, this system is electrostatic. Therefore, it has the detail, smoothness, transient response and delicacy inherent in that operating principle.

Second, I have carefully attended to linear frequency response, as demonstrated by the selection of crossover types and frequencies, equalization, rear-wave delay paths, woofer systems and driver balance. This system does not have the thin, bright, anemic character typical of electrostatics. Rather, it has a full, rich, powerful sound similar to that of the best magnetic speakers.

Third, at the outset it was clear that the biggest problem was going to be obtaining high output. I have extensively outlined the methods for accomplishing this. As a result, the system will reproduce commercial source material at levels well above those any reasonable human being can tolerate. It is even capable of reproducing "Row A" concert hall levels with clarity and ease.

Fourth, I have discussed imaging and dispersion and the unavoidable compromises associated with both. With the introduction of beam-splitter technology, I have largely resolved this very difficult issue. The focal point image has a degree of three-dimensionality and spatial definition you must experience to appreciate. The soundstage is reproduced between the speakers much as a visual image is produced by a laser holograph. At the same time, casual listening is not compromised.

Finally, distracting qualities such as edginess, exaggeration of noise, boxiness, strain and listening fatigue are absent. The speakers are neutral and able to extract full detail from all types of music. You also will not find it necessary to turn the volume way up to get the speakers to "bloom." The details can be heard at low levels.

FURTHER RESEARCH. Much work remains to be done to gain a better understanding of membrane speaker operation. The most pressing need is achieving larger excursions so smaller radiating areas may be used. The most promising approach is stacked (sandwiched) cells operated at higher voltages. These will require better transformers or acceptable direct drive amplifier designs. The cells also need to be more rugged. We need to understand why diaphragms "evaporate" as they age. Finally, the beam-splitter concept is new and needs refinement.

While these physical parameters are important, I find psychoacoustics intriguing. I have made several observations that have no clear-cut scientific answers and would like to know more about the issues. First, a single planar speaker has a tweeter beam as wide as the speaker, but when crossed during stereo listening, the beams subjectively become infinitely narrow. Second, planar ESLs sound subjectively louder than wide-dispersion ones, even though they radiate identical energies. Third, why are phase relationships so different between planar cells, curved planes, and domes/cones? I encourage anyone who has done, or is interested in doing, research in these areas to contact me with results or advice.

As always, I remain available to answer questions and assist with problems. Letters should include an SASE, and phone calls are best late in the evening (9 to 11 p.m. Pacific time). My address is Roger R. Sanders, Route 1, Box 125, Halfway, OR 97834, (503) 742-5023.

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TWEETERS	**1627**:72 CT 13/45 (cone tweeter)	8	1800			50	92			$8.50
	1730: 62CT 13/40 PPb (cone tweeter)	8	1500			60	89.5			9.00
	1528:94 DT 26/72 SF (SKO10)	8	1000			50	93			13.00
	1543:100DT 26/60 SF (LR10)	4	1128			100	90			11.50
	1544:100DT 26/60 SF (LR10)	8	1100			100	90			11.50
	1545:100DT 26/72 SF (SR10)	4	1066			100	93			13.00
	1546: 100DT 26/72 SF (SR10)	8	1100			100	93			13.00
	0665:115DT 26/72 SF (KO10DT)	8	1000			100	91			22.00
	1647:100HT 26/72 SF (Horn Tweeter)	8	1000			100	100			17.00
	4255: Voice coil (SKO-SR-LR-1647)	8				100				5.00
	4648: Voice coil (SKO-SR-LR-1647)	4				100				5.00
MIDRANGES	**1214**:134 DMR 51/100 SF (KA/J20DMR)	8	300	.65		120	89	chambered		$31.50
	1646:140 HDM 51/100 SF (Horn Mid)	8	450			120	93			31.00
	1385:122 MF 26/72 SP (KO40MRF)	8	230	.8		100	91	chambered		29.00
	1615:122 M 26/72 PPB (TO105)	8	400			150	90	chambered		32.00
	1602:130 MF 26/90 SP (Paper cone)	8	73	.28	6.3	150	90.8	2V	120	29.50
	4930: Replacement voice coil for 1214 mid									11.50
	4929:Replacement voice coil for 1646 horn mid									11.50

Madisound: Your source for Peerless Speakers

Peerless

	Model	Imp. Ω	Fs Hz	Qts	Vas Ltrs	Power Pgrm Watts	Efficiency db	Box Liter Sealed-Vented	F3 Hz	Price Each
WOOFERS	**1534**:130 WF 26/72 PPB (TO125F)	4	63	.42	8	60	88	1.3S/9V	77/58	$23.50
	1508 (1745)130 WF 26/72 PPB (TO125F)	8	60	.43	10	60	88	1.8S/12V	123/54	23.50
	1591:130 WR 26/72 PPB (TO125R)	4	55	.38	8	60	86	7V	57	24.50
	1592:130 WR 26/72 PPB (TO125R)	8	51	.46	9.7	60	86	2S/15V	98.5/41	24.50
	1593:130 WR 26/72 SP (KO50WG)	8	55	.37	10.5	60	87	8V	61	24.50
	1597:165 WF 33/100 PPB (TP165F)	4	39	.29	31.3	80	90.5	11V	61	27.00
	1429:165 WF 33/100 PPB (TP165F)	8	39	.31	34	80	90	14V	57	27.00
	1594:165 WR 33/100 PPB (TP165R)	4	38	.27	32	80	89	9V	66	30.00
	1599:165 WR 33/100 PPB (TP165R)	8	35	.34	37	80	88.5	21V	44	30.00
	1510:210 WF 26/72 PPB (TO205F)	8	45	.8	45	120	89	48S	50	22.50
	1604:210 WF 33/100 PPB (TX205F)	4	34	.34	73	120	91	42V	43	28.00
	1556:210 WF 33/100 PPB (TX205F)	8	34	.3	75	120	91	28V	52	28.00
	1722:210 WR 39/115 PPB (TD205R)	4	36	.41	50.7	125	89	8S/53V	77/35	38.00
	1721:210 WR 39/115 PPB (TD205R)	8	36	.41	50.7	125	89	8S/53V	77/35	38.00
	1603:250 WF 33/100 PPB (TX255F)	4	30	.42	153	120	91	26S	63	33.50
	1531:250 WF 33/100 PPB (TX255F)	8	28	.4	180	120	92	26S	63	33.50
	1565:250 WF 39/115 PPB (TD255F)	8	35	.33	110	140	93	57V	46	40.50

	Model	Imp. Ω	Fs Hz	Qts	Vas Ltrs	Power Pgrm Watts	Efficiency db	Xmax mm peak	Box Liter Sealed-Vented	F3 Hz	Price Each
CC LINE	**1687**:105 DT 26/72 SF (Round KO10DT)	8	980			100	91				$18.00
	1733:146 MR 26/102 PPB/AL (5¾" Midrange)	8	50	.29	10.8	130	87.9	±4	6V	67	30.50
	1757:180WR 33/102 PPB (7" Woofer)	4	36	.29	27	120	87	±5.5	20V	44	36.00
	1732: 180WR 33/102 PPB (7" Woofer)	8	40	.37	24	120	87.3	±5.5	20V	42	36.00
	1758:220 WR 33/102 PPX/AL (8½" Woofer)	4	30	.39	60	125	86.7	±5.5	54V	31	40.00
	1709:220 WR 33/102 PPX/AL (8½" Woofer)	8	25	.38	83	125	87.5	±5.5	45V	32	40.00
	1759:260 SWR 39/115 PPX/4L AL (10½" Woofer)	4	22	.34	125	150	88	±8.5	71V	28	52.00
	1727: 260 SWR 39/115 PPX/4L AL (10½" Woofer)	8	24	.38	105.7	150	87.6	±8.5	35S/87V	40/25	52.00
	1760: 315 SWR 39/115 PPX/4L AL (12½" Woofer)	4	24	.48	222	300	89.5	±5.0	60S	43	62.00
	1715: 315 SWR 39/115 PPX/4L AL (12½" Woofer)	8	18	.28	372	300	90.5	±5.0	111V	30	62.00

What Are Those Numbers??

1	2	3	4	5	6	7	8	9
1474	303	W	F	39/	115	HP	4L	AL

1 Model Number
2 Outer Diameter mm.
3 Tweeter, Midrange, Woofer
4 Surround: Foam, Rubber
5 Voice Coil Diameter mm. 4L=4 layer coil, AL=Aluminium
6 Magnet Diameter mm.
7 Cone Material SF—Soft Fabric, SP—Soft Paper,HP—Hard Paper, PPB—Polypropylene Black, PPX—Polypropylene extra thick
8 4L = 4 layer coil
9 AL = Aluminum short circuiting ring

Fast Reply #GE634

Madisound Speaker Components
8608 University Green
Box 4283 Madison WI 53711
Phone: 608-831-3433
Fax: 608-831-3771

Ordering Information: All speaker orders will be shipped promptly, if possible by UPS. COD requires a 25% prepayment, and personal checks must clear before shipment. Adding 10% for shipping charges facilitates shipping procedure (Residents of Alaska, Canada and Hawaii, and those who require Blue Label air service, please add 25%) There is no fee for packaging or handling, and we will refund to the exact shipping charge. We accept Mastercharge or Visa on mail and phone orders.

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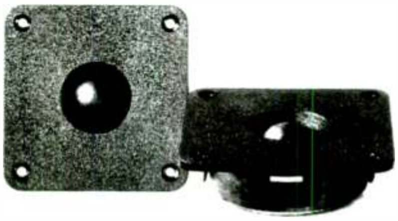
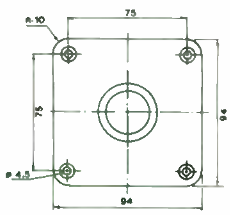
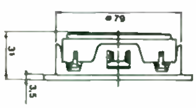
1528 Dome Tweeter 94 DT 26/72 SF 8 Ω (SKO10DT-N/8)

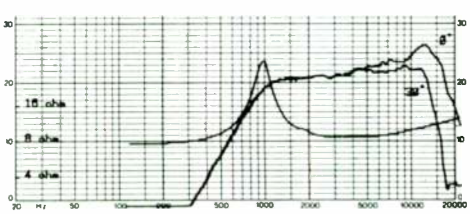




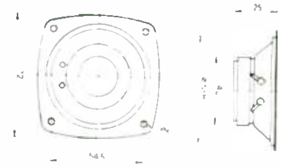


The construction of this unit is similar to that of No. 811546, but the aperture in the front flange has a different shape which gives this tweeter a somewhat aggressive performance, preferred by some, due to a lift in output at the higher frequencies.

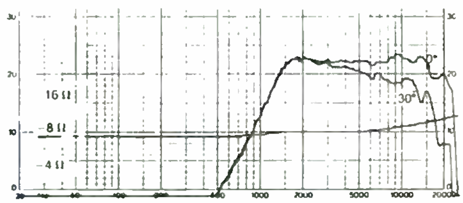
Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	8.3
Maximum impedance	Zo	<Ohm>	42
Dc resistance	Rdc	<Ohm>	7.2
Voice coil inductance	L	<mH>	0.1
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	1
Resonance frequency	fs	<Hz>	990
Total Q factor	Qts		0.8
Moving mass	Mmd	<g>	0.23
Force factor	BL	<N/A>	3.5
Working power		<W>	2.8
Characteristic efficiency level		<dB>	91.5
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	1.6
Voice coil layers	n		2
Flux density	B	<T>	1.5
Flux in the gap	Ø	<mWb>	0.3
Height of the gap	hg	<mm>	2.5
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.24
Rated power IEC (With 4000 Hz/12 dB crossover)		<W>	100
Rated power IEC (With 2000 Hz/12 dB crossover)		<W>	50



1627 Cone Tweeter 72 CT CT 13/45 PPb



Nominal impedance	Ohm	8
Min. Impedance	Ohm	8.0
DC resistance	Ohm	7.2
Resonance frequency	Hz	1800
Susp. Compliance		
Mech. Qfact.		1.2
Electr. Qfact.		6
Total Qfact.		1
Mechanical Resistance		
Moving mass	g	0.3
Eff. piston area	cm^2	18
Equivalent Volume		
Voice coil dia.	mm	13
Voice coil layers		2
Flux density	T	1.2
Flux in gap	mWb	0.1
Force factor	N/A	2
Height of gap	mm	2
Dia. of magnet	mm	45
Height of magnet	mm	8
Weight of magnet	g	55
Characteristic eff.	dB	92
Rated power	W	50
Music power		
u. Conditions	uF	4.7 in series
Recomm. freq. range	Hz	2000-20000



Ordering Information: All speaker orders will be shipped promptly, if possible by UPS. COD requires a 25% prepayment, and personal checks must clear before shipment. Adding 10% for shipping charges facilitates shipping procedure (Residents of Alaska, Canada and Hawaii, and those who require Blue Label air service, please add 25%). There is no fee for packaging or handling, and we will refund to the exact shipping charge. We accept Mastercharge or Visa on mail and phone orders.

Madisound Speaker Components
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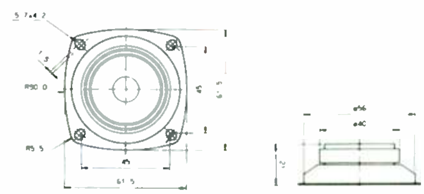
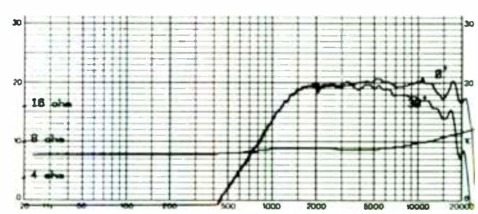
Madison WI 53711
VOICE (608) 831-3433
FAX (608) 831-3771

1730 Cone Tweeter 62 CT 13/40 PPb 8 Ω (K24PP/8)



This new cone tweeter from Peerless should remove all doubts using a cone tweeter for HiFi systems. Listen to it, and take a look at the frequency response. The voice coil is cooled by magnetic oil, and viscous damping eliminates the impedance rise in resonance – otherwise so disturbing for filter design. An absolute excellent tweeter.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.4
Maximum impedance	Zo	<Ohm>	6.8
Dc resistance	Rdc	<Ohm>	5.9
Voice coil inductance	L	<mH>	0.1
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	1
Resonance frequency	fs	<Hz>	1500
Total Q factor	Qts		0.8
Moving mass	Mmd	<g>	0.28
Force factor	BL	<N/A>	3.0
Working power		<W>	4.5
Characteristic efficiency level		<dB>	89.5
Voice coil diameter	d	<mm>	13
Voice coil length	h	<mm>	1.8
Voice coil layers	n		2
Flux density	B	<T>	1.0
Flux in the gap	Ø	<mWb>	0.1
Height of the gap	hg	<mm>	2.5
Diameter of magnet	dm	<mm>	40
Height of magnet	hm	<mm>	7.5
Weight of magnet		<kg>	0.04
Rated power IEC (With 4000 Hz/12 dB crossover)		<W>	60
Rated power IEC (With 2000 Hz/12 dB crossover)		<W>	40



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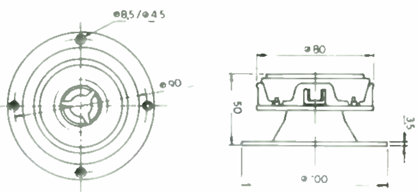
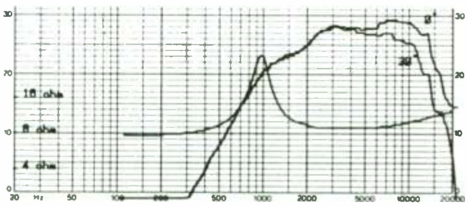
1647 Horn Tweeter 100 HDT
26/72 SF 8 Ω

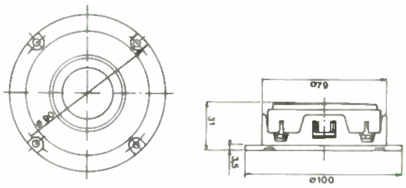


Dome tweeter horn of the most modern technique. The mounted horn with phase plug combines the high sensitivity of horn speakers with the undistorted, smooth response of a dome tweeter. High power handling and replaceable self-centering dome assembly. Especially suitable for disco boxes.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	8.3
Maximum impedance	Zo	<Ohm>	40.2
Dc resistance	Rdc	<Ohm>	7.2
Voice coil inductance	L	<mH>	0.1
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	1
Resonance frequency	fs	<Hz>	980
Total Q factor	Qts		0.8
Moving mass	Mmd	<g>	0.23
Force factor	BL	<N/A>	3.5
Working power		<W>	0.5
Characteristic efficiency level		<dB>	99.0
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	1.6
Voice coil layers	n		2
Flux density	B	<T>	1.5
Flux in the gap	Ø	<mWb>	0.3
Height of the gap	hg	<mm>	2.5
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.24
Rated power IEC (With 4000 Hz/12 dB crossover)		<W>	100
Rated power IEC (With 2000 Hz/12 dB crossover)		<W>	50

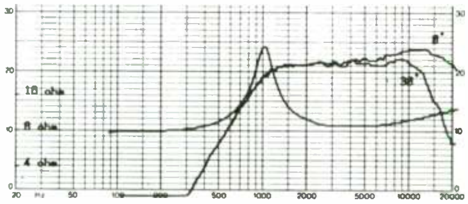


1546 Dome Tweeter 100 DT
26/72 SF 8 Ω
(SR10/8)
IN STOCK **1545** 4 Ω

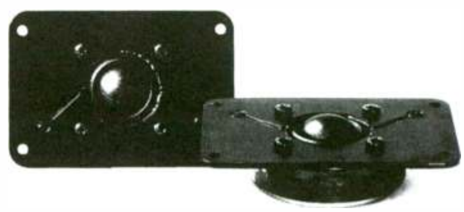


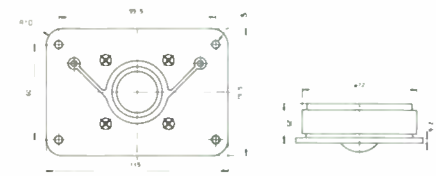
This is the most versatile Peerless tweeter. It incorporates many advantageous features: High sensitivity, smooth frequency response up to 30 kHz, absolutely natural reproduction, and high power handling capacity. The tweeter is tested with 2150 W for 1 ms at 5 kHz, and the response is just as clear and nice as for 1 W! The tweeter has an easily replacable self-centering diaphragm assembly.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	8.3
Maximum impedance	Zo	<Ohm>	42
Dc resistance	Rdc	<Ohm>	7.2
Voice coil inductance	L	<mH>	0.1
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	1
Resonance frequency	fs	<Hz>	1020
Total Q factor	Qts		0.8
Moving mass	Mmd	<g>	0.23
Force factor	BL	<N/A>	3.5
Working power		<W>	2.8
Characteristic efficiency level		<dB>	91.5
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	1.6
Voice coil layers	n		2
Flux density	B	<T>	1.5
Flux in the gap	Ø	<mWb>	0.3
Height of the gap	hg	<mm>	2.5
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.24
Rated power IEC (With 4000 Hz/12 dB crossover)		<W>	100
Rated power IEC (With 2000 Hz/12 dB crossover)		<W>	50



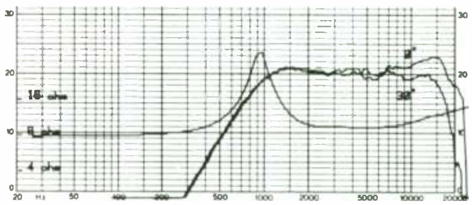
665 Dome Tweeter 115 DT
26/72 SF 8 Ω
(KO10DT/8)





An "evergreen" among dome tweeters, this famous unit has been on the market for several years. It has been copied many times, but never equalled. This dome tweeter has gained a reputation as one of the best tweeters by experts all over the world. This is proved by its use in studio monitors by broadcasting stations and in "high-end-of-the-market" loudspeaker boxes.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	8.3
Maximum impedance	Zo	<Ohm>	42.0
Dc resistance	Rdc	<Ohm>	7.4
Voice coil inductance	L	<mH>	0.1
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	1
Resonance frequency	fs	<Hz>	980
Total Q factor	Qts		0.8
Moving mass	Mmd	<g>	0.23
Force factor	BL	<N/A>	3.5
Working power		<W>	3.5
Characteristic efficiency level		<dB>	90.5
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	1.6
Voice coil layers	n		2
Flux density	B	<T>	1.5
Flux in the gap	Ø	<mWb>	0.3
Height of the gap	hg	<mm>	3.0
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.24
Rated power IEC (With 4000 Hz/12 dB crossover)		<W>	100
Rated power IEC (With 2000 Hz/12 dB crossover)		<W>	50



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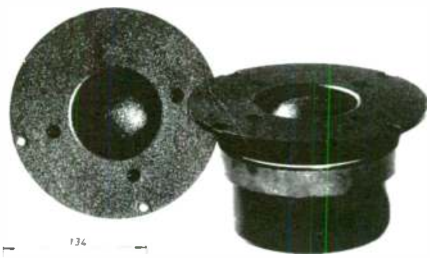
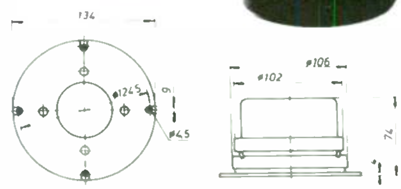
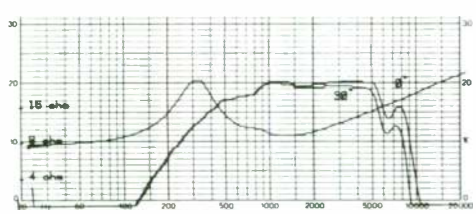
1214 Midrange 134 DM 51/100 SF 8 Ω (KA20DMR/8)



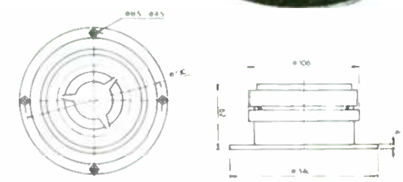


The well-known high class 51 mm dome midrange with very good price/quality relationship. The front flange has a special construction: The dome is set in a cylindrical aperture which forms an acoustic lens, providing excellent dispersion characteristics.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	8.6
Maximum impedance	Zo	<Ohm>	28.9
Dc resistance	Rdc	<Ohm>	7.3
Voice coil inductance	L	<mH>	0.4
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	6
Resonance frequency	fs	<Hz>	310
Total Q factor	Qts		0.5
Moving mass	Mmd	<g>	2.5
Force factor	BL	<N/A>	5.8
Working power		<W>	4.5
Characteristic efficiency level		<dB>	89.5
Voice coil diameter	d	<mm>	51
Voice coil length	h	<mm>	5.5
Voice coil layers	n		2
Flux density	B	<T>	1.0
Flux in the gap	Ø	<mWb>	0.7
Height of the gap	hg	<mm>	4.0
Diameter of magnet	dm	<mm>	100
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.47
Rated power IEC (>800 Hz)		<W>	120

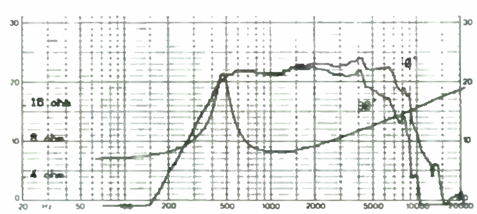


1646 Horn Midrange 140 HDM 51/100 SF 8 Ω

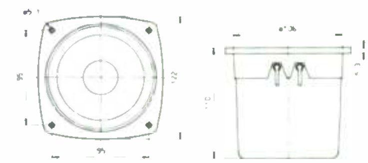


This is a horn midrange speaker with phase plug. The special horn construction gives a high sensitivity and extremely good sound dispersion. Suitable for high sensitivity systems. Especially suitable for disco boxes.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.6
Maximum impedance	Zo	<Ohm>	29
Dc resistance	Rdc	<Ohm>	5.5
Voice coil inductance	L	<mH>	0.4
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	6
Resonance frequency	fs	<Hz>	470
Total Q factor	Qts		1.0
Moving mass	Mmd	<g>	2.5
Force factor	BL	<N/A>	5.8
Working power		<W>	2.0
Characteristic efficiency level		<dB>	93.0
Voice coil diameter	d	<mm>	51
Voice coil length	h	<mm>	5.5
Voice coil layers	n		2
Flux density	B	<T>	1.0
Flux in the gap	Ø	<mWb>	0.7
Height of the gap	hg	<mm>	4.0
Diameter of magnet	dm	<mm>	100
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.47
Rated power IEC (>800 Hz)		<W>	120

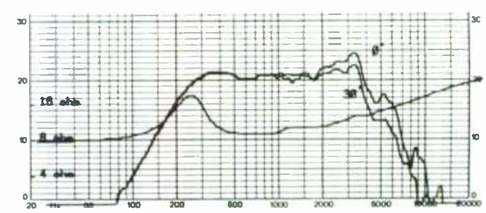


1385 Midrange 122 MF 26/72 SP 8 Ω (KO40MRF/8)



A closed-back midrange speaker whose die-cast housing forms an integrated non-resonant rear loading chamber and basket in one piece, eliminating window distortion. The long-fibred soft paper cone and foam surround gives this midrange a smooth frequency response.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	8.5
Maximum impedance	Zo	<Ohm>	20.2
Dc resistance	Rdc	<Ohm>	7.1
Voice coil inductance	L	<mH>	0.5
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	7
Resonance frequency	fs	<Hz>	262
Total Q factor	Qts		0.9
Moving mass	Mmd	<g>	4.0
Force factor	BL	<N/A>	6.0
Working power		<W>	3.2
Characteristic efficiency level		<dB>	91.0
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	5.7
Voice coil layers	n		2
Flux density	B	<T>	1.1
Flux in the gap	Ø	<mWb>	0.5
Height of the gap	hg	<mm>	5.0
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.24
Rated power IEC (>800 Hz)		<W>	100



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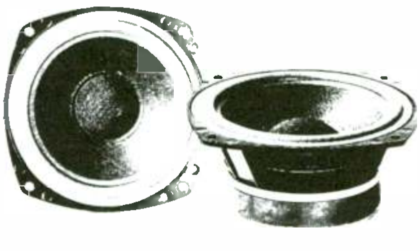
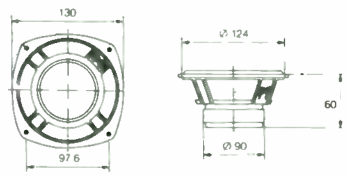
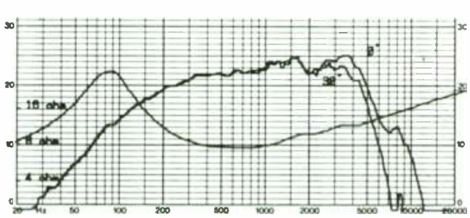
1602 Midrange 130 MF 26/90 SP 8 Ω



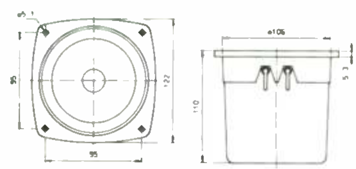


The midrange speaker for the most critical requirements. It has a die-cast basket and is an open-back type. A special heavy magnet and a 25 mm voice coil guarantee an extraordinary good transient response. Coloration free reproduction and lowest distortion even at the highest sound levels are special characteristics of this unit. Closed rear loading chamber should be from 1 to 5 l.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.9
Maximum impedance	Zo	<Ohm>	34.1
Dc resistance	Rdc	<Ohm>	6.1
Voice coil inductance	L	<mH>	0.5
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	7
Resonance frequency	fs	<Hz>	83
Total Q factor	Qts		0.32
Moving mass	Mmd	<g>	4.4
Equivalent volume	Vas	<l>	5.3
Force factor	BL	<N/A>	6.0
Working power		<W>	3.1
Characteristic efficiency level		<dB>	91.1
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	10.0
Voice coil layers	n		2
Flux density	B	<T>	1.3
Flux in the gap	Ø	<mWb>	0.6
Height of the gap	hg	<mm>	6.0
Diameter of magnet	dm	<mm>	90
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.4
Rated power IEC (>250 Hz)		<W>	120



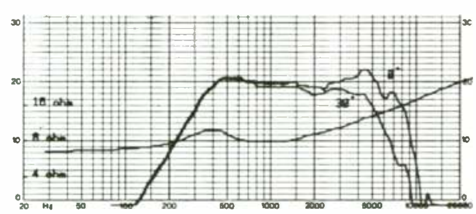
1615 Midrange 122 M 26/72 PPB 8 Ω (KO40MRX-PP-F/8)



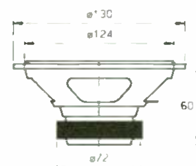
A closed-back cone midrange speaker whose die-cast housing forms an integrated non-resonant rear loading chamber and basket in one piece, eliminating window distortion.

The voice coil is damped by ferrofluid, and the black PP cone integrated with a surround of the same material gives a new adventure in sound.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	7.8
Maximum impedance	Zo	<Ohm>	8.9
Dc resistance	Rdc	<Ohm>	6.2
Voice coil inductance	L	<mH>	0.3
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	6
Resonance frequency	fs	<Hz>	410
Total Q factor	Qts		0.8
Moving mass	Mmd	<g>	5.0
Force factor	BL	<N/A>	8.0
Working power		<W>	4.0
Characteristic efficiency level		<dB>	90
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	9.0
Voice coil layers	n		2
Flux density	B	<T>	1.1
Flux in the gap	Ø	<mWb>	0.5
Height of the gap	hg	<mm>	5.0
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.24
Rated power IEC (>800 Hz)		<W>	120

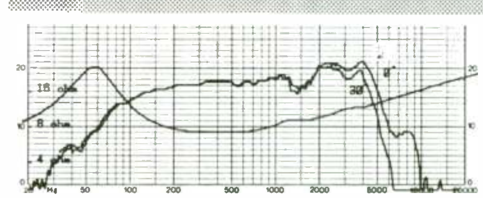


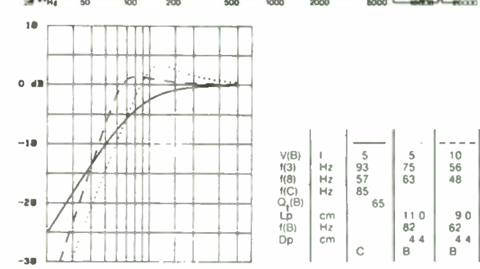
1593 Woofer 130 WR 26/72 SP 8 Ω (KO50WG/8)



Small woofer with die-cast basket with soft long-fibred paper and rubber surround. Especially suitable for very small bass reflex boxes, including built-in purposes for cars.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.7
Maximum impedance	Zo	<Ohm>	26.5
Dc resistance	Rdc	<Ohm>	6.2
Voice coil inductance	L	<mH>	0.5
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	7
Resonance frequency	fs	<Hz>	52
Mechanical Q factor	Qms		1.66
Electrical Q factor	Qes		0.51
Total Q factor	Qts		0.39
F (ratio fs/Qts)	F	<Hz>	134
Mechanical resistance	Rms	<kg/s>	1.2
Moving mass	Mmd	<g>	6.0
Suspension compliance	Cms	<mm/N>	1.6
Emissive dia. of the diaphragm	D	<cm>	9.6
Effective piston area	Sd	<cm2>	72
Equivalent volume	Vas	<l>	11.5
Force factor	BL	<N/A>	5.1
Working power		<W>	7.1
Characteristic efficiency level		<dB>	87.5
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	10.0
Voice coil layers	n		2
Flux density	B	<T>	1.0
Flux in the gap	Ø	<mWb>	0.5
Height of the gap	hg	<mm>	6.0
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.23
Music power DIN		<W>	60
Rated power IEC		<W>	50





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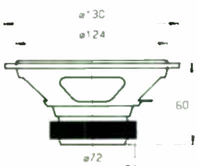
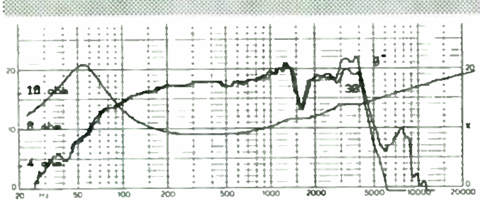
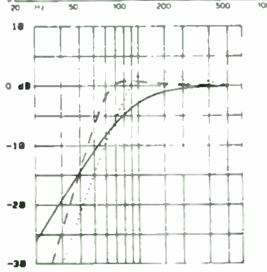
1508 Woofer 130 WF 26/72 PPB 8 Ω (TO125F/8) IN STOCK 1534 4 Ω



Small woofer with die-cast basket with polypropylene cone and foam surround. Especially suitable for very small bass reflex boxes.

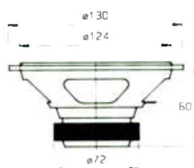
Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.7
Maximum impedance	Zo	<Ohm>	27.6
Dc resistance	Rdc	<Ohm>	6.2
Voice coil inductance	L	<mH>	0.5
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	7
Resonance frequency	fs	<Hz>	60
Mechanical Q factor	Qms		1.92
Electrical Q factor	Qes		0.54
Total Q factor	Qts		0.42
F (ratio fs/Qts)	F	<Hz>	144
Mechanical resistance	Rms	<kg/s>	1.2
Moving mass	Mmd	<g>	5.8
Suspension compliance	Cms	<mm/N>	1.2
Emissive dia. of the diaphragm	D	<cm>	9.9
Effective piston area	Sd	<cm2>	76
Equivalent volume	Vas	<l>	10
Force factor	BL	<N/A>	5.0
Working power		<W>	5.8
Characteristic efficiency level		<dB>	88.4
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	10.0
Voice coil layers	n		2
Flux density	B	<T>	1.0
Flux in the gap	Ø	<mWb>	0.5
Height of the gap	hg	<mm>	6.0
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.23
Music power DIN		<W>	60
Rated power IEC		<W>	50





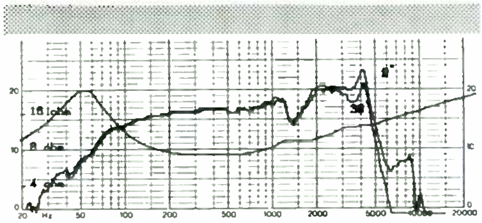
V(B)	l	5	5	10
f(3)	Hz	99	77	57
f(8)	Hz	61	63	48
f(C)	Hz	89		
Q_t(B)		65		
Lp	cm		11 0	9 0
f(B)	Hz		82	62
Dp	cm		4 4	4 4
		C	B	B

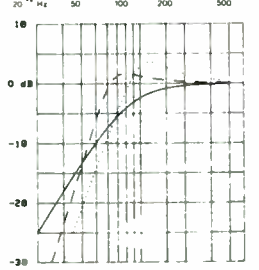
1592 Woofer 130 WR 26/72 PPB 8 Ω (TO125R/8) IN STOCK 1591 4 Ω



Small woofer with die-cast basket with polypropylene cone and rubber surround. Especially suitable for very small bass reflex boxes. May also be used as a built-in unit for cars.

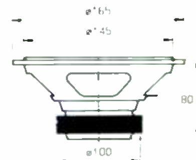
Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.7
Maximum impedance	Zo	<Ohm>	26.6
Dc resistance	Rdc	<Ohm>	6.2
Voice coil inductance	L	<mH>	0.5
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	7
Resonance frequency	fs	<Hz>	57
Mechanical Q factor	Qms		1.81
Electrical Q factor	Qes		0.55
Total Q factor	Qts		0.42
F (ratio fs/Qts)	F	<Hz>	135
Mechanical resistance	Rms	<kg/s>	1.2
Moving mass	Mmd	<g>	6.2
Suspension compliance	Cms	<mm/N>	1.4
Emissive dia. of the diaphragm	D	<cm>	9.4
Effective piston area	Sd	<cm2>	72
Equivalent volume	Vas	<l>	9.3
Force factor	BL	<N/A>	5
Working power		<W>	7.2
Characteristic efficiency level		<dB>	87.4
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	10.0
Voice coil layers	n		2
Flux density	B	<T>	1.0
Flux in the gap	Ø	<mWb>	0.5
Height of the gap	hg	<mm>	6.0
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.23
Music power DIN		<W>	60
Rated power IEC		<W>	50





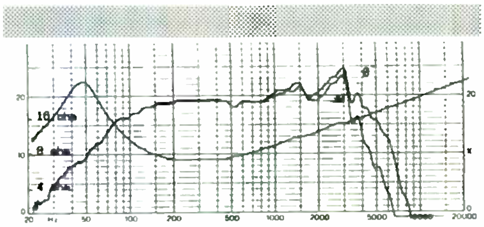
V(B)	l	5	5	10
f(3)	Hz	90	73	56
f(8)	Hz	57	61	46
f(C)	Hz	84		
Q_t(B)		65		
Lp	cm		11 0	9 0
f(B)	Hz		82	62
Dp	cm		4 4	4 4
		C	B	B

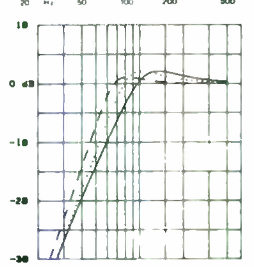
1429 Woofer 165 WF 33/100 PPB 8 Ω (TP165F/8) IN STOCK 1597 4 Ω



A woofer with excellent transparent sound reproduction. Polypropylene cone and foam surround. Suitable for small reflex and subwoofer boxes.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.8
Maximum impedance	Zo	<Ohm>	38.8
Dc resistance	Rdc	<Ohm>	6.0
Voice coil inductance	L	<mH>	0.9
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	14
Resonance frequency	fs	<Hz>	44
Mechanical Q factor	Qms		2.14
Electrical Q factor	Qes		0.39
Total Q factor	Qts		0.33
F (ratio fs/Qts)	F	<Hz>	133
Mechanical resistance	Rms	<kg/s>	1.6
Moving mass	Mmd	<g>	12.7
Suspension compliance	Cms	<mm/N>	1.0
Emissive dia. of the diaphragm	D	<cm>	13.0
Effective piston area	Sd	<cm2>	132
Equivalent volume	Vas	<l>	26
Force factor	BL	<N/A>	7.3
Working power		<W>	4.3
Characteristic efficiency level		<dB>	89.6
Voice coil diameter	d	<mm>	33
Voice coil length	h	<mm>	14.0
Voice coil layers	n		2
Flux density	B	<T>	0.95
Flux in the gap	O	<mWb>	0.8
Height of the gap	hg	<mm>	8.0
Diameter of magnet	dm	<mm>	100
Height of magnet	hm	<mm>	14.0
Weight of magnet		<kg>	0.43
Music power DIN		<W>	80
Rated power IEC		<W>	60





V(B)	l	6	10	15
f(3)	Hz	70	67	57
f(8)	Hz	65	56	48
f(C)	Hz			
Q_t(B)				
Lp	cm	12 0	6 0	5 0
f(B)	Hz	72	71	61
Dp	cm	4 4	4 4	4 4
		B	B	B

Madisound Speaker Components
8608 University Green
Box 4283 Madison WI 53711
Phone: 608-831-3433
Fax: 608-831-3771

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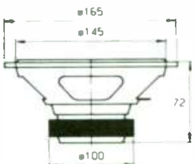
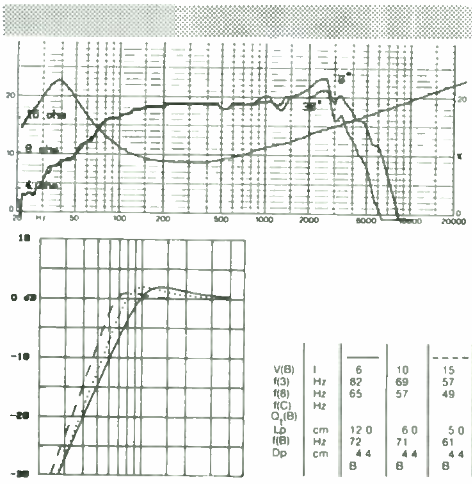
1599 Woofer 165 WR 33/100 PPB 8 Ω (TP165R/8) IN STOCK 1594 4 Ω

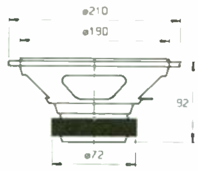


This woofer is suitable for a 2-way bass reflex system. It has rubber surround and polypropylene cone. High power handling.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.8
Maximum impedance	Zo	<Ohm>	36.9
Dc resistance	Rdc	<Ohm>	6.0
Voice coil inductance	L	<mH>	0.8
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	12
Resonance frequency	fs	<Hz>	38
Mechanical Q factor	Qms		1.75
Electrical Q factor	Qes		0.34
Total Q factor	Qts		0.28
F (ratio fs/Qts)	F	<Hz>	132
Mechanical resistance	Rms	<kg/s>	1.6
Moving mass	Mmd	<g>	12.2
Suspension compliance	Cms	<mm/N>	1.5
Emissive dia. of the diaphragm	D	<cm>	12.9
Effective piston area	Sd	<cm2>	130
Equivalent volume	Vas	<l>	36
Force factor	BL	<N/A>	7.1
Working power		<W>	4.4
Characteristic efficiency level		<dB>	89.6
Voice coil diameter	d	<mm>	33
Voice coil length	h	<mm>	14.0
Voice coil layers	n		2
Flux density	B	<T>	0.95
Flux in the gap	Ø	<mWb>	0.8
Height of the gap	hg	<mm>	8.0
Diameter of magnet	dm	<mm>	100
Height of magnet	hm	<mm>	14.0
Weight of magnet		<kg>	0.43
Music power DIN		<W>	80
Rated power IEC		<W>	60

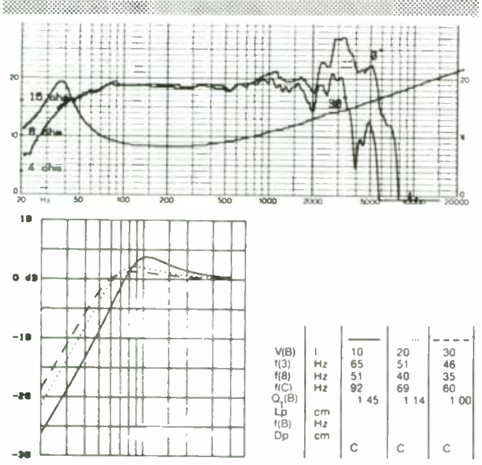


1510 Woofer 210 WF 26/72 PPB 8/6.4 Ω (TO205F/8)

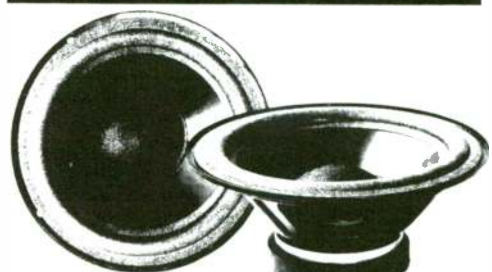


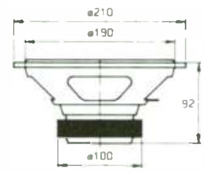
Universal application woofer for medium-sized boxes. Unique price/performance relationship. Suitable for 2 or 3-way systems. Black polypropylene cone and foam surround.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.6
Maximum impedance	Zo	<Ohm>	25.5
Dc resistance	Rdc	<Ohm>	6.0
Voice coil inductance	L	<mH>	0.8
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	11
Resonance frequency	fs	<Hz>	37
Mechanical Q factor	Qms		2.59
Electrical Q factor	Qes		0.80
Total Q factor	Qts		0.61
F (ratio fs/Qts)	F	<Hz>	61
Mechanical resistance	Rms	<kg/s>	1.3
Moving mass	Mmd	<g>	14.3
Suspension compliance	Cms	<mm/N>	1.3
Emissive dia. of the diaphragm	D	<cm>	15.6
Effective piston area	Sd	<cm2>	191
Equivalent volume	Vas	<l>	67
Force factor	BL	<N/A>	5.0
Working power		<W>	5.3
Characteristic efficiency level		<dB>	88.7
Voice coil diameter	d	<mm>	26
Voice coil length	h	<mm>	14.0
Voice coil layers	n		2
Flux density	B	<T>	1.0
Flux in the gap	Ø	<mWb>	0.5
Height of the gap	hg	<mm>	6.0
Diameter of magnet	dm	<mm>	72
Height of magnet	hm	<mm>	15.0
Weight of magnet		<kg>	0.23
Music power DIN		<W>	120
Rated power IEC		<W>	90



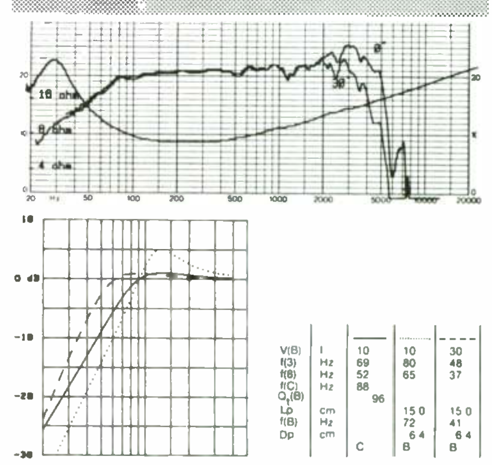
1556 Woofer 210 WF 33/100 PPB 8 Ω (TX205F/8) IN STOCK 1604 4 Ω



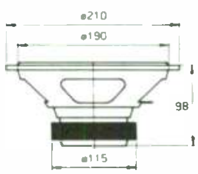


Woofer with smooth frequency response up to 3000 Hz. Suitable for reflex boxes of medium size. Voice coil dimensions allowing continuous high power handling.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.7
Maximum impedance	Zo	<Ohm>	39.2
Dc resistance	Rdc	<Ohm>	6.0
Voice coil inductance	L	<mH>	0.8
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	11
Resonance frequency	fs	<Hz>	29
Mechanical Q factor	Qms		2.06
Electrical Q factor	Qes		0.37
Total Q factor	Qts		0.32
F (ratio fs/Qts)	F	<Hz>	90
Mechanical resistance	Rms	<kg/s>	1.6
Moving mass	Mmd	<g>	18
Suspension compliance	Cms	<mm/N>	1.2
Emissive dia. of the diaphragm	D	<cm>	16.3
Effective piston area	Sd	<cm2>	208
Equivalent volume	Vas	<l>	104
Force factor	BL	<N/A>	7.2
Working power		<W>	3.6
Characteristic efficiency level		<dB>	90.4
Voice coil diameter	d	<mm>	33
Voice coil length	h	<mm>	14.0
Voice coil layers	n		2
Flux density	B	<T>	0.95
Flux in the gap	Ø	<mWb>	0.8
Height of the gap	hg	<mm>	8.0
Diameter of magnet	dm	<mm>	102
Height of magnet	hm	<mm>	14.0
Weight of magnet		<kg>	0.43
Music power DIN		<W>	120
Rated power IEC		<W>	100

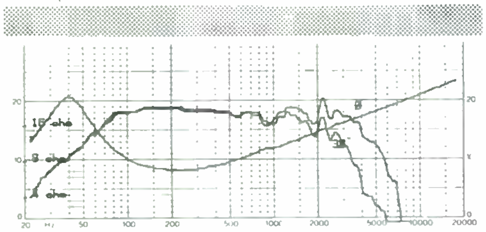


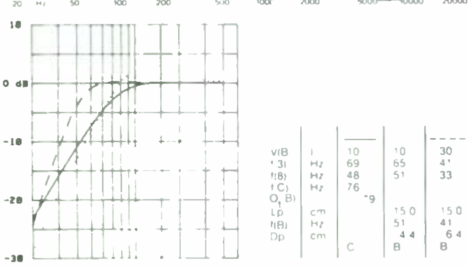
1721 Woofer 210 WR
39/115 PPB 8 Ω
(TD205R/8)
IN STOCK 1722 4 Ω



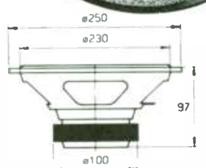
Extra high power capacity, with rubber surround and polypropylene cone. Should be used in bass reflex of medium size.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.3
Maximum impedance	Zo	<Ohm>	30.4
Dc resistance	Rdc	<Ohm>	5.2
Voice coil inductance	L	<mH>	1.1
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	17
Resonance frequency	fs	<Hz>	37
Mechanical Q factor	Qms		2.21
Electrical Q factor	Qes		0.46
Total Q factor	Qts		0.38
F (ratio fs/Qts)	F	<Hz>	99
Mechanical resistance	Rms	<kg/s>	3.0
Moving mass	Mmd	<g>	28
Suspension compliance	Cms	<mm/N>	0.6
Emissive dia. of the diaphragm	D	<cm>	16.6
Effective piston area	Sd	<cm2>	216
Equivalent volume	Vas	<l>	42
Force factor	BL	<N/A>	8.7
Working power		<W>	5.0
Characteristic efficiency level		<dB>	89.0
Voice coil diameter	d	<mm>	39
Voice coil length	h	<mm>	20.0
Voice coil layers	n		2
Flux density	B	<T>	1.2
Flux in the gap	O	<mWb>	1.1
Height of the gap	hg	<mm>	8.0
Diameter of magnet	dm	<mm>	115
Height of magnet	hm	<mm>	17.5
Weight of magnet		<kg>	0.7
Music power DIN		<W>	125
Rated power IEC		<W>	100



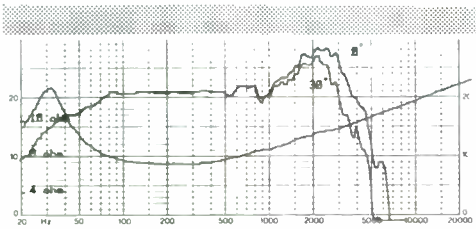


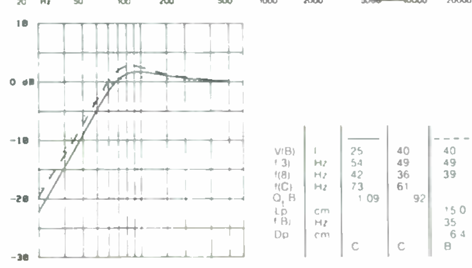
1531 Woofer 250 WF
33/100 PPB 8 Ω
(TX255F/8)
IN STOCK 1603 4 Ω



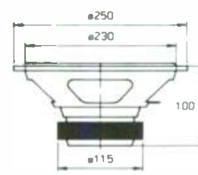
Universal application woofer for larger boxes, reflex and closed types. A high sensitivity woofer fitted with black polypropylene cone and foam surround.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	6.7
Maximum impedance	Zo	<Ohm>	36.4
Dc resistance	Rdc	<Ohm>	5.9
Voice coil inductance	L	<mH>	1.0
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	15
Resonance frequency	fs	<Hz>	33
Mechanical Q factor	Qms		2.74
Electrical Q factor	Qes		0.53
Total Q factor	Qts		0.44
F (ratio fs/Qts)	F	<Hz>	75
Mechanical resistance	Rms	<kg/s>	1.7
Moving mass	Mmd	<g>	22
Suspension compliance	Cms	<mm/N>	1.1
Emissive dia. of the diaphragm	D	<cm>	19.2
Effective piston area	Sd	<cm2>	289
Equivalent volume	Vas	<l>	125
Force factor	BL	<N/A>	7.1
Working power		<W>	3.1
Characteristic efficiency level		<dB>	91.1
Voice coil diameter	d	<mm>	33
Voice coil length	h	<mm>	14.0
Voice coil layers	n		2
Flux density	B	<T>	0.95
Flux in the gap	O	<mWb>	0.8
Height of the gap	hg	<mm>	8.0
Diameter of magnet	dm	<mm>	100
Height of magnet	hm	<mm>	14.0
Weight of magnet		<kg>	0.43
Music power DIN		<W>	120
Rated power IEC		<W>	90



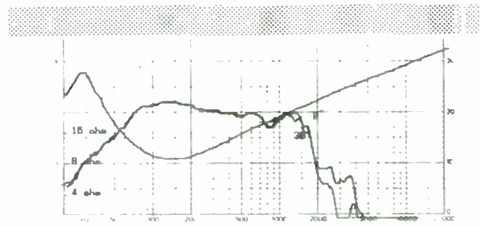


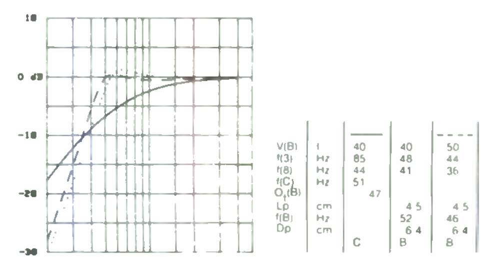
1743 Woofer 250 WF
39/115 PPB 4L 8 Ω
(TD255F/8)



This four-layer woofer is especially suited for bass reflex. High sensitivity, high power capacity and resistance to overload are some of the features offered by this unique woofer.

Nominal impedance	Z	<Ohm>	8
Minimum impedance	Zmin	<Ohm>	7.1
Maximum impedance	Zo	<Ohm>	62.0
Dc resistance	Rdc	<Ohm>	5.6
Voice coil inductance	L	<mH>	3.1
Capacitor in series with 8 ohm (for impedance compensation)	C	<uF>	47
Resonance frequency	fs	<Hz>	31
Mechanical Q factor	Qms		2.99
Electrical Q factor	Qes		0.30
Total Q factor	Qts		0.27
F (ratio fs/Qts)	F	<Hz>	113
Mechanical resistance	Rms	<kg/s>	2.4
Moving mass	Mmd	<g>	37
Suspension compliance	Cms	<mm/N>	0.7
Emissive dia. of the diaphragm	D	<cm>	19.6
Effective piston area	Sd	<cm2>	301
Equivalent volume	Vas	<l>	94
Force factor	BL	<N/A>	11.6
Working power		<W>	3.1
Characteristic efficiency level		<dB>	91.1
Voice coil diameter	d	<mm>	39
Voice coil length	h	<mm>	18.0
Voice coil layers	n		4
Flux density	B	<T>	1.0
Flux in the gap	O	<mWb>	1.0
Height of the gap	hg	<mm>	8.0
Diameter of magnet	dm	<mm>	115
Height of magnet	hm	<mm>	17.5
Weight of magnet		<kg>	0.7
Music power DIN		<W>	180
Rated power IEC		<W>	140





Madisound Speaker Components
8608 University Green
Box 4283 Madison WI 53711
Phone: 608-831-3433
Fax: 608-831-3771

Tools, Tips & Techniques

'SWANDERFUL

To all of us poor souls who cannot afford, or do not have room for, the Swan IV, take heart . . . you *can* have "half the cake and eat it too." Since a full-blown Swan IV was beyond my financial means, I decided to build a small, narrow transmission line enclosure capable of handling the two Focal 5N412 DBL drivers, Dynaudio D28, and Treble Coupler. Here's how I built my "Baby Swan."

The enclosure resembles the Craig Cushing design described in *SB* 1/88, page 57. The outside measures 46.5" × 8.75" × 13". The line is folded and measures 66" in length. I lined one side of the line with 1.5" egg-crate foam, and three sides with 1" Hollofil. At the beginning of the line, midpoint and termination, I stuffed about one fistful of long-haired wool. These points correspond to the first, third, and fifth harmonic points of the line.

The enclosure is constructed of ¾" MDF with oak veneer surface. I rounded all corners and rabbeted the drivers into the front panel. The crossover is mounted on the exterior rear surface. The drivers are wired with Apature wire.

The sound far exceeds what I had hoped for. It is very open, detailed and natural. Lateral imaging and depth is excellent, and the speakers seem to disappear from the sound stage. I can listen to it for hours without fatigue.

Early on, I worried whether the pair of Focals in the short line could produce adequate bass. I have no way to measure F3, but subjectively I believe they give good bass response down to the high 40s with diminished useful response down to the high 30s. The quality of the bass is excellent, clean and tight, but it does not overwhelm the listener at reasonable levels. I am amazed and delighted at the way they perform on the Dorian/Guillou "Pictures at an Exhibition" CD, even though this is asking a lot from a pair of 5½" drivers.

My thanks to Messrs. D'Appolito and Bock for one heck of a speaker design. I'm saving my money for the other half, but meanwhile I'm getting a lot of enjoyment out of the Baby Swan.

George Jennings
Chanhassen, MN 55317

BASS DRIVER SPECS

Increasingly, we are seeing the principle of T/S parameters F_S, V_{AS}, and Q_{TS} published in advertisements and catalogs. These specifications make it possible to evaluate products by subjecting them to mathematical scrutiny. You don't really know much about a driver until you have its T/S parameters.

Peak displacement volume and reference efficiency are the most important

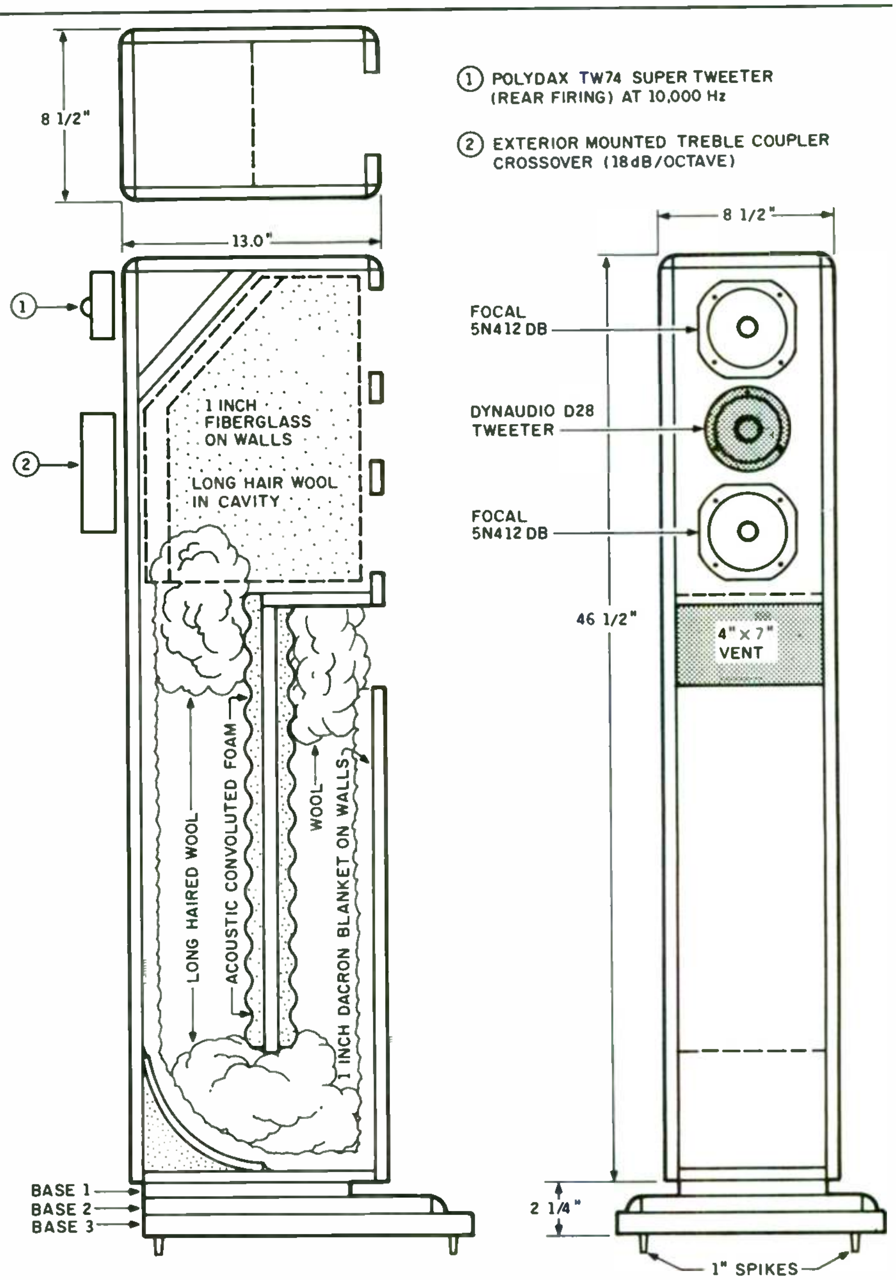


FIGURE 1: Cutaway view and overall dimensions of the "Baby Swan."

specifications. Reflex enthusiasts may also want effective piston area broken out separately if they're particular about certain vent calculations. These specs are especially important for large-signal analyses, but unfortunately many manufacturers apparently do not appreciate their significance.

However, the data needed for *calculating* these parameters often is presented, notably in the extensive spec sheets offered by European makers. Sometimes we are given enough information in one way or another to enable us to solve the S_D—X_{MAX}—V_D problem, and Q_{ES} is not usually a spec difficult to come by. If you have this data you can quickly whip it into your calculator, but the unit conversions preparatory to entry into a computerized box design algorithm can still be a nuisance. After all, who carries all those conversion factors around in his head?

My home-brew computer program, "Bass Driver Specs," addresses this problem. The program will calculate no from V_{AS}, F_S, and Q_{ES} whether you input V_{AS} in liters or cubic feet. It will find any one of three, for two knowns, of the $X_{MAX} \times S_D = V_D$ equation for either meters or inches. It will give approximate S_D from nominal frame diameter and calculate X_{MAX} from voice-coil overhang dimensions. You can convert units between English and metric for any of these specs. The essential math is very simple, but the program will take the work out of it once you get the code on a disk.

There is no hard-copy printing, so be ready with a pencil to write down the on-screen data. Menu-driven, the program will tell you what you need to input and in what form. It will allow you to enter data in either English or metric, and will also output in both.

I wrote bass alignment calculation programs for both reflex (Small- Keele) and closed-box (see TT&T *SB* 4/89) which make short work of driver analyses. This program has made going directly from catalog to box design a breeze. I no longer have to drag out the calculator and conversion tables just to get started.

I wrote the program in BASIC on a Commodore 64. Very minor syntactical alterations would be all that was needed for translation to other machines' requirements.

Commodore users desiring a disk with this code should write expressing their interest. The disk would include my closed-box design and Sallen & Key active filter programs, with a few other nice math utilities thrown in.

Paul W. Graham
Independence, MO 64050

[If you'd like a copy of Paul's program listing, just write us. Please enclose a SASE.—Ed.]

THE GOOD DIODE, JUNG

Readers who have modified their Magnavox CD players per the June 1987 *Audio* article by Walt Jung may want to make the following amendments to those modifications.

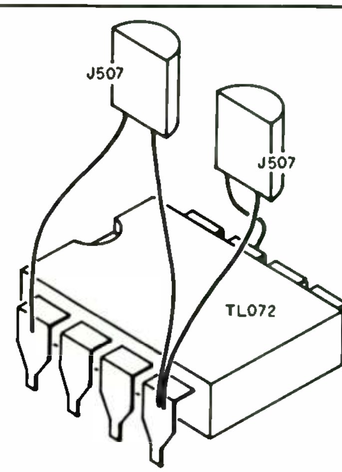


FIGURE 1: Cathode attachments for current regulator diodes.

1. Replace the 3.92k 1% metal film resistors placed between pins 1 to 4 and pins 7 to 4 of each op amp with Siliconix J507 current regulator diodes. The cathodes of these 2mA current sources are both attached to pin 4. (*Fig. 1.*)

The original resistors shunted the P-N-P transistors in the outputs of each op amp and converted their output stages from push-pull Class B into "single ended" class A operation. However, when a signal is present, the bias current is "modulated" by that signal and the current and thermal envelopes established at quiescence become disrupted. Current sourcing eliminates these problems because current regulator diodes are immune to these voltage swings.

2. Jung's modification can be further improved by substituting the once ubiquitous Texas Instruments TL072 op amp for the NE5535 op amps specified. While the NE553X series of op amps have impressive specs, I believe they have sonic failings due to their circuit complexity. The TL072, however, remains a musical contender due to its inherent simplicity. Remember, it was designed specifically for audio applications. *[As was the Signetics 5534—Ed]*

Note: the above amendments will have their maximum effect only if the player remains on at all times.

Finally, you really should place a V130LA10 MOV across the line voltage in your player to guard against line spikes should you choose to leave your player on. Enjoy the music!

Roger Artman
Penn Valley, CA 95946

DOME, DOME ON THE FLANGE

Here's a great way to send exposed dome tweeters by mail or UPS, especially if you no longer have the original packing material. To get started, cut a piece of 5/4 pine slightly larger than the OD of the drivers. For example, use a 4" square piece for a 3" tweeter. Now cut out a hole

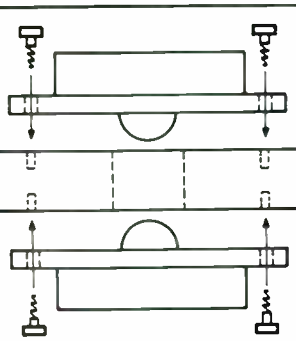


FIGURE 1: Pine block stiffens and protects dome tweeters in transit.

larger than the dome diameter and drill several screw holes.

Screw the tweeters to each side of the wood. Make sure the domes clear the hole and that they touch no sharp edges.

I recently received two tweeters via UPS by this method and they arrived in excellent condition.

William Wagaman
Mertztown, PA 19539

BEEFING UP YOUR THIN-WALL CABINET

I would like to share with you my "Pressdamp" method of loudspeaker enclosure resonance damping. We all know that thicker enclosure panels move the resonant points higher to a more unobtrusive frequency, although their duration is slightly longer. Thinner panels have a lower, more objectionable resonant frequency of shorter duration.

My aim was to achieve optimum sound without sacrificing too much cabinet space. The resulting design is depicted in the accompanying illustration.

As shown in the drawing, two horizontal rails (B) are cut to length from ¾″ × 1″ cleat stock. These are then let in ¼″, glued, and screwed inside the cabinet (A), while letting ¾″ protrude from the interior cabinet wall. One-inch thick, open cell, air conditioner filter foam (C) is then placed between the two rails. Lastly, doubled ¼″ pegboard (D) is used to compress the 1″ filter foam down to ¾″, flush with the protruding rails. Line up the holes of the two sheets and make sure to use fender washers under the screws.

The net effect of this system is one relatively dead cabinet. As a bonus, the holes in the pegboard also allow some beneficial damping of the bass driver's backwave.

Experiment with "Pressdamp." Altering the thickness and type of compressible material or the percentage of compression might yield even better performance.

Gary A. Fretz
Red Hill, PA 18076

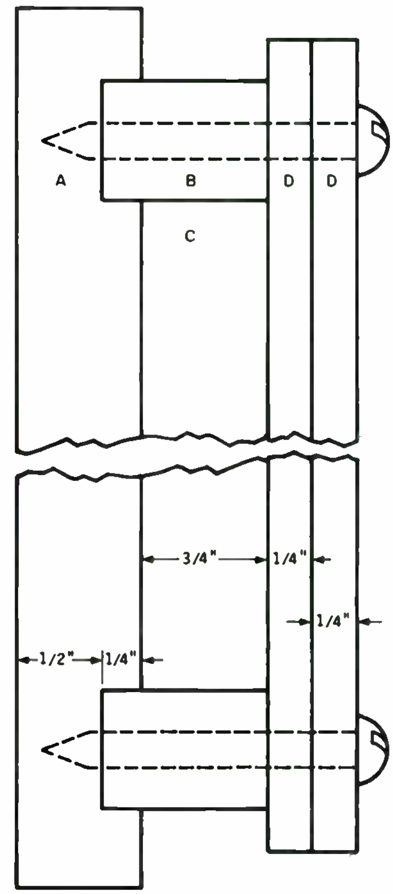


FIGURE 1: Side view of "pressdamp."

Thin Bin

Mother Hubbard's cupboard was no doubt in worse condition than our file folders for *SB*'s "TT&T" and "Craftsman's Corner" features, but we're about to get the "impending famine" warning light on our computer. Your handy tips, shortcuts and unique insights are all welcome, and *SB* pays $7.50 minimum for them. (It's a great way to pay for your subscription.) Photos of your handiwork and an account of how and why you built your beautiful gear are also welcome. Payment for illustrated tips is $15 and up, depending on length of copy and quality and number of photos.

Book Report

Road Kill

By Robert M. Bullock, III

Killer Car Stereo on a Budget, by **Daniel L. Ferguson**, Audio Amateur Press, 1989, paperback, 115pp. Available from Old Colony Sound Lab, PO Box 243, Peterborough, NH 03458, (603) 924-6371, $19.95 plus $1.75 shipping.

Killer Car Stereo on a Budget is an excellent, concrete, hands-on treatment of the cost-effective design and installation of a high quality automobile sound system. Ferguson concentrates on the loudspeaker end of the system, contending that this is the weak link in automobile sound systems. High quality auto electronics are readily available at reasonable cost, but high quality auto loudspeakers are not.

I completely agree with this view and for years have used a conventional home speaker system in my car to obtain satisfying sound. The units sit in the back seat, where they are an invitation to theft, are a potential hazard in sudden stops, must frequently be removed to accommodate passengers, and make the vehicle resemble a loaded truck more than a passenger car. This book has convinced me I can trade these inconveniences for a custom auto system without sacrificing sound quality.

The author starts by listing the deficiencies of standard auto loudspeakers and then describing a "killer" auto sound system to correct these deficiencies. The rest of the book addresses the problems of implementing this killer system unobtrusively, given a car's space constraints.

Ferguson first discusses the problems of driver location and loading. He solves these in different ways for sedans, hatchbacks and trucks, describing implementation details of several alternative loudspeaker systems for each body type. Along the way, he recommends drive units and relates the pros and cons of the proposed systems.

With sedans, the trunk can serve as a woofer enclosure, but with trucks and hatchbacks you need a box to provide satisfactory bass response. The author deals with this problem, giving plans for four box systems, each based on a particular woofer drive unit. Even if you design your own woofer system, this chapter offers some useful information specific to the vehicular environment.

The next chapter covers the construction of an active woofer crossover, an integral part of the author's overall design. Ferguson's unit actually performs several functions, offering a versatility that can be extremely useful given the constraints of auto systems.

The last chapter contains information on electrical hookup and final system tuning. It also has a summary of steps to follow and the order in which they should be performed to build and install a "killer" system.

With its excellent discussion of equipment, design, installation, and modification options, I have found the book a useful reference in planning a system for my car. I am sure it will be just as useful when I get to the construction and installation phase. I commend it to you if you are at all interested in building your own auto sound system.

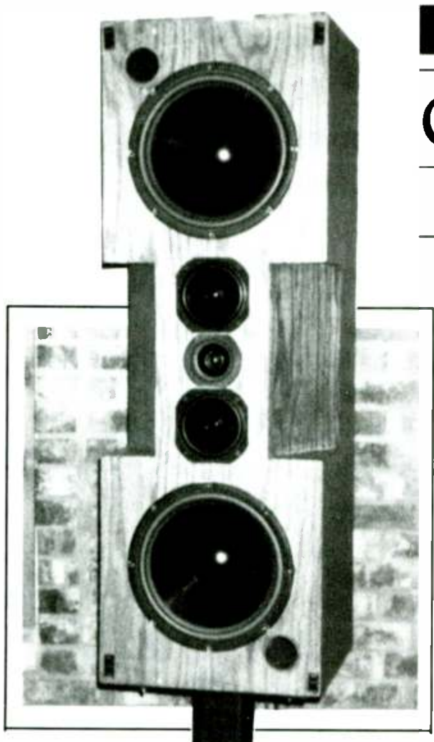


PHOTO A: Overall view of the Kellers' version of the Swans.

Craftsman's Corner

Swan Songs

The hours spent with a component can be both comforting and limiting—comforting because of our growing familiarity with the presentation, style and character of the particular component's impact on the music, and limiting because of our tendency to overlook any physical flaws or aberrations of this increasingly treasured component. Thus, after 20 years of living with two sets of 1950 vintage University S-9S front-loaded folded-horn speaker systems, we decided to move to a more modern design.

Our decision (I had already decided but was waiting for Barb's confirmation) was reached about the same time our first copy of *Speaker Builder* arrived (4/88). That particular issue featured the Swan IV system by D'Appolito and Bock.[1] It was love at first sight. During the next year we developed our version of the Swan IV.

Even though there are probably hundreds of successful replications of this design, we felt our construction strategy and design might be of interest to readers.

TECHNIQUE. To ensure straight cuts and true corners, we used a "gauge and guide" method with our circular saw. We periodically checked the perpendicularity of the carbide tipped saw blade relative to the saw's foot (plate) with a carpenter's square. As a gauge we used a block of wood the width of which matched the distance from the saw blocks inside (left) edge to the left edge of the foot (plate). We used this one block to locate the guide relative to every cut line. Using one block as a gauge ensured consistency (not accuracy) of cuts. Our guide was the factory edge of an 8′ length of ¾″ particle board, approximately 6″ wide. We simply clamped the guide to the piece to be sawed in the location provided by the gauge.

We had successfully built the folded horn prototypes using well-glued, heavily screwed butt joints. Consequently, we used yellow carpenter's glue and 3″ drywall screws (other types may be better, but these were readily available) on 3″ centers. We pre-drilled and countersunk all holes. Rather than brace corners, we used rounded braces between interior parallel wall surfaces.

After building the particle board boxes, we glued ¼″ oak veneer to all surfaces except the back. Each surface's veneer piece was rough cut approximately 1″ larger (in all directions) than its finished size. We then labeled each piece as to its final location and clamped each to its designated surface. We marked the outline of the enclosure on the back of the veneer, which was removed and its thickness (¼″) added to all edges except the back. We clamped a different straight guide on the exterior surface of the veneer at the ¼″ line. With a 45° chamfering bit with a roller guide on our router we produced the bevel joints. We completed the routing from the back side of the veneer.

We finished all the rough sawing, locating, marking, chamfering, and so on before we glued any veneer pieces in position. Since we didn't want to risk using a caustic glue, we used Liquid Nail (#LN-603 from Macco) to bond the veneer. A series of pipe clamps aided by small underlay nails driven through waste pieces of veneer held the work until the glue cured. Of course, we later filled the holes left by the nails with color-coordinated filler.

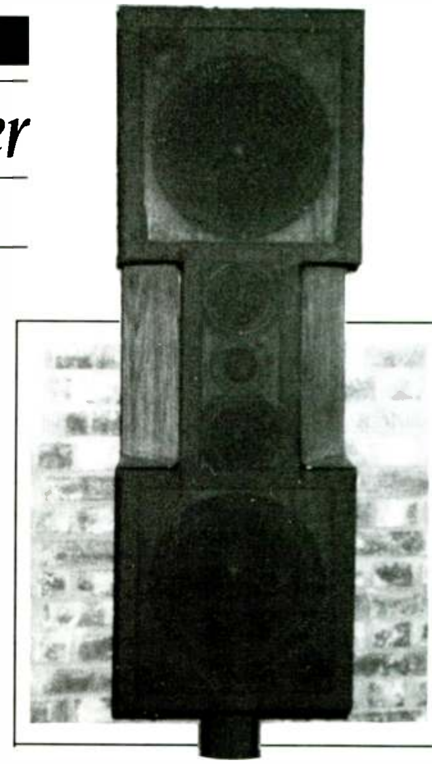


PHOTO B: Closeup of the cabinetry with the grille in place.

SWAN IV VARIATIONS. It took approximately one month of our spare time to complete. Now, let's move ahead to our variation of the Swan IVs.

We altered the basic design in two ways which were simple extensions of the original design. First, we extended the symmetrical design to include the

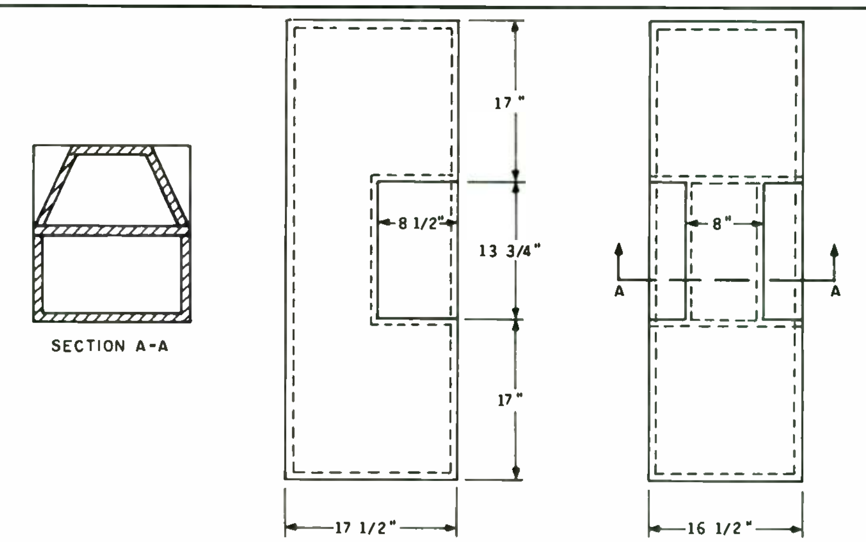


FIGURE 1: Construction details.

woofers. This resulted in a design with a front too broad for the MTM array, which might have altered imaging and focus. Therefore we reduced the width of the front panel in the area of the MTM array to that specified in the original design. We then angled the side panels in this area to intersect the enclosure's sides about halfway to the back. The enclosure of the MTM array has a triangular shaped cross-section when viewed from above.

Our second variation was a decision to retain the ultimate bass potential of the system by not reducing the size of the enclosures. Remember, we were accustomed to four five-foot horns (two per side—one stacked on the other). Therefore we built the cabinets with an internal bass volume of 145 liters. The woofer's backwaves were acoustically interconnected by means of an 8 × 16″ column along the back of the separate MTM sections (*Fig. 1*).

We lined and filled the bass and MTM enclosures as per D'Appolito and Bock. Plus, we wrapped all internal braces with hospital bed foam.

DRIVERS. We ordered all drivers in October, and the MTM components arrived almost immediately. The woofers were back ordered. We eventually received the Carbonneau Swan 305s during the first week in December.

The Dynaudio and Focal were impressive, but being used to 15″ 20-pound drivers from the horns, we were a bit skeptical of the bass unit's potential. Nevertheless, all drivers and crossovers were installed and the speakers made their first sounds on December 8, 1989. We finally understood the meaning of words like "imaging," "focus," and "air."

Until January 21, 1990, we used a Marchand crossover set at 200Hz. Our preamp had both an infrasonic filter and a bass boost circuit similar to those in the Pedal Coupler. During that weekend we assembled the Pedal Coupler crossover (modified for less bass boost as per D'Appolito and Bock, *SB* 4/88). This further enhanced our enjoyment of the system especially using the direct CD input.

STANDS. Any use of the Swan IV design necessitated speaker stands, since our favorite listening positions happen to be kitchen stools approximately 10′ from each speaker, which places our ears 51″ above the floor. We choose this position for three reasons. First, it places the sound well above any obstacles in the room. Second, it reduces the coupling of the bass units to the floor. Third, someone standing has nearly the same sound as someone seated.

We made our stands out of ¼″ steel plates and 4″-square metal tubing. We centered and welded the pipes to the bottom plates, filled them with dry sand and welded on the top plates. All plates were drilled near the corners so we could bolt the enclosures to the stands and install homemade spikes.

Since our modifications resulted in a top-heavy system, we bolted each enclosure to the narrow brick column behind. (We didn't want to crush any old, slow-moving audiophiles, innocent children or unsuspecting cats.)

The speakers are driven by a used set of Crown D150 basic amps, a NAD 1155 preamp, and a Denon DCD1300 CD player. The headphone output of the CD player feeds the Pedal Coupler. A Thorens TD160 turntable is available to play vinyl. Speaker wires are Belden 12 gauge on bass and 20-gauge doorbell wire on MTMs.

We would like to thank D'Appolito and Bock for sharing their creativity and expertise with us through *Speaker Builder* magazine. We enjoyed the building project and the end products—Swan Songs.

Barbara J. and Kenneth W. Keller
Bonnie, IL 62816

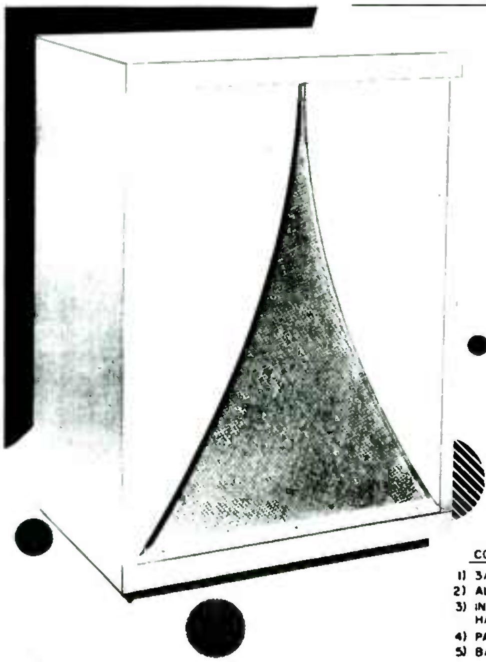
ACKNOWLEDGMENTS
We thank our friends Laura Eader, Bill Morris and Martha Smith for their assistance, patience, and knowledge.

REFERENCE

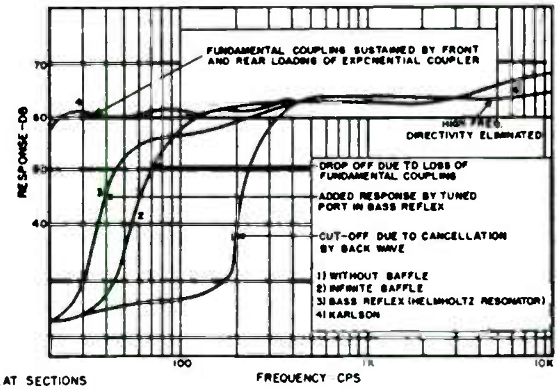
1. D'Appolito, Joseph, and James W. Bock, "The Swan IV Speaker System," *SB* 4/88, p. 9.

Vintage Designs

The Karlson Speaker Enclosure

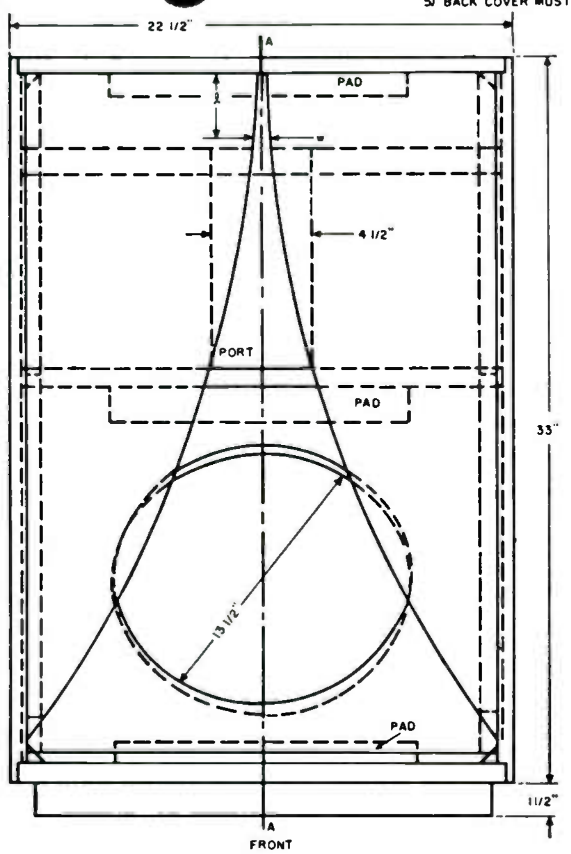


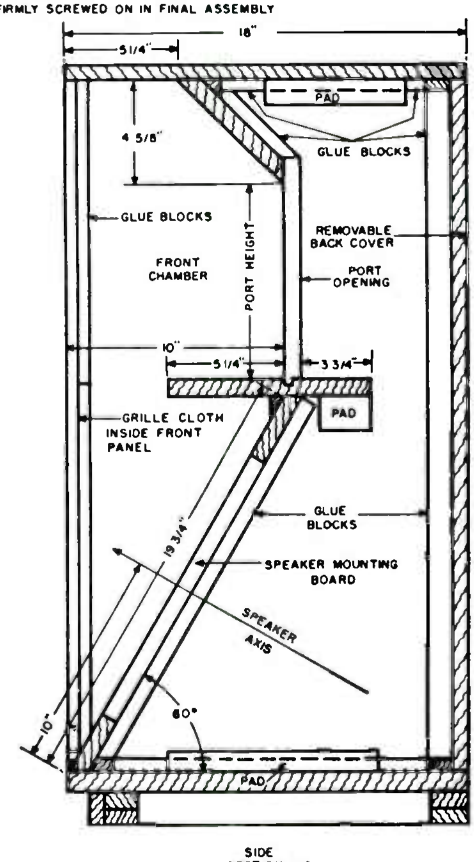
"Legendary" is a term applicable to the Karlson loudspeaker enclosure, but not as a compliment. John E. Karlson invented the device which enjoyed a unique niche in the history of audio reproduction, along with the Pedal Coupler and other oddities. The Karlson has its devotees, however and rumor has it that the Karlson is being manufactured for professional use as a monitor or performer's speaker. We are here reprinting it from the *Hi-Fi Annual & Audio Handbook* of 1956, published by Ziff-Davis, Inc., New York. We reprint the accompanying information at the request of a number of readers. No one on the staff of this magazine will answer any questions concerning this device.



CONSTRUCTION SPECS.

1) 3/4" PLYWOOD USED FOR ALL MAJOR FLAT SECTIONS
2) ALL JOINTS MUST BE GLUED FIRMLY AND VIBRATION PROOF
3) INSIDE SURFACES OF FRONT CHAMBER MUST BE FINISHED WITH A HARD AND SMOOTH SEALER COMPOUND OR FOUR COATS OF SHELLAC
4) PADS TO BE APPLIED AS SHOWN
5) BACK COVER MUST BE FIRMLY SCREWED ON IN FINAL ASSEMBLY





TAPERED APERTURE DIMENSIONS

l	w
1	0.46
2	0.52
3	0.64
4	0.80
5	1.00
6	1.24
7	1.52
8	1.88
9	2.22
10	2.64
11	3.12
12	3.62
13	4.18
14	4.76
15	5.42
16	6.10
17	6.82
18	7.60
19	8.42
20	9.30
21	10.14
22	11.16
23	12.18
24	13.18
25	14.28
26	15.38
27	16.58
28	17.80
29	19.04
30	20.34
30 3/16	20.50

RECOMMENDED SPEAKERS (PARTIAL LIST)

JENSEN	ALTEC	STEPHENS	RCA	WHARFEDALE	HARTLEY	STROMBERG-CARLSON	UNIVERSITY	ELECTRO-VOICE
G-610	604-C	106 AX	LC1A	SUPER 12/CS/AL	215	RF-475	6201	SP-15
H-510	604-B	206 AX					6200	15TRX
H-222	602-A							
H-530								

OLD COLONY MINI-CAT 1

KT-2: THE BORBELY PREAMP KIT [4:85, 1:86]
Erno Borbely's preamplifier rivals commercial units costing several times the KT-2 kit price. Three requirements compete against each other in the choice of circuit topology and components. The three, sometimes exclusive, design goals are low noise, high gain and wide dynamic range. The key is the use of the best available discrete transistors rather than operational amplifier ICs.

The first stage input is directly coupled to the gates of a complementary pair of low noise JFET transistors. The circuit design, high voltage power supply and device matching, together, achieve wide dynamic range, linearity and low noise.

The second gain stage is a complementary, common emitter pair, directly driving a similar output stage. The high signal-to-noise ratio established in the first stage is preserved here. Mr. Borbely uses the best available complementary bipolars: ROHMs 2SB737/2SD786 pair. They have low source impedance, good linearity and an extremely low shot/flicker noise.

The servo amplifier, an LF411CN, can null input offsets of as much as one hundred millivolts and provides DC coupled performance, eliminating output coupling capacitors.

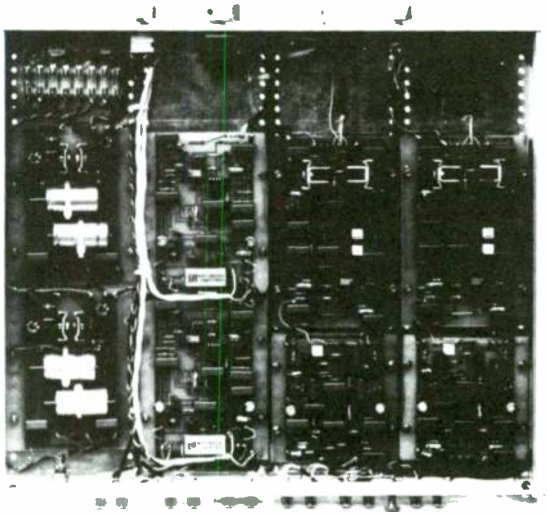
The input circuit board also has passive high frequency RIAA rolloff. The two RIAA networks are separate, allowing cleaner implementation.

The next board contains three complementary gain stages, a servo amp and an active low frequency section of the RIAA network. Power is 48V, about 18V higher than the first board. This board contains regulators for all gain stages.

KT-2 includes five sections for each channel. Each is built on its own board. In addition, a tape buffer, line amplifier and power supply are included. The kit comes complete with two function switches, Alps volume control, two toroidal power transformers, gold-plated connectors and precision components. An article reprint is included. The kit does not contain hook-up wire, cable, solder, housing or knobs. **$650**

KT-2 Sections: (1-5) Available separately. Inquire for pricing.

KT-2/KW-3: With an elegant power supply upgrade to KW-3 (see *Power Supply* section). **$795▼**



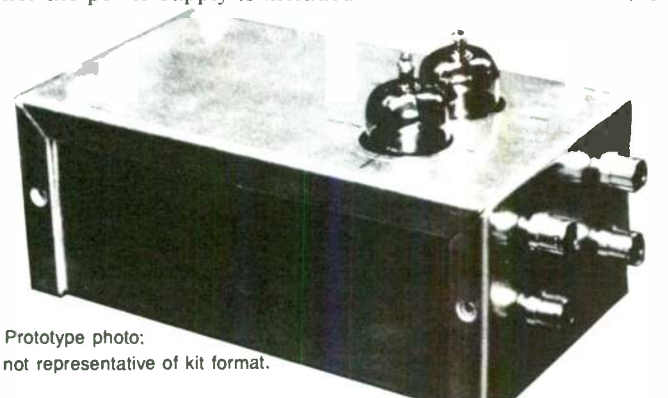
Prototype photo: not representative of kit format.

KV-3: CURCIO AUTO MUTE [1:86]
Included in the kit is a small circuit board, parts and a relay to delay the sound output for 45 seconds from Joe Curcio's Daniel tube preamp. This delay protects power amps/speaker drivers from turn-on transients. Unlike solid state preamps, which may be left on continuously without ill effect, tubed preamps should be turned off when not in use to extend tube life. Also may be used to delay any low-level stereo signal from any preamp where 15–20V DC is available. **$18**

KT-1: CURCIO'S DANIEL VACUUM TUBE PREAMP [2:85]
Joe Curcio's no-compromise vacuum tube/semiconductor hybrid preamplifier pays special attention to the issues of sensitivity, low noise, stability and the sonic contribution of the individual components. Each channel has three gain stages. The first is a modified cascode configuration offering wide dynamic range, low noise and two possible levels of gain: either 38dB, which is sufficient for most moving-coil cartridges, or 32dB for high output cartridges. The second stage is a parallel dual triode fixed at 26dB gain. Between these stages Curcio implements the RIAA equalization with a passive RC network. Output is available after the second stage or, for an added 26dB, at the output of an identical third stage. Output impedance in either case is 20kΩ. The 6DJ8 dual triode vacuum tube is used throughout the amplifier.

The most notable feature of the design is the on-board regulation of each tube's B+. Filaments are powered by separately regulated DC for each channel. The power supply primary AC is switched by low voltage DC. Thus no 60Hz current is present on the main board, always a potential noise problem in low level gain stages. Within the power supply housing the filament and B+ are switched by an optically coupled, zero-crossing triac and an electromechanical relay. The kit is complete with all needed parts for the amplifier and its power supply. Not included are housings for the amplifier or power supply and knobs for the rotary controls. **$385▼**

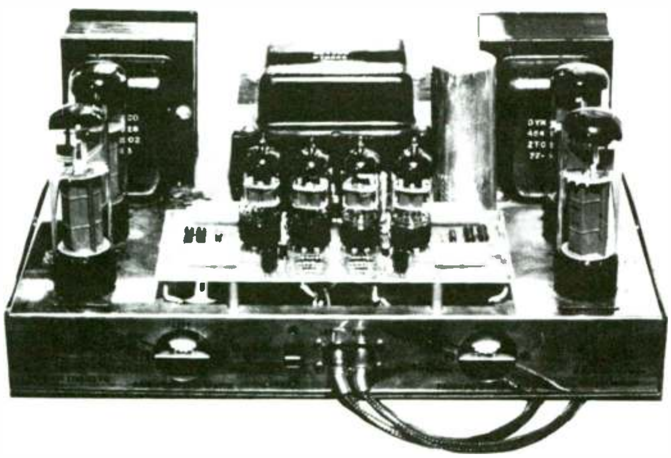
KS-6: CURCIO VACUUM TUBE STEREO PRE-PREAMP [5:84]
Joe Curcio addresses the problem of the low output levels of moving-coil cartridges in this two channel, two-tube amplifier. In his design a lot of attention is paid to the power supply. The power for the filaments is regulated DC. The tube's plate supply regulator is in two sections and maintains low impedance across a wide bandwidth. The kit is sold with two 6DJ8 vacuum tubes although several other types may be used. The article reprint included with the kit lists several alternates. KS-6 comes complete with two circuit boards (4¾" x 2¾" and 4¾" x 3¾"), high quality metal film resistors, capacitors, phono jacks, tubes and sockets, fuse and fuse holder and all semiconductors. Housing for neither the amplifier nor the power supply is included. **$135▼**



Prototype photo: not representative of kit format.

AMPLIFIERS

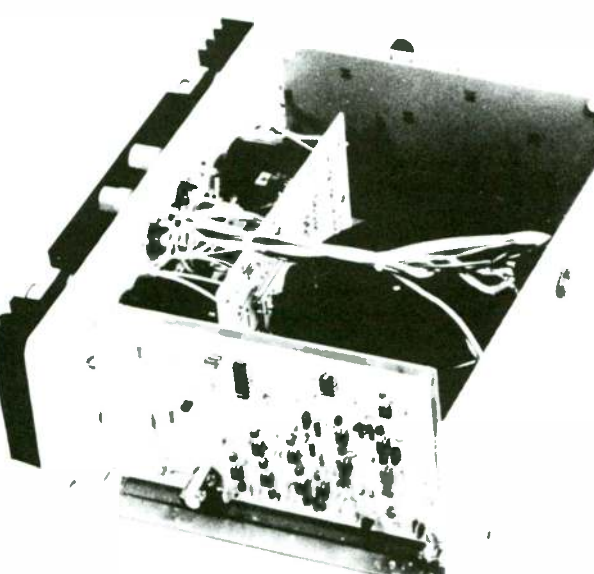
GKB-1: THE CURCIO DYNACO ST-70 MODIFICATION [*GA* 1:89]
Joe regulates all voltages in his amp design (except filaments) and drives the outputs with a constant current cascode differential driver, direct-coupled to a triode-configured output stage. Field tested for two years in over two dozen sites, the Curcio ST-70 fits within the existing chassis, using only the power and excellent output transformers from the original unit. Old Colony's kit includes boards and all needed parts right down to new mica-filled sockets for the output tubes. All parts are exceptionally high quality and the sound is the best available from the venerable ST-70 chassis. **$345▼**



ST-70 chassis and transformer not included in kit.

KX-3: CHATER 40W ALL-MOSFET POWER AMPLIFIER [2, 3:88]
Bill Chater's carefully planned design for a 40W all-MOSFET amplifier includes several novel and exciting features, such as servo-controlled bias at both the driver and output stages, and a servo-nulled offset to control output drift. Listening tests reveal excellent headroom and extremely fast overload recovery. Yet the circuit requires no adjustments, uses only one optional capacitor in the signal path, and is free of turn-on and turn-off thumps. Contains all parts except the chassis, hook-up wire and connectors. **$180**

KX-3S: CHATER 40W ALL-MOSFET STEREO AMPLIFIER [2, 3:88]
Includes two KX-3s and one KX-3P power supply. **$540▼**



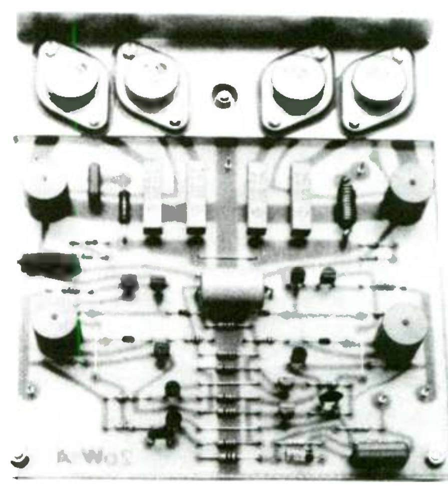
Prototype photo: not representative of kit format.

KV-2S: THE LANG 20W CLASS A MOSFET STEREO POWER AMP [2:86]
Using four push/pull power MOSFETs this 20W/channel amplifier is a beautiful modular unit with each channel on a 5.7" x 6.1" circuit card which includes direct mount arrangements for the output devices. A ⅛" thick L-bracket couples the power drivers' heat to an external heatsink which can be the wall of the enclosure or a rack mount panel. Ideal for multi-amplifier systems, especially electrostatic drivers. Rated by some experts as the most advanced, innovative power amp design published by *Audio Amateur*.

Specifications are impressive: 20W into 4Ω loads, +0–0.5dB @ 20Hz–20kHz; +0–3dB @ 10Hz–60kHz; Input: 0.775V = 0dB (max power); 22dB voltage gain; Input impedance: 40kΩ; Noise: (100mV into 4Ω) unweighted –66dB; "A" weighted –90dB; Transient IM distortion: –80dB; Harmonic distortion: –84dB @ 20W; –100dB @ 4W/4Ω. Power consumption: 80W/channel; Quiescent current: 2A/channel.

All parts supplied, two separate power supplies (±24V @ 100mA; ±15V @ 8A) with toroidal type transformers and Hitachi MOSFETs, heat-coupling bracket and article reprint. Stereo. **$285**

KV-2DM: THE LANG 20W, CLASS A MOSFET DUAL-MONO POWER AMP [2:86]
Contains two amplifier channels and two each of the ±15V and ±24V power supplies for dual-mono-mode operation (each channel independently powered). **$350▼**



KS-3: BORBELY DC 100 MOSFET POWER AMP [2:84]
Erno Borbely keeps the MOSFET output circuit of the Servo 100 but designs a new driver/bias section and dubs the resultant amplifier, the DC 100. The highly symmetrical circuit features floating constant current sources and a complementary pair of monolithic JFETs as the input stage. Excellent thermal tracking in this stage ensures minimal offset drift at the output in spite of the 26dB gain available at DC. Mr. Borbely's conservative design and insistence on stability results in a real workhorse amplifier with a strong heart. Full power output into 8Ω is 100W, into 4Ω it is 125W. This power is not at the cost of THD which is 0.0025% (1kHz) and 0.0065% (10kHz). Slew rate without the input filter is 75V/μS. This kit is similar to the KS-1 in that it comes complete with board (4⅛" x 6½"), heatsinks, active and passive components and instructions. Power required for the amplifier is the same as for the Servo 100. Refer to the power supply section for suitable power supplies. Single channel. **$160**

KS-3M: BORBELY DC 100 MONO AMP [2:84]
Includes one KS-3 and one KS-3PB power supply. **$285**
Two or more **$270**

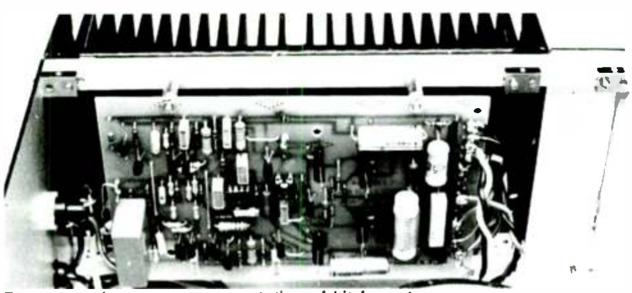
KS-3S: BORBELY DC 100 STEREO AMP [2:84]
Includes two KS-3s and one KS-3PA power supply. **$470**

KS-1: BORBELY SERVO 100 MOSFET POWER AMP [1:84]
Erno Borbely's design for a more powerful MOSFET output single channel amplifier. The circuit uses bipolar and field effect transistors to their best advantage, MOSFETs in the output section and bipolars at the input. The driver section is a symmetrically balanced amplifier with an open loop gain of 56dB over a wide bandwidth. The bandwidth is restricted at the input and the resulting rolloff at 20kHz is 3dB. Just over half the gain available is fed back.

Overall closed loop gain as a result is a clean 26dB. The amplifier design provides an input capacitor to be used if excessive DC offset is present in a preamp's output. A shorting option is provided on the PC board to remove this input capacitor if DC coupling is possible. The kit comes with the circuit board (4⅛" x 6½"), quality resistors and capacitors, heatsinks and an article reprint detailing the design and the kit construction. Requires ±40V at 3A. A suitable power supply capable of powering one KS-1 is the KS-3PB. For two channels, the KS-3PA is recommended. See the power supply section for complete descriptions. **$150**

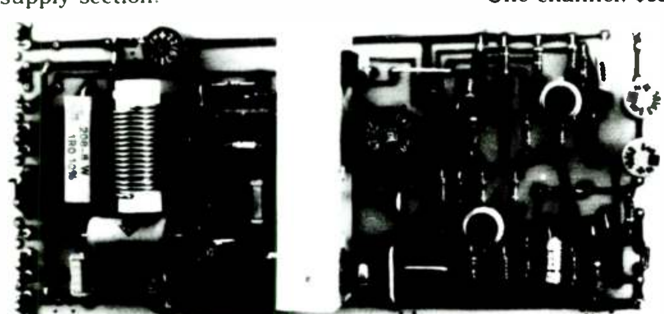
KS-1M: BORBELY SERVO 100 MOSFET MONO POWER AMP [1:84]
Contains one KS-1 and one KS-3PB power supply. **$275**
Two or more, **$260**

KS-1S: BORBELY SERVO 100 MOSFET STEREO POWER AMP [1:84]
Contains two KS-1s and one KS-3PA. **$450▼**



Prototype photo: not representative of kit format.

KP-3A: BORBELY 60W MOSFET Amp [2:82]
This kit is based on Erno Borbely's design for a single channel workhorse to drive today's power hungry speakers. Whether used in a multi-amp system with active crossover or in a simpler two amplifier passive crossover arrangement this unit provides power, fidelity and rugged reliability. As a professional designer, Mr. Borbely is quite aware of the shortcomings of bipolar power transistors. The thermal runaway and hot spot degradation of bipolars are problems avoided by the power MOSFETs chosen for this design. The amplifier's THD specifications are .002% @ 1kHz and .015% @ 10kHz (60W into 8Ω). Internal slew rate is 40V/μS. This rate is limited to 2V/μS at the input by a low-pass filter. Maximum power output into a 4Ω load is 75W. The kit is complete with board (3⅜" x 6⅛") and all parts except for an easily constructed air core output coil. An instructive article reprint is provided. The amplifier requires ±50V @ 2A with surge current capability several times that. A suitable power supply is the KP-3P detailed in the power supply section. One channel, **$90▼**



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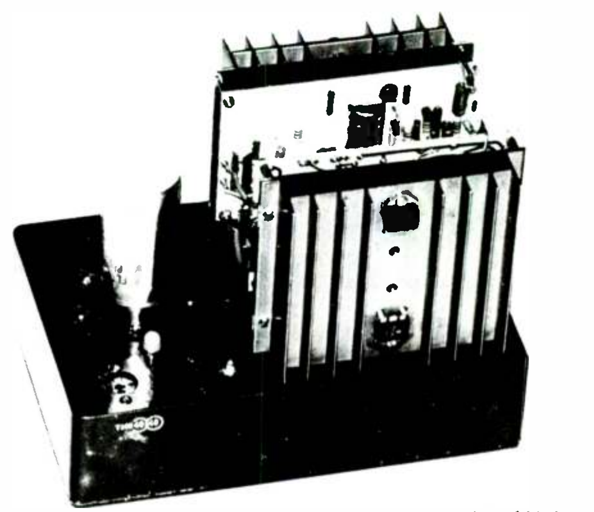
KM-7: CITATION 12 MOSFET MODIFICATION [2:81]
Harman Kardon's 60W/channel Citation 12 forms the basis of a new amplifier with improved performance devised by Nelson Pass of Threshold Corporation. The original Citation's power supplies and much of its circuitry remain as first designed. This modification replaces the original 40636 bipolar output power transistors with IRF-130-MOS power field effect transistors. The bias circuit is also changed. The amplifier is a significant sonic improvement over the original, particularly in the high end where the Citation 12's veiled characteristic is replaced by a detailed, somewhat sweet sound. The imaging and midrange definition also are much improved. The bass response, one of the Citation 12's strongest points, remains much the same. Distortion over most of the spectrum is lowered significantly. This package contains all parts and detailed instructions needed for the modification. **$170**

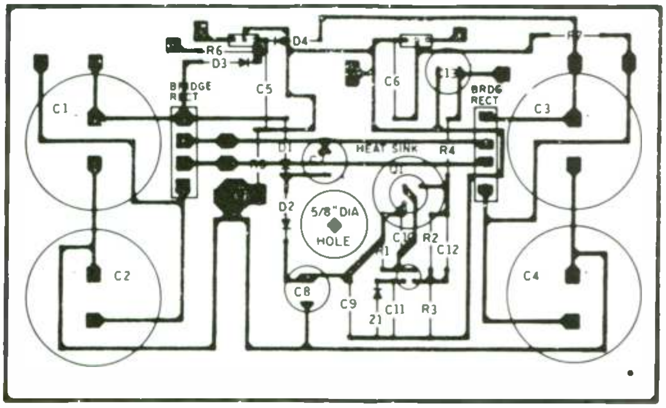


Prototype photo: not representative of kit format.

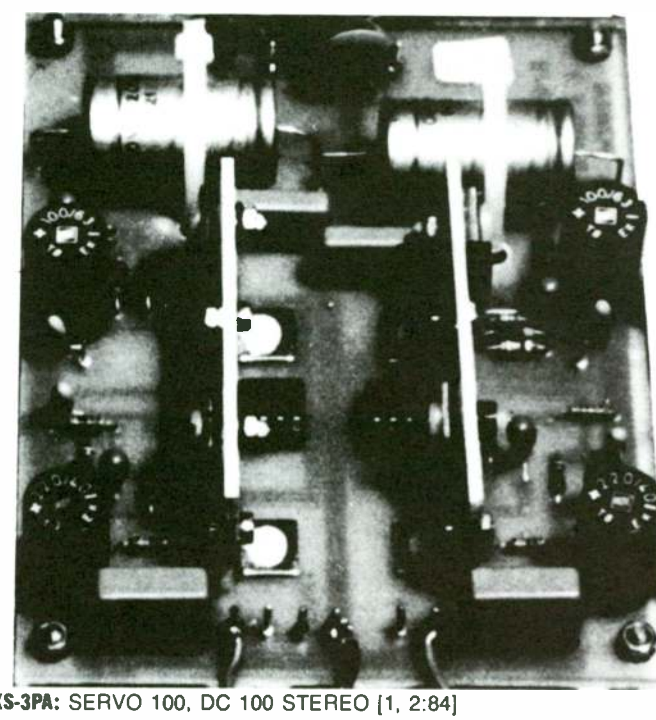
KK-13CH: WILLIAMSON 40/40 [4:79] ▲
Reg Williamson's straightforward single supply bipolar power amplifier is highly recommended to both the experienced builder and the newcomer. The new builder will appreciate the relatively simple circuit with its uncomplicated power needs. The veteran audio constructor might consider several of these in a system with active crossovers. The modest, by modern standards, output power of 40W is plenty when powering a single driver over a restricted bandwidth as in multi-amp active crossover systems. This power level is also enough for many apartment dwellers who share thin walls with neighbors. Figures for total harmonic distortion at full power output (40W/8Ω) are 0.05% @ 1kHz and less than 0.1% @ 15kHz. Transistors are Toshiba high performance types, 3" x 5" circuit cards are included and all parts except heatsinks. The 65–68V @ 2A DC power requirement can be supplied by the Williamson designed KK-13P. **$170**

KJ-5-7: NELSON PASS CLASS A 40W AMP, A40 [4:78]
This highly popular bipolar design from Nelson Pass of Threshold Corporation is as rugged as it is clean. Rugged because of hefty output transistors and clean because of carefully designed Class A circuitry. Mr. Pass direct-couples this amplifier to its load, selecting output transistors with six times the dissipation rating needed in normal amplifier operation. Anyone who has had to replace output devices or speakers because of a timid designer's excessive attention to the bottom line (economic) can appreciate this. This no-compromise approach in the A40 leads to impressive THD figures. At 40W output the 1kHz distortion is 0.1%, at 10kHz the figure is an impressive 0.03%. This kit contains two boards (3" x 3") and all parts for two channels, including eight heatsinks and all parts for one ±44V @ 8A (KJ-5-4) stereo power supply. **$465**
West of Rockies, **$475**

KX-3P: CHATER 40W MOSFET POWER SUPPLY [2, 3:88]
Chater supply for one or two KX-3 amplifier channels. **$215▼**



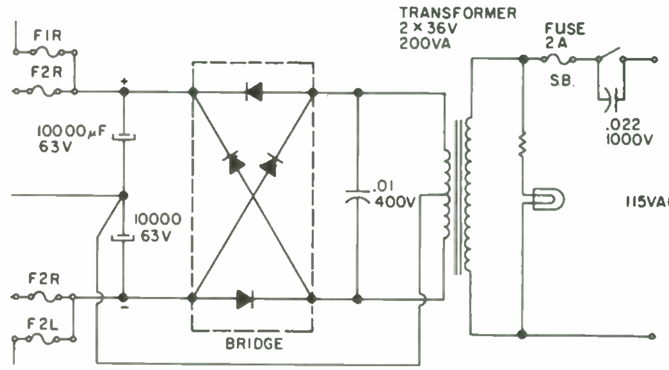
KW-3: BORBELY IMPROVED PREAMP POWER SUPPLY [1:87]
This single channel, low impedance supply was designed for the exacting requirements of Erno Borbely's moving-coil preamp (2:86, 1:87). The design utilizes polypropylene caps, 1% metal film resistors and LM317/337s in the preregulator and Signetics NE5534 in the op amp regulator. The kit includes a low profile 24V toroidal transformer, 4¼" x 5½" circuit board and all board mounted components. Chassis and heatsink are not included. **$135**
Two or more, **$125▼**



KS-3PA: SERVO 100, DC 100 STEREO [1, 2:84]
This ruggedly designed power supply handles a two channel Borbely Servo 100 or DC 100 amplifier. The toroidal transformer is rated at 500VA. In addition the kit comes with two 10,000μF filter capacitors, bridge rectifier and line fuse. **$175**

KS-3PB: SERVO 100 OR DC 100 MONO [1, 2:84]
This supply is similar to the KS-3PA but has a smaller toroidal transformer (225VA) and two 10,000μF filter capacitors. It is designed to supply a single channel of a Borbely power amplifier, Servo 100 or DC 100 or the equivalent. Separate supplies for each channel provide better performance and channel separation. **$125**

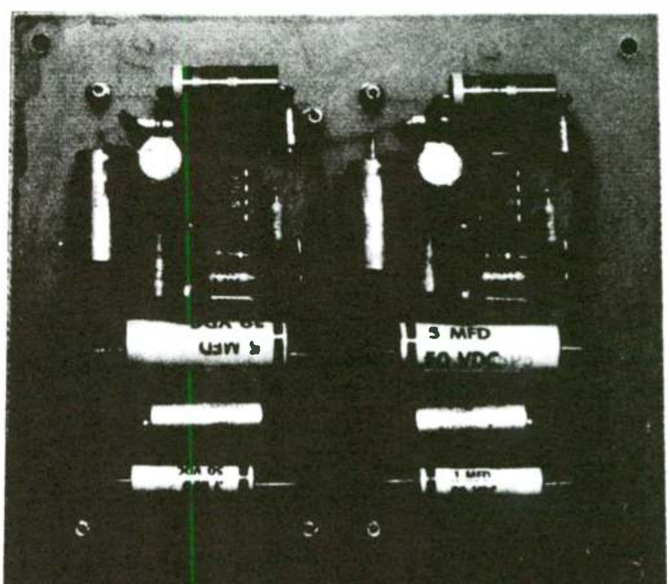
KP-3P: BORBELY 60W MOSFET AMP POWER SUPPLY [2:82]
This hefty unregulated power supply is conservatively designed to power two 60W Borbely power amps. It will maintain a minimum output of 45V (bipolar) when supplying two fully loaded amplifiers (60W into 8Ω). The kit is complete with all parts except the filter capacitors and chassis. **$80▼**



KL-4A: SULZER OP AMP PREAMP POWER SUPPLY REGULATOR [2:80]
This unit supplies quick acting DC regulated power, with an ultra low impedance as seen by the load of very high quality transistorized or IC preamplifiers. The impedance at the outputs (+15 and −15V DC) is less than 10 milliohms from DC to 100kHz. Each output is able to source or sink up to 30mA. The regulator requires a bipolar 21V DC filtered source such as the KL-4B. **$40**

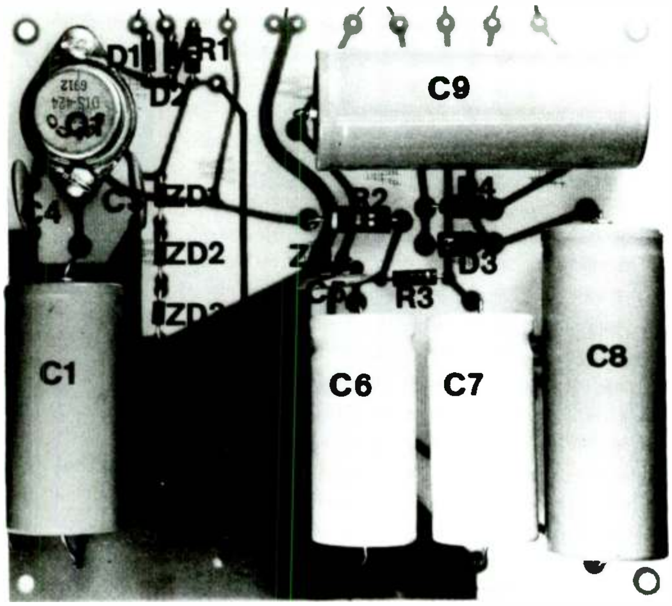
KL-4B: SULZER DC RAW SUPPLY [2:80]
A complete kit of parts to build an unregulated bipolar DC supply with 20V/300mA outputs. Each output is filtered by a 5,000μF capacitor. Ideal for powering two KL-4A regulators. **$60**

KL-4C: SULZER DC SUPPLY [2:80]
Same kit as KL-4B except a high quality, low hum and noise ±22V toroidal transformer is supplied for the very highest possible performance. (See transformer section for KL-4D specifications.) **$85▼**



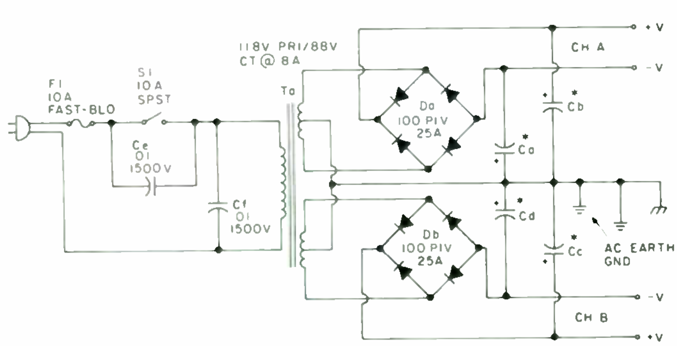
POWER

KK-7: WALDRON TUBE CROSSOVER POWER SUPPLY [3:79]
Designed to power the Waldron vacuum tube crossovers, this kit is capable of powering four crossover boards, a total of eight 12AX7/ECC83 tubes. Maximum output for the supply is 300V at 70mA regulated and 12.6V DC at up to 1.5A for filaments. In addition a positive bias of 47V, regulated at 500μA is available. Comes complete with all needed parts, printed circuit board (5⅛" x 5⅝"), transformer, capacitors, semiconductors, fuse and line cord. **$110▼**



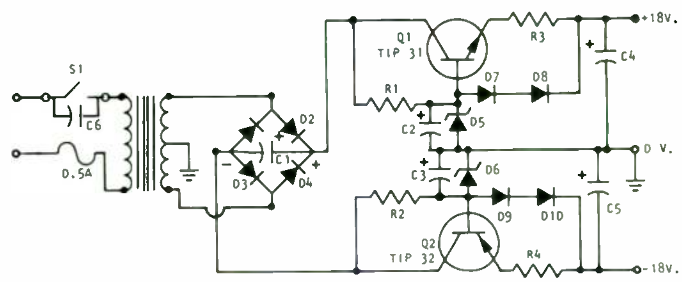
KE-5: OLD COLONY POWER SUPPLY
A small economical bipolar unregulated supply with outputs of ±18V at 55mA each. All parts are mounted on the board (2½" x 3"). Filtering is provided for each output by capacitor input RC networks. **$20**

KJ-5-4: NELSON PASS A40 [4:78]
Designed to power two Pass A40 Class A power amplifiers under their maximum rated loads. The transformer is a 500VA ILP toroidal. The kit comes complete with all parts, including four 9,000μF filter capacitors and clamps, two high current bridge rectifiers, line cord, fuse and holder. **$175**
West of Rockies. **$180▼**

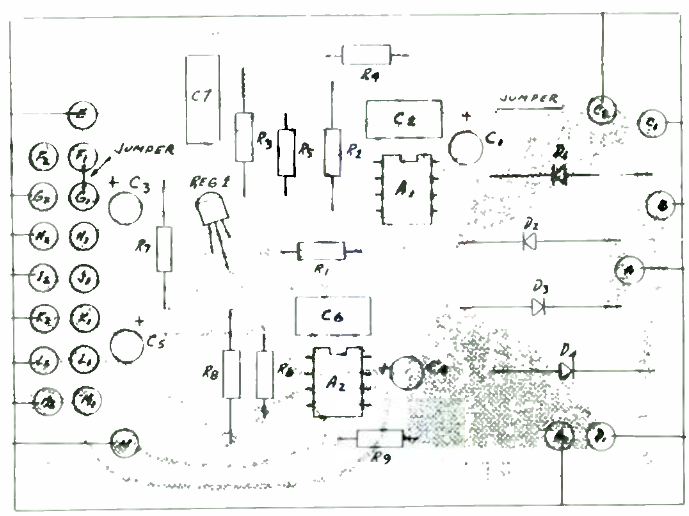


KJ-8A: DYNACO MARK III POWER SUPPLY MOD [1:78]
An inexpensive way for the Dynaco Mark III owner to upgrade an already superior power amplifier. After the modification, hum and noise are down an additional 11dB, full load B+ is up 10%, and the output at 20kHz is raised 4W. Response is flat within 0.05dB over the range 20Hz–20kHz. Also included are all parts necessary to add a balance control and an adjustable, independent bias control for the Mark III. **$38**

KF-3: GATELY REGULATED SUPPLY [2:75]
A bipolar power supply capable of either ±18V or ±15V @ 100mA at the outputs. Regulation is by zener referenced pass transistors mounted on a small heatsink (supplied). Each output is shunted by 1,000μF capacitors. Kit is complete with all needed parts including transformer and printed circuit board (2¼" x 4"). **$52▼**



KE-2: REGULATED POWER SUPPLY [4:74]
This lab quality bipolar regulator has outputs of +15 and −15V each capable of 1.5A. Regulation is by means of a pair of op amps referenced to an IC three-terminal regulator. The negative output is a voltage "mirror" of the positive output. This mirroring means the two voltage magnitudes will always be exactly equal, an important point for the powered device. Two LM395K ultra high reliability power transistors are the regulator pass elements. The kit comes with the board (3⅛" x 4⅜") and all board mounted parts. To construct a power supply based on this regulator two additional parts will be needed: a transformer (36V CT @ 2A), and a heatsink for the LM395Ks. **$51▼**



TRANSFORMERS

KJ-5-6: ILP TOROIDAL POWER TRANSFORMER: four 22V secondaries @ 5.5A, 121VA. As supplied with KJ-5-4. **$75**

KL-40: TOROIDAL, ±22V, VA, may be used for ±18, ±15 or 42V supplies up to 250mA. **$55**

KS-3TA: TOROIDAL. Two 40V windings @ 500VA. Powers two channels of Borbely's Servo 100 [1:84] or DC 100 [2:84] amplifiers. **$140**

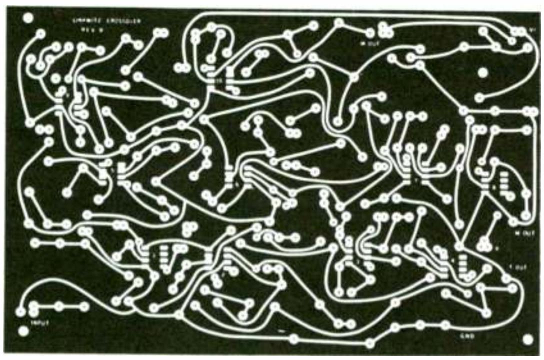
KS-3TB: TOROIDAL. Two 40V windings @ 225VA. Powers one channel of Borbely's Servo 100 [1:84] or DC 100 [2:84] amplifiers. **$88**

CROSSOVERS

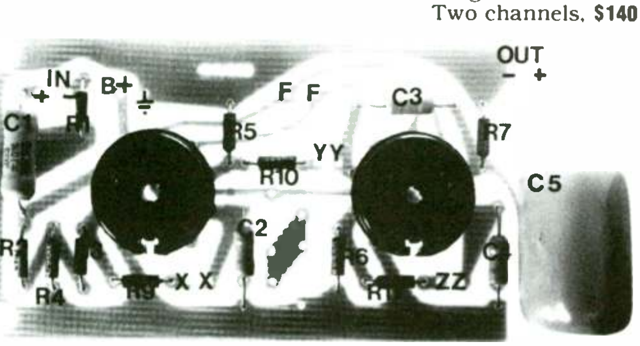
SBK-C1A: ELECTRONIC CROSSOVER [*SB* 3:82]
A single channel, two-way crossover. May be built with 6, 12 or 18dB/octave rolloff. The kit comes complete with all needed parts, 4136 IC and circuit board (3" x 3"). When ordering be sure to select the corner frequency, one of the following: 60, 90, 120, 250, 500, 1k, 2k, 5k, or 10kHz. A suitable power supply is the KL-4A/KL-4B or KW-3 or equivalent (see power supply section). **$32**

SBK-C1B: THREE-WAY CROSSOVER [*SB* 3:82]
This kit is similar to the SBK-C1A but adds a midrange output. When ordering select *two* frequencies from the list above. **$60**

SBK-C1C: STEREO, BI-AMP CROSSOVER BASS [*SB* 3:82]
This kit provides a single bass channel made up of summed left/right low-pass filter outputs in addition to the left and right HP outputs. Choose one frequency from the list above. **$64**

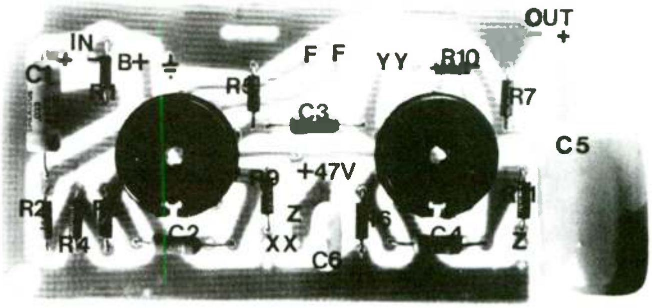


SBK-A1: LINKWITZ CROSSOVER/FILTER/DELAY [*SB* 4:80] ▲
This kit is the result of a very detailed investigation by Siegfried Linkwitz into active crossover design. His special attention to group delay compensation is evident in this kit's circuitry. The detailed article reprint supplied with the kit not only outlines the design's main points and tradeoffs but also provides details on constructing an excellent 3-box speaker system. Linkwitz also cites the advantages of active over passive crossover systems. The kit includes all high quality precision components and board (5½" x 8½") for one channel of a three-way filter/crossover. The 100Hz and 1.5kHz rolloffs are 24dB/octave. Below 30Hz the slope becomes 12dB/octave. Delayed turn-on for the bass is provided for driver protection. A suitable power supply is the Sulzer KL-4A/KL-4B or KW-3 or equivalent (see power supply section). Dr. Linkwitz has become world famous for his work on crossover behavior. Single channel, **$75**
Two channels, **$140**



LOW PASS

KK-6L: WALDRON TUBE CROSSOVER, Low Pass [3:79] ▲
A variable corner frequency low-pass filter, Butterworth 18dB/octave type. Includes three-gang pot, level control, (3) frequency determining capacitors and 12AX7 tubes. Complete parts and 2⅛" x 4½" circuit board. Specify *one* frequency range per single channel kit. 19–210; 43–465; 88–960; 190–2,100; 430–4,650; 880–9,600; 1,900–21,000Hz. **$60**

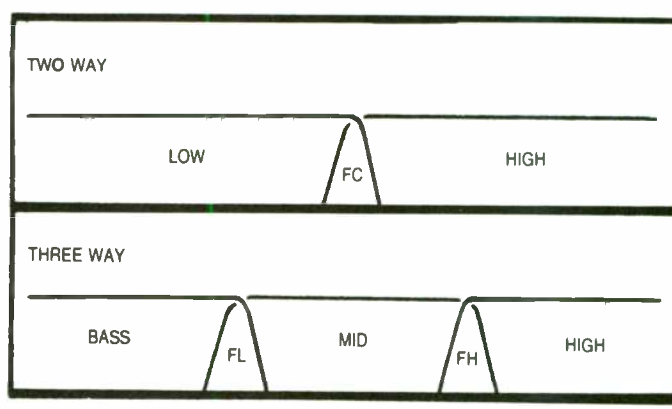


HIGH PASS

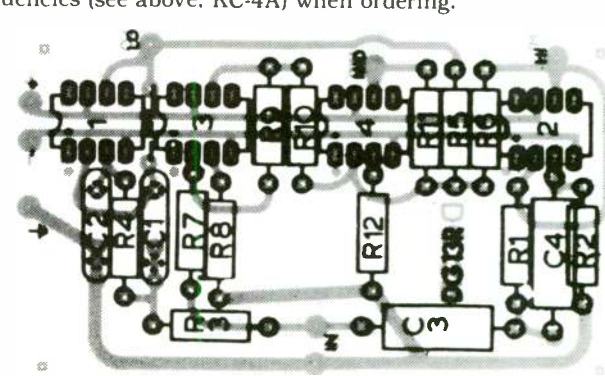
KK-6H: WALDRON TUBE CROSSOVER, HIGH PASS [3:79] ▲
Similar to the KK-6L except high-pass type. Select one frequency range from those listed above. Single channel, **$62**

Waldron Power Supply KK-7 is recommended for up to four filters (a stereo, bi-amp system). For specifics on this kit see the power supply section.

KC-4A: ELECTRONIC CROSSOVER, TWO-WAY [2:72]
A single channel two-way active crossover designed around the LF351 IC. The filter rolloff is 12dB/octave with corner at one of the following frequencies (choose one), 60, 120, 240, 480, 960, 1,920, 5kHz or 10kHz. These units may be cascaded for 24dB/octave rolloff. Kit is complete with all parts including board (2" x 3¼"). Requires a power supply, ± 17V @ 25mA. Suitable supplies include the KE-5 and KF-3. **$14▼**



KC-4B: ELECTRONIC CROSSOVER, THREE-WAY [2:72] ▲
Similar to the KC-4A but adds a center-pass filter. Specify two frequencies (see above, KC-4A) when ordering. **$18▼**



Circuit Boards

Old Colony's circuit boards are made of top quality epoxy glass, two ounce copper and reflowed solder coated material for ease of constructing projects which have appeared in *Audio Amateur*, *Computer Smyth*, *Glass Audio* and *Speaker Builder* magazines. Many also have the component layout printed right on the board!

The builder needs the original article (indicated by the date in brackets) to construct the projects. Articles are not supplied but are available through *Audio Amateur Publications.*

AUDIO AMATEUR

A-1: WILLIAMSON TWIN 20 POWER AMPLIFIER. (RW-8) 3 x 5" [1:70] Each **$8.35**

A-2: WILLIAMSON TWIN 20. Power supply board. (RW-9:2) 2½ x 3" [1:70] Each **$6.85**

B-2: WILLIAMSON-WATLING 4+4 MIXER. Staked terminals. (RW:AW) 3½ x 5" [2:71] Each **$10.00**

B-5: WILLIAMSON TWIN 20 PREAMP. Stereo. (RW-11) 3⅜ x 8" [2:71] Each **$16.00**

B-7: V.U. METER. (DG-7-A) 1¾ x 3" [3:71] Each **$8.00**

C-4: ELECTRONIC CROSSOVER. Board takes 8 pin DIPs, ten eyelets for variable components. (DG-13R) 2 x 3" [2:72] Each **$10.00**

C-5: GLOECKLER VOLUME CONTROL. 23 position wafer. (FG-1) 3 x 3" [2:72] Each **$5.50**

D-1: HERMEYER ELECST AMP II. 4½ x 4⅞" [3:73] Each **$12.00**

E-2: REGULATED LAB POWER SUPPLY. ±15V. (Ref. 1) 4⅜ x 3⅛" [4:74] Each **$8.00**

F-3: GATELY ±18V POWER SUPPLY. Regulated. (EG-2) 2¼ x 4" [2:75] Each **$8.00**

F-6: 30Hz FILTER/CROSSOVER. High pass or universal filter or crossover. (WJ-3) 3 x 3" [4:75] Each **$10.00**

G-1: GATELY PEAK DETECTING OVERLOAD INDICATOR. Two channel. (EG-3) 1½ x 2½" [2,3:76] Each **$6.40**

H-2: SPEAKER SAVER. (WJ-4) 3¼ x 5¼" [3:77] Each **$13.25**

H-4: GATELY MICROMIXER. Input. 15 pin plug-in gold edge. (MIC-10S) 8¾ x 3" [3:77] Each **$17.00** Five or more, Each **$15.00**

H-5: GATELY MICROMIXER. Output. 15 pin plug-in gold edge. Two channel. (MIC11-005) 12¾ x 3" Each **$26.20**

H-7: GLOECKLER 101dB ATTENUATOR. (FG-3) 2 x 2" [4:77] Each **$8.00** Five for **$35.00**

H-8: MORREY SUPER BUFFER. Two channel. (WM-3) 1½ x 2½" [4:77] Each **$8.00**

J-4: DIDDEN AUDIO ACTIVATED POWER SWITCH. (J-4) 3 x 4⅛" [3:78] Each **$7.55**

J-5: PASS A-40 POWER AMP. One channel. 3 x 3" [4:78] Each **$6.00**

J-6: SCHROEDER CAPACITANCE CHECKER. (CT-10) [4:78] 3¼ x 6" Each **$9.95**

K-3: CRAWFORD WARBLER. 3¼ x 3⅜" [1:79] Each **$11.20**

K-6: WALDRON TUBE CROSSOVER. (Two needed per 2-way channel). 2 x 4½" [3:79] Each **$12.00** Four **$40.00**

K-7: WALDRON TUBE CROSSOVER POWER SUPPLY. 5 x 5⅝" [3:79] Each **$12.95**

K-11: WILLIAMSON 40/40 POWER AMP. One channel. 3 x 5" [4:79] Each **$7.00**

L-1A: BOAK POWER AMP REGULATED SUPPLY. Plus or minus supply for power. 2¾ x 4⅛" [1:80] Each **$8.00**

L-2: WHITE LED OVERLOAD & PEAK METER. One channel. 3 x 6" [1:80] Each **$18.70**

L-4: SULZER OP-AMP PREAMP POWER SUPPLY. ±15V supply for pre-amps. 4⅜ x 4" [2:80] Each **$12.00**

L-6: MASTEL TONE BURST GENERATOR. 3½ x 6⅝" [2:80]. Each **$15.75**

L-9: MASTEL PHASE METER. 6⅝ x 2⅜" [4:80] **$11.25**

M-1: MULLER-CARLSTROM. Sweep Generator-Oscillator. (Two required). (CM-2) 2 5/16 x 5" [2:81] Each **$8.50** Pair **$14.00**

M-2: MULLER-CARLSTROM. Log Sweep Board. (CM-4) 2 x 2⅛" [2:81] Each **$5.00**

M-3: MULLER-CARLSTROM. Sweep Power Supply. (CM-5) 2⅝ x 3⅝" [2:81] Each **$6.50**

M-4: MULLER-CARLSTROM. Logger Board. (CM-3) 3½ x 4" [3:81] Each **$9.25**

M-5: MULLER-CARLSTROM. Logger Power Supply. (DG-12B) 2½ x 2¾" [3:81] Each **$5.00**

M-6: CARLSTROM IM FILTER. Intermodulation Filter. 2⅝ x 3¾" [1:82] Each **$6.50**

P-3: BORBELY 60W POWER AMP. (EB-60) 3⅜ x 6⅛" [2:82] Each **$11.75**

P-5: SWEEP MARKER ADDER. 3½ x 2¾" [2:82] Each **$6.20**

P-6: ADVENT MIKE PREAMP UPDATED. (K5) 3⅞ x 2⅜" [3:82] Each **$18.75**

R-2: BORISH DIGITAL DELAY. 5¾ x 9" [1,2:83] Each **$79.80**

R-4: DIDDEN MAIN PWR AMP. 4⅝ x 6⅜" [4:83] Each **$30.00**

S-1: BORBELY SERVO 100 AMP. 4⅛ x 6½" [1:84] Each **$16.00**

S-3: BORBELY DC 100 AMP. 6½ x 4⅛" [2:84] Each **$16.00**

S-5: KRUEGER MOD FOR MORREY IG-18. 2 11/16 x 2⅛" [3:84] Each **$7.60**

S-6: CURCIO VACUUM TUBE PRE-PREAMP AMP/REGULATOR. 4¾ x 2¾" [5:84] Each **$12.35**

S-6A: CURCIO VACUUM TUBE PRE-PREAMP MASTER POWER SUPPLY. 4¾ x 3¾" [5:84] Each **$10.35**

S-8: DIDDEN FAN CONTROL. 6¼ x 1⅝" [4:84] Each **$11.25**

T-1: CURCIO VACUUM TUBE PREAMP/AMP REGULATOR. 10 11/16 x 6 15/16" [2:85] Each **$36.00**

T-1A: CURCIO VACUUM TUBE PREAMP MASTER POWER SUPPLY. 3 3/16 x 2 11/16" [2:85] Each **$8.00**

T-2A: BORBELY R1AA-1. 3⅞ x 3⅞" Each **$10.50**

T-2B: BORBELY R1AA-2. 3⅞ x 5⅞" Each **$15.00**

T-2C: BORBELY TAPE BUFFER. 1⅝ x 3⅞" Each **$5.45**

T-2D: BORBELY LINE BUFFER. 3⅞ x 5⅛" Each **$17.60**

T-2S: BORBELY PREAMP BOARD SET. Eight boards. [4:85, 1:86] Set **$90.00**

T-2F: BORBELY PREAMP POWER SUPPLY. (Two required). 3⅞ x 4⅞" Each **$12.00**

V-2: LANG CLASS A MOSFET AMP. 5 11/16 x 6 1/16" [2:86] Each **$21.40**

V-3A: CURCIO AUTO MUTE. 1½" x 2" Each **$8.00**

W-3: BORBELY IMPROVED POWER SUPPLY. 4¼ x 5½" [1:87] Each **$16.00**

X-3: CHATER 40W MOSFET AMP. Two sided, one channel. 4 x 6¾" [2, 3:88] Each **$26.00**

X-3A: CHATER AMP POWER SUPPLY. 3½ x 6" [2, 3:88] Each **$14.00**

X-4A: VIKAN CAR AMPLIFIER. 4 x 5" [1,2:88] Each **$23.20**

X-4B: VIKAN PWR SUPPLY. 4⅛ x 5⅛" [1,2:88] Each **$17.00**

Y-2: RYAN ADCOM GFA-555 POWER SUPPLY REGULATOR. (One per channel required). 3 x 6¼" [4:89] Each **$28.50**

SPEAKER BUILDER

SB-A1: LINKWITZ CROSSOVER. 5½ x 8½" [4:80] Each **$25.50**

SB-D2: WITTENBREDER PULSE GENERATOR. 3½ x 5" [2:83] Each **$11.85**

SB-E2: NEWCOMB PEAK PWR INDICATOR. 1x2" [2:84] Each **$3.90**

SB-E4: MULLER PINK NOISE GENERATOR. 4⅛ x 2 3/16" [4:84] Each **$9.40**

GLASS AUDIO

G-B1A: CURCIO ST-70 POWER SUPPLY. 5 x 9" [1:89] Each **$27.00**

G-B1B: CURCIO ST-70 DRIVER BOARD. 3¼ x 7" [1:89] Each **$17.00**

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Please print *in clear block capitals* quantity needed, board number and price. Total the amounts and **REMIT IN US $ ONLY** by MC/VISA, check or money order. Postpaid in US, Canada please add 10%; overseas add 20%.

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continued from page 4

over built with ideal (lossless) components; it will display a constant input impedance only if it is a constant-power crossover. With no losses, constant power out means constant power in; thus constant input resistance. Conversely, *Fig. 1* shows the input impedance to a two-way second-order all-pass crossover terminated with fixed 7Ω resistors. Typical of two-way all-pass crossovers, it shows an impedance rise at the crossover frequency (1kHz) of two to one. This corresponds to the 3dB dip in output power this crossover exhibits at the crossover frequency.

Three-way crossovers are much harder to predict. *Figure 2* shows the schematic for a three-way third-order crossover using the cascaded midrange topology. *Figure 3* shows the input impedance for R. M. Bullock's positive bandpass all-pass crossover using the schematic of *Fig. 2* and with crossover frequencies of 500 and 2,000Hz. See *SB* 2/85, p. 26, and 4/87, p. 9. Again with fixed resistive loading, and not using Bullock's series padding resistor (R_A), the input resistance dips two to one throughout the midrange region. *Figures 4* and *5* show the schematic and input impedance for the same crossover response implemented via transposed midrange topology. For this implementation, the impedance dips slightly only at the crossover frequencies.

I concur there is merit to providing an amplifier with a constant and resistive load. Take this into account when selecting your crossover type and topology. However, it is dangerous to attempt to force the input impedance of a non-constant-power crossover to be constant and resistive via Zobels on the various drivers.

I also find the conclusions drawn from *Graphs 4* and *5* of the original article regarding the effects of the woofer Zobel on the vented-box impedance peaks contrary to my experience. I have measured this impedance numerous times with and without Zobel and found no change at low frequency. I believe the explanation may be that the enclosure was opened and resealed between these two tests. The impedance minimum (between the two peaks) dips just below 7Ω in *Graph 4* and nearly to 5Ω in *Graph 5*. The impedance dip resistance of a vented box is a direct indicator of box loss or Q_B. If the dip were to the driver DC resistance (R_E), then the box losses would be zero. I believe *Graph 5* shows an enclosure with improved sealing relative to that of *Graph 4*.

I encourage readers to heed the work described by Mr. Cox. I have also found you can greatly improve purchased

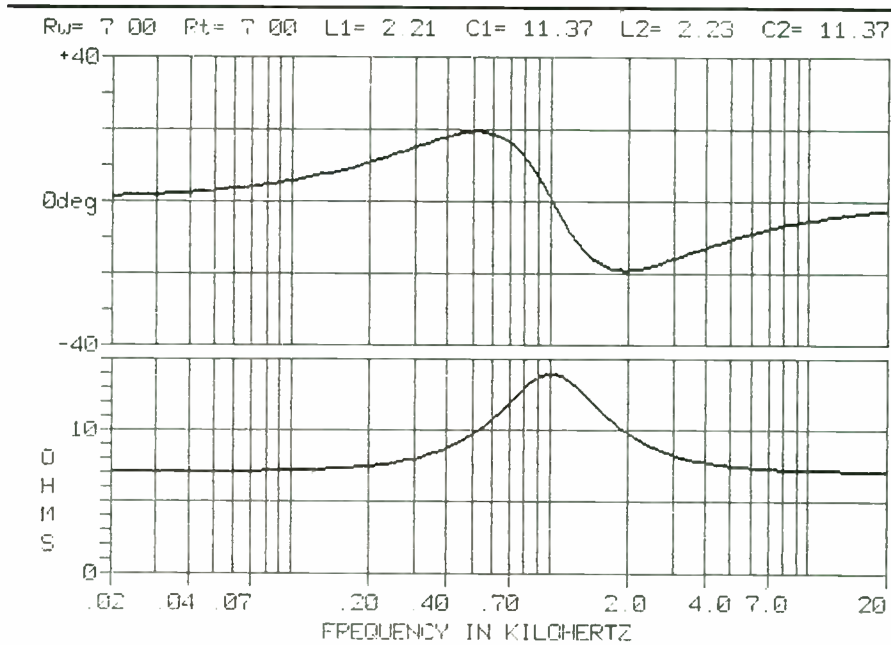


FIGURE 1: Input impedance to second-order all-pass crossover.

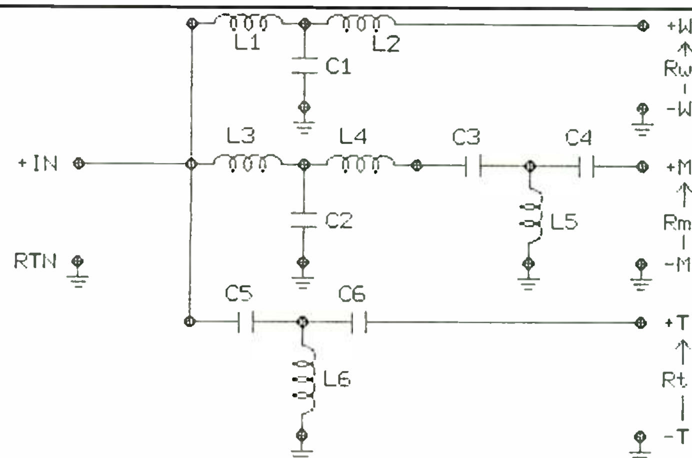


FIGURE 2: Schematic for third-order crossover, cascaded midrange.

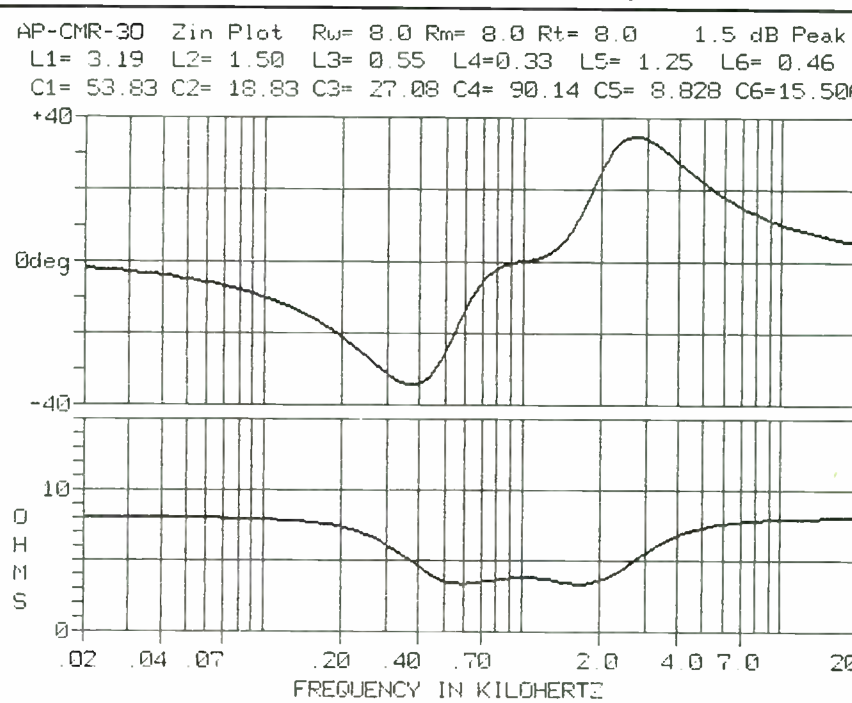


FIGURE 3: Input impedance for third-order all-pass crossover, cascaded midrange.

speaker systems by reworking the supplied crossover design.

G. R. Koonce
Liverpool, NY 13088

S. Wayne Cox replies:

I thank you for your comments, which I will discuss in order.

I must admit I do not like to see large impedance fluctuations ("humps") above F_H in a vented loudspeaker system, for reasons I stated in the article. Using impedance equalization, you can achieve much flatter (if not absolutely flat) curves above F_H, and in the process, reduce crossover misinterpretation problems associated with such humps. You correctly identify certain crossover formats with which Zobels might prove troublesome.

I refer readers to R. M. Bullock's excellent series on passive crossover networks appearing in earlier issues of *SB* (1, 2, 3/85, 1/86 and 4/87), particularly if they are unsure whether their crossovers are APC, CPC, or both simultaneously, as in odd-order networks. Part V of this series (*SB* 4/87) addresses the situations you describe in your letter. I will certainly mind your warnings as I design a three-way crossover for a new loudspeaker system based on the drivers in my JEL L166s.

I would advise anyone involved in loudspeaker design, whether using Zobels or not, to run impedance curves for the 20Hz-20kHz band at the very least prior to powering up a proposed system. This will allow you to catch dangerously low impedances which crop up from time to time because of wiring errors or in those special cases to which you refer.

I would be interested in seeing curves similar to those in your letter, for asymmetric 6/12 and 6/18dB/octave two-way networks.

The change in Q at F_H, which I attributed to Zobelling the 7se's woofer (*Graphs 4* and *5*) may have been caused by a change in the quality of the woofer seal, as you suggest. Since I also tightened the tweeter screws and those attaching the crossover/speaker input terminal assembly to the back

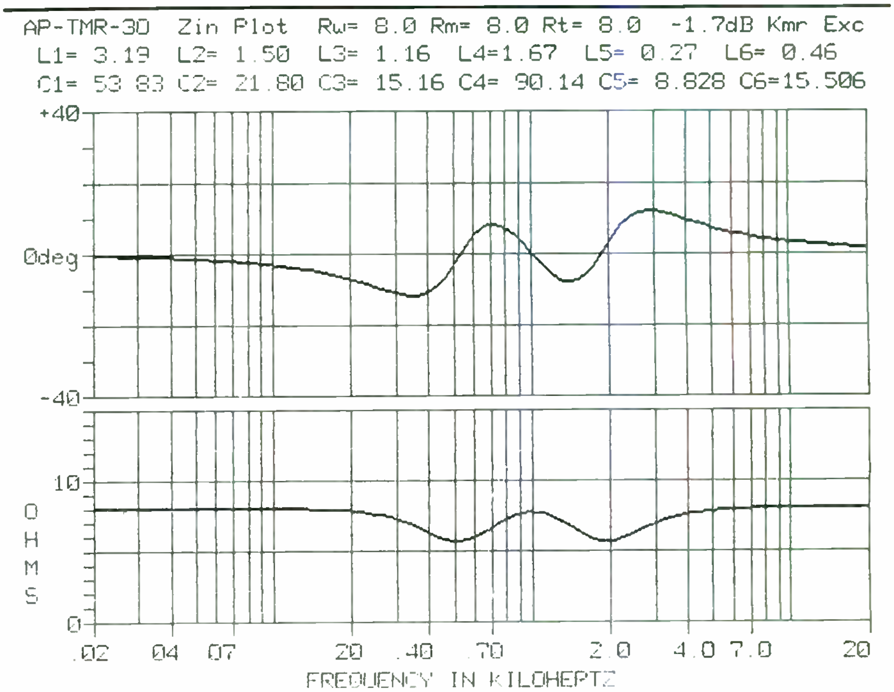


FIGURE 4: Schematic for third-order crossover, transposed midrange.

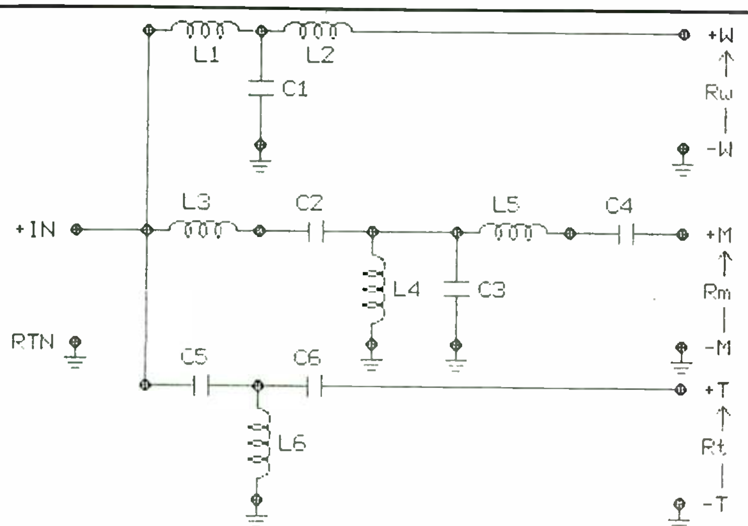


FIGURE 5: Input impedance for third-order all-pass crossover with transposed midrange.

panel at the same time, their sealing might also have contributed to the observed changes. In *Graph 1*, however, before and after F_L and F_H, Qs are in much closer agreement. In this case, I removed the woofer and attached test leads to its terminals before running them out through the port. Then I remounted the driver before running the upper (stock) and lower (Zobelled, with the Zobels clipped to the test leads) curves. I have, however, noted Q changes of the driver resonant peak following Zobelling before, even in sealed-box systems. I will investigate this matter further.

The impedance minima at F_B were actually 6.4 and 5.6Ω for *Graphs 4* and *5*, respectively. This is in good agreement with the value of 5.8Ω found by D. B. Keele, Jr., in his review of the Paradigm 7se in the September/89 issue of *Audio* (*Fig. 10*, p. 88). Mr. Keele attributes the degree of internal box loss (Q_B) in this speaker to the use of a relatively large amount of damping material. Other sources of box loss in vented systems are leakage and vent losses. These are undoubtedly all responsible to some extent for the impedance at F_B exceeding R_E. I do not think it is possible in the real world for box losses to be equal to zero. Every speaker I have tested had an F_B impedance at least 1Ω greater than R_E.

In closing, I certainly do not see the Zobel as a panacea in loudspeaker design. It is merely one of several tools for achieving better/more predictable performance from a given loudspeaker system.

CHOOSING THE RIGHT CAPACITOR

In his *SB* 3/86 and 4/86 articles, Mr. Koonce presents data from which the AC voltage and current requirements of crossover components may be estimated. This is a truly commendable series whose implications, I suspect, are being largely ignored because speaker builders can't find a supplier for capacitors with an AC voltage and current rating. Can't *Speaker Builder* help by informing some capacitor manufacturers of the specific capabilities needed for service in loudspeaker passive filter circuits, and ask or request for some feedback on the matter?

David J. Meraner
Scotia, NY 12302

G. R. Koonce replies:

First let me thank Mr. Meraner for his kind comments on my articles covering the stress placed on passive crossover components. His specific question regards a matter of policy for *Speaker Builder* and I can not respond directly to this request. However, I can comment on the general question of the capabilities of capacitors used in passive crossovers.

The crossover components stress articles (*SB* 3/86 and 4/86) do allow builders to estimate the stress placed on the coils and capacitors for various crossover topologies and shapes. Part I (*SB* 3/86) shows how I evaluate coils for their current capability, and a later article (*SB* 6/88) shows a more dangerous steady-state coil evaluation approach. The focus has definitely been on the coils as I find they cause problems, and visual examination of the coil does not give a good indication of its capability.

Mr. Meraner makes a good point about the AC current capability of capacitors, something I have worried about but not approached in a scientific way. The current through the capacitors in a passive crossover can be several times the current delivered to the driver and thus needs some consideration. I work on the crossover, changing or adding components while the system is playing away. If you have done this, the size of the spark when a capacitor is added or removed gives some idea of the current these components are asked to carry.

I will not comment on non-polar electrolytic capacitors as I avoid them if at all possible because of the sound quality destruction they cause. I have successfully used mica (small values to trim), paper, ceramic and all forms of plastic film capacitors. While these come in different sizes and shapes, and with big or small leads, I must admit I have never had a problem with any capacitor. Please do not misunderstand this statement. Different type capacitors will definitely affect sound quality; it is just that I have never had one change the sound as a function of signal level (a very common effect with coils) or had one burn out.

I seldom use any capacitor below a 100V rating; I go even higher for more powerful systems. My approach has been to use capacitor types that I have used before because I know what to expect. Admittedly, I have no experience with the very expensive film capacitors used in the high end speaker systems—they are just too expensive for what I am trying to accomplish.

I breadboard the crossover outside the cabinet to allow trimming it for the best possible sound. After a listening session, I touch all the components to see if I can detect heating in any coil, capacitor or resistor. I have never detected any heating in a capacitor and would change it immediately if I did. I also select the capacitors based on their physical size, and lead wire diameter based on how hard I am going to push them. This is not a scientific approach and I may be fooling myself in some situations, but again, I have never had any trouble.

This does not help Mr. Meraner in his quest to know what capacitor types to buy, but my experience is that there is little problem with any plastic film capacitor. This may not be true if you are building a very high-powered system. I will give some consideration to a technique to test capacitors; again, an approach that works after the fact and not before you make your purchase. Perhaps other builders will relate their experiences with various capacitor types in passive crossover application.

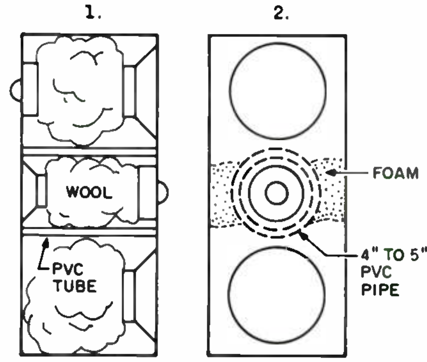
DIPOLES WORTH THE MONEY?

I'm an advocate of dipolar radiation. To me, it imparts a comparative sense of realistic depth and ambience. Contrarily, however, typical large dipoles lack pinpoint focus of individual instruments and voices such as afforded by small dynamic "satellite-type" systems. I am curious to know, *in theory of, course*, whether bidirectional radiation could be successfully applied to Joe D'Appolito's "symmetrical satellite" configuration.

Would the first-arrival sound uphold the design's controlled response pattern, or would rear radiation destroy the entire concept? If such a configuration *were* feasible, would a rear-firing midbass driver cancel out the effects of diffraction loss? Does the "symmetrical satellite," *as is*, project a sense of omni-directional depth—rendering the above considerations superfluous?

Finally, Dynaudio claims their T330D driver was developed toward the fulfillment of the "D'Appolito approach"—I wondered if Mr. "D" has experimented with this driver and if so, whether it's worth its not inconsiderable price.

Leigh A. Wax
Gainesville, FL 32601



Joe D'Appolito replies:

I will answer your questions in the order you pose them:

1) The direct path or "first-arrival" polar response pattern would not be affected by the rear radiation.

2) The rear-firing midbass drivers will tend to cancel the diffraction loss phenomenon. At frequencies where the front-to-rear distance equals one-half wavelength, however, there will be a dip in response. Using the Swan IV satellite as an example, and doubling the enclosure depth to accommodate the volume required for the extra set of drivers, this frequency would occur around 320Hz.

3) In properly treated rooms with properly recorded material, the sense of depth created with the symmetrical satellites is uncanny.

4) The biggest difficulty I have experienced with the T330D is its sheer physical size and weight. I have no plans to use this driver in any current designs. As to whether or not it is "worth its not inconsiderable price," I'm afraid you will have to decide that for yourself.

DOUBLE CHAMBERS

What effects and possible benefits would be noted in using G. L. Augspurger's "Double Chamber Speaker Enclosure" using H and α from your alignment tables, or from D. B. Keele's calculation method as David Weems did in "A Small Double-Chamber Reflex" (*SB* 4/85)?

Another question—many P.A. bass cabinets have used a tapered "horn-loaded" port—have you tried modeling this to see if it has any useful application? (Perhaps augmenting the low bass output in low Q_T alignments?)

Fred Ireson
Huntington, WV 25701

Robert Bullock replies:

I did some rough modeling of double-chamber systems a while back in order to respond to an earlier *SB* letter on the subject and it was my impression they are relatively insensitive to driver characteristics. This leads me to expect that applying vented-box alignments would probably not hurt. But I see little reason to expect it would help either, since a different loading is involved. Your best chance for a satisfactory system is to reproduce one of the published designs.

I have not worked with horns at all except in the transmission line context, so I have no feeling for what horn loading a port might accomplish, except that vented-box alignments probably couldn't be used. Possibly a horn expert such as Bruce Edgar might be able to say more.

Bruce Edgar comments:

As far as I know, nobody has adequately modeled the horn-loaded port for bass reflex speakers. The idea is an old one which appeared on several designs in the 50s and 60s, notably the Klipsch "Rebel." Paul Klipsch has disavowed the design because the output from the horn-loaded port swamped that from the driver radiator (*SB* 4/89). However, there are probably applications to low-Q_{TS}/high-sensitivity (100dB) woofers now on the market, but each driver will have to be handled on a case-to-case basis.

ALIVE AND WELL

We recently received a copy of *Speaker Builder* 1/90 and saw the letter from R. F. Stonerock and Michael Lampton's reply (p. 64). We are happy to report that Gold Ribbon is alive and well and continues to ship its patented vapor deposition ribbon diaphragms around the world.

We acquired Gold Ribbon Concepts in October, 1988, and have recently completed the first phase of new product development. Along with the original Concepts team, we retained Alan Hulsebus, the engineer who transformed the Gold Ribbon diaphragm from an esoteric component into the centerpiece of a system that inspires all who hear it. We are happy to report that we shipped Mr. Stonerock eight ribbon diaphragms on February 22.

Thomas E. Simon
Gold Ribbon Sound
Iowa City, Iowa 52246

HELP THE BLIND

The New Mexico Talking Book Library lends recorded books and magazines to people who cannot read regular printed material due to blindness or visual or physical handicap. We serve about 3,000 people with 80,000 items per year. We work in cooperation with the National Library Service for the Blind and Physically Handicapped, the US Postal Service, and volunteers.

We also lend cassette and record players and headphones. Until this year, the National Library Service provided us with headphones. This service suddenly stopped and we now depend on donations.

If you have any stereophonic or monaural headphones you are not using, our patrons will put them to good use. The Telephone Pioneers, an organization of veteran telephone workers, have volunteered to recondition donated headphones in need of repair.

The USPS will carry this equipment for free. In place of stamps on the parcel, write "Free Matter for the Blind and Physically Handicapped." Send donations to: New Mexico Talking Book Library, 325 Don Gaspar, Santa Fe, NM 87503.

FENDER BLENDER

I enjoyed Glenn DeMichele's article "Cylindrical Symmetric Guitar TLs" (*SB* 1/90)—great to hear about hi-fi techniques applied to live-sound reinforcement. So many electric musicians pay plenty of attention to their chops but their amplified tone is awful.

Many of the techniques for hi-fi can be adapted for clean, acoustic-sound guitar on stage (without problematic microphones), but a flat response system isn't really the goal. It's almost impossible to use equalizing to get the proper brilliance —you end up with horrendous hissing. So, I like to build the sound into the speakers themselves.

Here's a speaker for guitarists who want that clean acoustic sound: the Audax TX 2025 RSN (the cast frame and larger magnet versions are fine, too). This is the driver Dick Olsher made famous in his "Dahlia-Debra." The same midrange peak that "honks" (sorry, Dick, *someone* had to say it) is *perfect* for amplified guitar, especially a guitar using the usual inductance (coil + permanent magnet) transducer. And this is a really dynamic, punchy speaker. Run this 8″ driver full range; the peak begins at roughly 1.5kHz and runs right out to 5 or 6kHz before taking a pretty steep dive.

These drivers handle a scant 50W, so you need more of them than the usual guitar drivers for higher SPLs. Their high Q and relatively stiff suspension mean you can run them in an open-back cabinet if you don't play bass guitar through them. Their efficiency is quite high since that peak in the midrange/treble is allowed to run free. Roll in a Morel MHT 37 semi-horn-loaded 28mm soft-dome professional tweeter (97dB efficiency *and* hi-fi) with a fourth-order passive network somewhere between 2 and 5kHz. One tweeter per two to four woofers is enough. You can add a switch to turn off the tweeters if you want to get "dirty"—the Audax drivers sound great with an overdrive sound. Rig the switch so the crossover is *completely* out of the circuit when turned off. You can easily rig a foot switch to shut off the *ground* to the tweeter crossover.

Nothing beats a big tube amp for high head room; tweeters will sound *awful* with even the tiniest bit of amplifier clipping. You would need a transistor amplifier with nearly 10 times the rating of a tube amp. Believe it or not, I recommend you dust off that old Fender Twin (best with its 4-6L6s) or Super (2-6L6s)—a Deluxe, with its dual 6V6s, just doesn't have enough head room. Any vintage will do since you can upgrade the capacitors with high-voltage polypropylene and polystyrene units, and replace some of the more critical resistors with metal-film types.

Around 1968, Fender changed the capacitor at the input of the power amp from 0.001 to 0.01. This changed the old "surf" sound to "muddy/boomy bass." Try 0.002 to 0.005 (polypropylene, naturally), re-bias those old 6L6GCs and check for microphone 12AX7s.

My favorite pickups are the L.R. Baggs piezo bridge pickup for flattops, and the Bartolini 1C "Beastie II" for arch-tops and electrics. Make up some of your own not-too-long cables from *good* wire and *good* connectors.

I think fans of that crystal-clear acoustic sound will be amazed at this combination. The Fender tube amps have always been a great design—and with some upgrades in parts and *really* hi-fi speakers —well, get ready for a sound that'll make you drool!

David G. Helder
San Francisco, CA 94110

THE HUMAN SIDE OF ENGINEERING

Being one of the four percent of U.S. college students who will graduate with engineering degrees, I am in complete agreement with your recent editorial (*SB* 2/90). I have experienced firsthand "the suffocation of curiosity under an avalanche of raw fact." This phenomenon does not end in junior high or high school, but continues through college, and for me, ends where theory meets useful application. Math and science have always been difficult and abstract, and while instructors must always look for better ways to teach material and pique students' interest, the bottom line is that these subjects are difficult to master. Anyone considering science as a career must acknowledge this. Still, the curiosity of the individual and the love of discovery are just as important as ability, but are too often overlooked.

Perhaps one reason for the technical lethargy of the United States is the motivation behind the studying and hard work. A survey of engineering students will usually reveal that the chief reasons for studying the subject are money and career opportunities. Few have experienced the process of discovery which is the whole reason for *SB*'s existence. I believe it is this sort of fascination—passion, if you will—which leads to success. Reading *SB* in high school made me aware of what I could do if I understood the math and physics behind sound reproduction. It also gave me the impetus to continue my studies. This was especially helpful later when many tough courses in college seemed pointless. But I kept going, and in the last semester or two my courses have become very interesting.

In saying this, I wish to give *SB* a pat on the back for encouraging each reader to explore the wonders of science and art at his or her own level, without fear of being condemned (or flunked) for not making Ph.D.-level discoveries. Thank you for a unique magazine and keep up the good work.

Perry L. Sink
Lincoln, NE 68504

UNLINE vs. SHORT/MICROLINE

I have read John Cockroft's TL articles (*SB* 3/87, 4/88, 5/89) with great interest and intend to build the Shortline or Microline in due course. My friend built the Octaline using the KEF B110. He did not have the Unline article; this would have told him that the B110 is unsuitable for the Octaline length. Except for low bass, he is extremely pleased with it.

I am a little confused with the Unline article as compared to the Shortline/Microline articles. The Octaline figures are within 10% of the formula in the Unline article. The Shortline uses an RS 1021 which has a Q_{TS} = 0.41, implying a length of 65″ and a density of 0.525 lb/ft³. But the article shows Shortline having a length of 36″ and a stuffing density of 0.84 lb/ft³.

The replacement woofer K1825WFX PP has a Q_{TS} of 0.38 (from Peerless catalog). This is even worse!

For the Microline, the L050WFX PPO has, you say, a f_S/Q_{TS} of 60z/0.43. The Peerless catalog puts it as 45Hz/0.4. Never mind. After the mods, the new Q_{TS} (0.52) puts line length as 25″ and stuffing density as 0.845 lb/ft³. You used 0.9 lb/ft³—close enough (perhaps).

My question is, why is it so different for the Shortline? Apparently, if you want to reduce the line length from the calculated figure (for the Shortline it is from 65″ to 36″) you need to increase the stuffing density. The relationship isn't clear. Please comment.

I intend to use the KEF B200, which has a published Q_{TS} of 0.51, and use about 27–30″ line length. Incidentally, KEFs are about 20% cheaper here as compared to US prices.

Thank you for sharing your experience in TLs. It is appreciated.

K. G. Vergis
46000 Petaling, Jaya, Malaysia

John Cockroft replies:

What a pleasure to hear from you! Your letter is the first I have received from your part of the world. Thank you for your interest in my articles and in my speakers.

I looked up the specs for the KEF B110 and found Q_{TS} to be 0.31 to 0.33 (depending on the model). This probably would cause a reduction of deep bass in the Octaline. The F_S of 37Hz is close to that of the modified Radio Shack 40-1022, the one used. However, the Q_{TS} was close to 0.5, if I remember correctly. You didn't mention whether he modified the B110s. My guess is that due to the cost of them he perhaps didn't. By adding series resistance he could raise the Q_T (at least temporarily) to see if it would help. Adding 2Ω would give a Q_T of about 0.41. (This is based on an approximate average of the parameters of the two model B110s. I assumed R_E = 7Ω and Q_{TS} = 0.32). A 3Ω resistor would give a Q_T of about 0.457. To arrive at those figures I used: Desired $Q_T = Q_T \times (R_E + R_X/R_E)$, where R_E is the added series resistance.

You can also determine the series resistance for a desired Q_T by: R_X = (desired Q_T/Q_T) × R_E − R_E.

While you're just testing, it might be desirable to insert the series resistance ahead of the input of the Octaline. In this way you won't have to readjust the tweeter section to balance input to the woofer. If the series resistance improves the bass, it could be retained or mass could be added to the B110 cones (in this case F_S would also be lowered). The MM of the B110 is close to 10 grams. If 6 grams were added to the cone the mass would increase by a factor of about 1.6. This would raise the Q_T by about 1.26, giving about 0.4048. F_S is lowered by 0.79, to about 0.79Hz. In either case the power loss should be the same. Octalines are not efficient, but in a moderate-size room and given enough power, they can be very pleasing. It's good to have at least 60W/channel or so. The price for bass is always efficiency (except in public relations departments).

You aren't the only person to be confused by the Unline article. Several others have written as well. In the original manuscript the word "arbitrary" was included in the title to describe the model. The publisher, for reasons of his own, chose to remove it. All of the transmission lines I have designed (except for the Unlines) were arrived at empirically, by trial and error. The Unline article came about when I was working during the Thanksgiving holidays a couple of years ago. (The physicists got the turkey, I got the bird.) While staring at the four walls, I began to think of the TLs I had made and tried to find some relationships among them. The result was the article, which I originally didn't intend to publish. The equations and the table tend to "idealize" some parameters, but they're close. Then, to see if there was any merit in the situation, I built the Unline. They worked fine.

The actual Q_T of the RS 40-1021 I used in the Shortline was 0.529 (not the published 0.41.) We can think of this as being about 20% high for a 36″ line (at least according to my table), or a pretty good match for a 24″ line. I actually made a 24″ line that I called the Squatline, which I may someday get around to writing up. It sounded very much like the Shortline, close enough to be able to use the two speakers as a stereo pair. When I made these speakers I wasn't thinking of Q_T; that came later, while I was staring at the walls.

When Q_T is quite low, the system begins to roll off about F_S as a result of the drooping overdamped curve. I suppose that if F_S was low enough, say in the 20s, the problem wouldn't be as serious as it would be if F_S were in the upper 30s or 40s. In sealed boxes, Q_T and F_S rise considerably higher than occurs in TLs. I read somewhere that Q_T can actually drop in a TL, I don't really know about this.

When I designed the Shortline, the F_S of the speaker was lower than the one in the Octaline. Also, the Shortline was essentially a straight line. Someone once stated that when lines were folded, they appear longer. This prompted me to use a higher-density stuffing for the Shortline. A lower F_S, I thought, would produce frequencies with longer wavelengths. Since only a fraction of longer wavelengths would be involved with the stuffing, I thought the higher density would be more effective. If I recall rightly, I started with 0.957 lbs./cu. ft. and eventually arrived at 0.845. Conceivably, I might have gotten down to 0.7, but the speaker performed so well at 0.845 that I didn't want to touch it. If it works, leave it alone. (Except when you feel really tweaky.) Alas, a neighbor took my Shortline with him when he moved, so I no longer have it to play with.

Regarding the Peerless woofer in the Shortline, it did indeed have a lower Q_T than the Radio Shack woofer. Several people, including myself, thought it sounded quite well. There came a time when I had a chance to listen to it for an extended period, and I eventually added about 10 grams to the cone. Part of the reason for this was that the woofer was more efficient than the tweeter. (I had also changed the latter.) The speaker seemed to become more solid in the bass, as well as becoming more balanced. So maybe the Shortline isn't really so different. Maybe it just works well in spite of its shortcomings.

My arbitrary model describes speakers that would produce a sound I like. Other TLs could be designed and built to other specs. Their output might be a little different but still be just as "valid" as the sound I like. There are, after all, many different tastes. In my opinion, just about any TL will generate a sound similar to all the rest. The differences would be merely a matter of degree.

Speaker system design is still mainly a matter of art or lore. In spite of all the hype, the "science" isn't very intensive or accurate. Even Thiele/Small stuff is only a vague approximation, based on an analogy to an entirely different subject. My Unline article is a "crutch" and maybe a little bit more. The fact that I have been able to successfully design systems using its figures merely tells me that perhaps TLs are very forgiving beasts. Consider the article a road sign: it points out the direction but it doesn't walk the road for you.

I probably confused things in the article by including "The design for a given Q_T." I should have been more careful to point out that as Q_T started to get really high, the lines indicated by the equations are impossible to realize. One reader was concerned because he came up with a line 4½″ long (!). Of course it wouldn't work. The speaker basket and magnet would take up all the room for the stuffing. On the other hand, lines of the Unline length (11½″) work surprisingly well. In fact, I am listening to one right now. It has an 8″ Peerless speaker with its cone mass increased. I am using it as a bi-amplified woofer with a pair of Octalines. I suspect, though, this is its absolute limit.

The woofer I used in the Microline is apparently the one listed in the current Peerless catalog as 831745 and also (T0125F/8), just to confuse those of us who knew it as the old number of the American-made Peerless 5¼″ woofer, no longer made. (I wish it was. I used one in a 5″ Unline with a Jvc ribbon tweeter and it is one of the best sounding speakers I have ever heard.) Q_T is listed as 0.42 and F_S is listed as 60Hz. At least I hope it is the one. It sure looks like it. Peerless has an annoying habit of not marking the model number on their units. This makes it hard for readers who want to duplicate a published system design. It makes it hard for authors, too.

The KEF B-200 should work all right in the Shortline inasmuch as the Q_T and F_S are similar to the RS woofer I used in the original. I have no idea though whether the published crossover will be compatible, so you may have to play around

Continued on page 85

Continued from page 83
a bit. But it should probably work just as well in the shortened length you describe.

The Microline stuffing density is 0.9 lbs./cu. ft. and it works well. This was the first line of this length I ever designed—it was made before the Shortline— and possibly I overdid it. However, it works and I don't want to tamper with it. I'm much more interested with a fine sounding system than I am with a neat-looking graph or table. I have built 24″ lines with a stuffing density of 0.7 (or 0.75) and these worked quite well, too. Apparently, things aren't so terribly critical when it comes to shorter TLs. This is a very nice thing.

I really don't know the ultimately correct stuffing density for these lines. All I really have to go on is my empirical experience. I know of no one else who has written anything on this (except, of course, Dr. Bailey, when he introduced the TL to the world; he was referring to his longer lines). I feel my recommendations are reasonable, however, as many lines have been successfully constructed following them.

The same is true of the Q_T thing. To my knowledge, no one besides myself addressed this area. (I seem to recall Gary Galo, or Craig Cushing, or someone once mentioning that lower Q_T's were better, but again, longer lines were involved and I'm not certain that the advice is prudent, even for them. Possibly, in a given situation, it may be apt. I don't know.) It just seemed to me the right way to go. It's quite possible that the exact Q_T figures I quote aren't the ideal ones, but I'm pretty sure they are more correct than the vacuum of information that surrounds my recommendations. In other words, usable TLs have been produced using my figures.

Many people have actually constructed my designs, or modifications of them and they tell me they are pleased with the results. So I guess I'm on the right track. I would love to hear your comments when you complete your lines.

ALWAYS READ THE SPEC SHEET

In *SB* 6/89, Robert Bullock stated that the linear excursions given by Dynaudio need to be halved. Is this right? For a 30W100, I should enter 4mm into my software? Are there other manufacturers whose X_{MAX} specs might throw me?

How does one use a single voice-coil driver as a subwoofer? Can you just put both channel outputs from two separate crossover networks into the driver (positive-to-positive, etc.), or is there a special network for this?

The Loudspeaker Design Cookbook and seven issues of *Speaker Builder* are my main source of information. I recall reading somewhere that two two-way crossover networks do not a three-way crossover make. Is there any way to add a subwoofer to an existing system?

I am particularly interested in compound woofer systems because of the advantages they offer: decreased distortion, higher power handling, and significantly smaller boxes. In such a system, what is the upper limit? Recently I had this odd idea of making a dipole subwoofer by sticking two woofers on a baffle in a compound configuration. Could such a dipole actually work? Would it offer the advantages listed above?

Greg Bryson
Martinsville, VA 24112

Bob Bullock replies:

Dynaudio states in their spec sheets that the excursion number is peak-to-peak (p-p). The number X_{MAX} is excursion from *center* to peak, so Dynaudio's numbers must be halved. It's very important to read spec sheets carefully.

Attaching both channels of an amplifier to the same points might damage your amplifier. If I wished to combine the channels, I would do it actively *before* the amplifier.

Cascading two two-way crossovers actually does yield a three-way crossover, but not necessarily a good one. In the case where the purpose is to add a subwoofer, the result will probably be O.K. if the original system is two-way. The idea is to keep the subwoofer crossover point far below that of the main system. This might be hard to do if the main system is three-way. Naturally, the best results are obtained by using one of the optimization programs available for crossover design. But if you are willing to spend time listening and tweaking, I think you could come up with an acceptable design.

The upper useable limit in a multiple-driver woofer system is hard to predict accurately. But as long as you use it mainly below 100-200Hz and you use an enclosure, you shouldn't have problems that you don't have with a single woofer. Using only a finite baffle introduces additional variables that I don't care to deal with.

THEATER SPEAKERS GET TWO THUMBS UP

I hope to retire my old audio system in the near future. It wasn't anything spectacular when I bought it used some 12 years ago, and working for a pipe organ builder while I was a student seemed to make me lose interest in audio recordings altogether for a time. I might have been worn out after spending entire days tuning pipes ranging from 32′ reeds sounding like jackhammers to mixtures like a chorus of dog whistles! Recordings of pipe organs always were a disappointment.

My interest in audio revived while I was studying cinematography at the Swedish Film Institute. Classes were quite small and we all received instruction in production sound recording as well as editing, etc. The teaching and equipment were absolutely first rate, and it was a revelation to find a world beyond consumer electronics and pressure sales. The "quality first" attitude was something I had missed since leaving the pipe organ shop.

Work on feature films has been sporadic, so to keep the wolf from the door, I also work as a projectionist in the neighborhood "grind-house" (a six-screen complex).

Recently the exhibitor decided to upgrade the sound systems, and I was able to salvage the midrange drivers and tweeters from three mono theaters. At first I was not very enthusiastic as the theaters had sounded awful, but I found the tweeters had been blown and the 30W amplifiers were probably the cause of our problems.

I sent for new diaphragms for the tweeters and was greatly surprised to hear how bright and sweet those dusty old things sounded at home. Aside from a friend's Klipschorns, I have never heard anything like it in a home system. They really are worth building a system around.

Now I am considering buying the best amp and preamp kits I can afford as well as building woofers to complement the theater components. Electro-Voice has been very helpful and is sending the data sheets for the drivers, only recently discontinued. Against the odd chance you might be familiar with them and willing to offer suggestions, the drivers are from Electro-Voice Sentry IV B horn loaded system, mid-range #1823M and tweeter #ST350A. The crossovers are mounted on the midrange horns and include a rolloff adjustment as well as a bi-amp input.

I expect to have to do a lot of homework and build a system. Any help you could offer would be greatly appreciated.

Glen Gustafson
Berkeley, CA 94705

Bruce Edgar replies:

I am familiar with the E-V Sentry speaker for PA use but not for home applications. PA speakers have different design criteria as compared to typical audiophile speakers. The mid and tweeter horns on the Sentry are designed to spread the sound evenly over a wide horizontal area. This distribution characteristic will smear the image considerably. But if you're most interested in pipe organ simulation, then you are looking for a high SPL. And the E-V Sentry will perform that task.

WONDERSEALANT

Brian D. Smith's article, "Adjusting Woofers for High Performance," brought to mind a product I've been using for quite some time.

GEOCEL brushable sealant looks like a thinner version of RTV, but it isn't.

It absolutely works wonders on the thin paper cones of Autosound factory speakers, rendering them much more tolerable. It also dramatically helps the mid- and high-range paper cone drivers typical of rack system speakers. But where it really comes into play is on paper-coned woofers, making them sound much closer to polypropylene or Bextrene.

GEOCEL sealant, when mixed with clean, dry pool sand also makes a good speaker cabinet damping compound.

Lastly, I will caution anyone to use GEOCEL with plenty of ventilation, and not to use it in your cellar or near a furnace.

It is also possible the solvent does not agree with rubber or foam surrounds, so be careful.

Gary A. Fretz
Red Hill, PA 18076

ADVICE ON SUB-WOOFER

I was thinking of building a sub-woofer using the SEAS 33F-ZBX/DD. Do you know of any plans which exist for creating such a device? If not, do you know of anyone who could come up with a suitable cabinet design and appropriate wiring?

I am a very good woodworker but only minimally acquainted with electronics.

Doug Wolff
Middlefield, MA 01243

Bjorn Borja, SEAS, replies:

To use a 33F-XBX/DD as a subwoofer, we recommend a heavy, well-braced cabinet with a net volume of 85 litres. A bass reflex tube with an i.d. of 150mm and a length of 220mm will tune the Helmholtz resonance to 30Hz, slightly lower than a standard QB3 tuning.

As it is very difficult to make a passive crossover which ensures reasonable impedance and pressure frequency responses and which, at the same time, gives a low enough crossover frequency, we strongly recommend the use of a separate power amplifier with a suitable low pass filter to feed the amplifier.

GOING OFF THE DEEP END

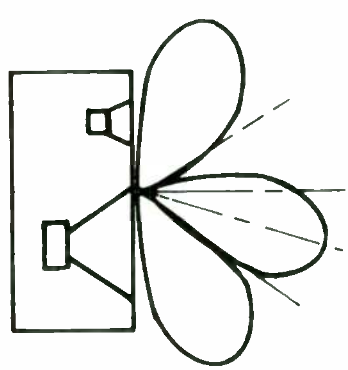
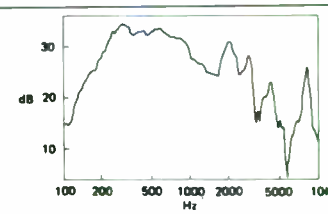
I have written before concerning loudspeaker theory and received a quick and pertinent response from Contributing Editor John Cockroft. Since then I have gone off the deep end and am embarking on a three-way full D'Appolito geometry design. I have some questions concerning various aspects of such a design.

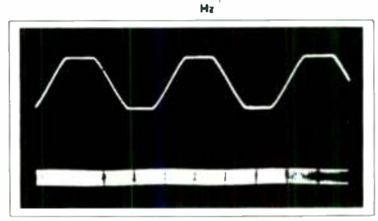
I am planning an Isobarik push-pull

woofer format. This will allow me to achieve a net 8Ω impedance in the woofer section in much the same way as does the Swan IV midrange section. It also reduces the volume to about seven cubic feet externally. The midrange section is where my first question arises. The woofer section could also easily be configured to 4Ω but the tweeter of my choice is 8Ω only. My question, then, is that while the tweeter and 4Ω mids may be equally efficient at one drive voltage, will the efficiency ratio remain constant at different drive voltages, thus changing the speaker's tonal balance? This assumes that the amplifier will drive them equally and that the speakers are otherwise ideal transducers.

My next question concerns Mr. D'Appolito's geometry and the crossover restraints imposed by that geometry. Everything I have read states that this geometry requires odd-order crossovers since their lobing patterns serve to fill in the void zones in more conventional speakers with odd-order crossovers. Crossover order is the net response curve of the driver as yielded by its natural response plus the effects of crossover filters. The Focal Arias are described as having true 24dB slopes. The tweeter seems to have 18dB of electrical filter, plus the responses of the tweeter and the woofers only show 12dB, the other components being impedance matchers. Are these then truly D'Appolito configurations, or do these other crossovers also yield the correct lobing patterns? The Swan IV has 12dB of electrical filtering. I couldn't locate a statement that Joe also incorporated the natural roll-off into the tweeter section.

I have also designed the system with driver staggering to help align drive centers as discussed with some frequency in *Speaker Builder*. However, Mr. Dickason asserts in the *The Loudspeaker Design Cookbook* that this is a predominantly negative goal as the good response area is narrow. Joe confirms this in his article on the Swan IVs. Arguing from logic, it seems that off-axis response should be more even in an aligned system since the radiation sources are coincident vertically, the interference patterns should be reduced. And in a full D'Appolito configured system with drivers aligned, time relations should be constant around the speaker radially in the horizontal plane,



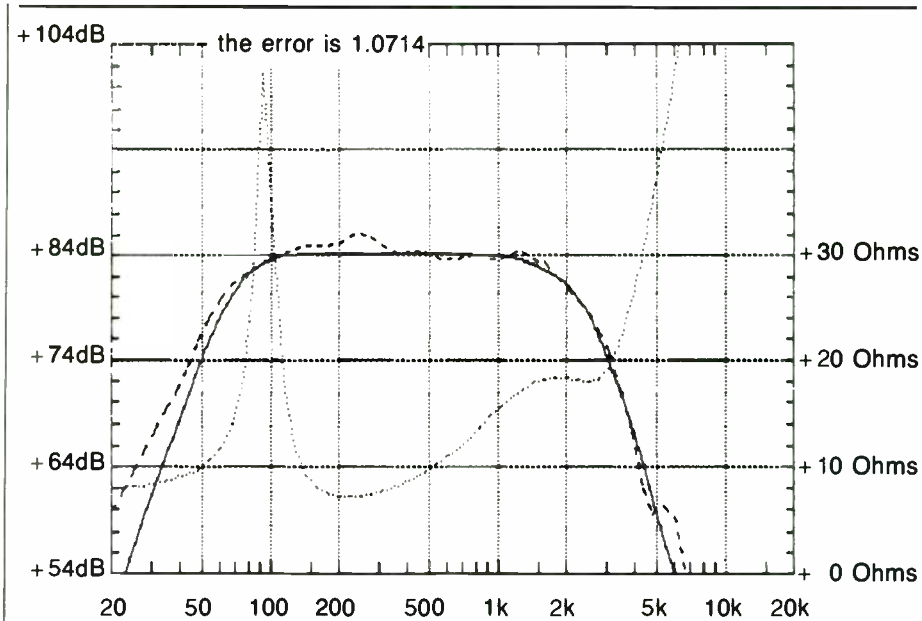


FIGURE 1: Response of dual 5K013Ls in Aria Five enclosure (dashed line) and ideal fourth-order response (solid Line). Input impedance (5ks only, dotted line).

i.e., a line source. This plane should be centered on the tweeter in a system as I have described. I would be doing a "kangaroo" style to avoid ceiling reflections. With careful shaping and some of the damping foams available, a kangaroo system shouldn't introduce any more surface diffractions than other straight line baffles.

My last question is much more subjective. In their argument for glue-mounting drivers instead of screw mounts, glue advocates state that the absorptive qualities of the glue stops baffle resonances. I accept that. But doesn't the energy transferred to the driver frame, and subsequently dissipated in the glue, reduce the efficiency of the driver and contribute to Doppler effects in the driver? A screw mount, while potentially less airtight, couples the driver to an essentially infinite mass enclosure in comparison to the mass of the driver alone, forcing only the cone to respond to driver input. Other methods could be used to control panel resonance. In any case, I think sealants should be applied to the driver to halt the leaks.

Phillip Hatch
Salt Lake City, UT 84109

Joe D'Appolito replies:

Apparently you plan to build a system similar in appearance to the Swan IV, but otherwise of your own design. The efficiency or, more properly, the sensitivity, of the drivers will not change with operating voltage as long as they are not overdriven.

The use of odd-order crossovers with my geometry produces the broadest, most uniform vertical polar response. However, many readers have interpreted this statement to mean that odd-order crossovers *must* be used to obtain the benefits of my geometry. This is not true. The main benefit of the 3/2 geometry is the stabilization of vertical polar response and the elimination of polar axis wander independent of crossover type or interdriver phase differences. As explained in our Swan IV article, a broad vertical polar response is often undesirable as it creates unwanted floor and ceiling reflections. In this case, an even-order or in-phase crossover may be superior because it narrows the polar response without shifting the central response axis.

The Arias do indeed have true 24dB/octave acoustic slopes. You are letting the circuit topology fool you. The extra parts are not impedance matches. The Aria Five low-pass filter starts off with a 6dB slope, transitions to a 24dB slope and finally ends up falling off at 12dB/octave. This response has been very carefully tailored to the acoustic response of the 5K013Ls to obtain an overall Linkwitz-Reily response. An in-phase crossover was deliberately chosen to narrow the vertical polar response. It is very uniform within ±15° of horizontal and then falls off rapidly to reduce floor and ceiling reflections. *Figure 1* shows the overall on-axis response of the 5K013Ls in the Aria Five and compares that response to the ideal fourth-order response curve.

Interference patterns are predominantly a function of driver vertical separation and are very little affected by the zero-delay plane offset which is only about 1.2 cm. Physical setback of the tweeter by 1.2 cm time aligns the drivers, strictly speaking, only along the principal axis of the tweeter. The alignment error grows as the cosine of the off-axis angle, however, so that reasonably good alignment is obtained out to angles of 30° or so. The real question is whether or not time alignment is worthwhile in practice. I have no compelling evidence that correction of the zero-delay plane offsets results in a superior loudspeaker system. However, there is irrefutable evidence that frequency response and polar response are the dominant measures of speaker performance. Time alignment is, at best, a second order effect. The ability to produce a good square wave on axis does not necessarily correlate with good sound. Time alignment is certainly nice to have, but not at the expense of frequency and polar response.

With regard to driver mounting, I have heard successful systems using both rigid and flexible mounting and have tried both techniques myself. Obviously, both approaches can be made to work well. I don't feel that efficiency is an issue here. For example, the ratio of cone mass to basket/magnet mass for a 5K013L is about 1/200. Thus, even when the driver is completely floating, only 0.5% of the input power is dissipated in the motion of the driver frame.

WOOFER DATA DEBATED

I would like to respond to Mr. Schwefel's letter regarding Radio Shack 40-1022A woofer variations (Mailbox, *SB* 1/90). I would propose that the variations across this set of woofers (including the "rejects") are unimportant.

The accompanying table lists the T/S parameters as well as some additional calculated parameters for a nominal and two rejected drivers measured by Mr. Schwefel.

Notice that the T/S parameters of the rejected units are substantially different from the nominal unit. Also notice the similarity of the calculated parameters for all three drivers. These numbers can be considered "relative performance parameters" and provide a more reliable way of comparing woofers. F_S/Q_{TS}, for instance, indicates the *relative* cutoff frequency in an "optimum" box. By contrast, the *absolute* cutoff frequency in an optimum box is about 0.85 times this number for a sealed box, and 0.35 times this number for a ported one.

Perhaps the most useful "relative performance parameter" for nominal applications is $f_S.V_{AS}^{.5}$. It indicates the relative cutoff frequency in a "standard box." The uniformity of this parameter for the three drivers says they will have the same cutoff frequency in most applications i.e., when box volume is less than about $11*(V_{AS}Q_{TS}^2)$. The plot shows the system responses for the three drivers in a 0.25 ft³ box tuned to 60Hz. This application has a relatively higher sensitivity to T/S parameters, yet variations are small. Note the consistency of the cutoff frequencies as predicted by $f_S*V_{AS}^{.5}$.

This example illustrates the problem with using the T/S parameters for comparing drivers. The relative performance parameters not only provide an intuitive means of comparing woofers, but guidance in their application as well. (For example, a good criterion for whether to port a box is if its volume is greater than $2*(V_{AS}Q_{TS}^2)$.)

If there is sufficient interest, I will submit a manuscript describing the inter-

TABLE I

T/S PARAMETERS

#	f_S	Q_{TS}	V_{AS}	Status	f_S/Q_{TS}	$f_S{}^*V_{AS}{}^{.5}$	$V_{AS}{}^*Q_{TS}{}^2$	$V_{AS}{}^*f_S{}^2$
1	55	0.356	0.238	OK	155	26.8	0.030	720
4a	49	0.307	0.293	REJECT	160	26.5	0.028	703
6a	62	0.428	0.184	REJECT	145	26.6	0.034	707

pretation and application of the relative performance parameters in more detail.

Mark Rumreich
Indianapolis, IN 46220

Bill Schwefel replies:

When I tested my Radio Shack drivers I sensed that something similar to your analysis was happening. I would be very interested in an article describing "relative performance parameters." Perhaps you could include information as to the probable cause of parameter variations. For instance, can we tell from the "relative performance parameters" whether an F_S variation problem is due to a change in cone mass as opposed to a change in magnetic strength? Such information would be very helpful.

My reason for rejecting two woofers, however, was based on Joe D'Appolito's suggestion (*SB*, 4/84, p. 14) to closely match F_S parameters of series-connected drivers. In my design I used four woofers per channel hooked in series/parallel. It was necessary to reject two drivers in order to ensure good power sharing between the series-connected pairs.

THUNDERBIRD à la MOOSE JAW

I have been trying to build a subsystem similar to Chris Edmondson's "Thunderbird Isobarik" (*SB* 3/89) but I have had no success in determing box size.

I am trying to build a sub with an F_3 less than 40Hz with a flat, vented alignment enclosure no greater than 4 ft³.

Using 4 JBLGT100s 10", manufacture:

F_S = 31Hz
Q_{TS} = 0.3700
V_{AS} = 4 ft³
Ohms = 8
Size = 10"

No one in my area has equipment to check drive parameters.

Could you please help me in finding information to build this.

Ron Brown
Moose Jaw, SK S6H 4H6

Chris Edmondson replies:

One simple way to determine the proper parameters of a vented box is to use the Small-Margolis equations presented by G. R. Koonce in the *SB* 3/87 article, "How To Use Non-Optimum Vented Boxes". I use these formulas when designing auto sound systems because the volume of the enclosure is quite often determined by the vehicle rather than by an optimum alignment. I have found the resulting systems behave predictably and sound quite good.

First, calculate the optimum volume for a single woofer, V_{BOPT}:

$$V_{BOPT} = 20\ V_{AS}\ (Q_{TS})\hat{}3.3 \quad V_{BOPT} = 3.0\ ft^3$$

CAVEAT CORRESPONDENTS

Things that go bump in our round file:

1. "I'm thinking of building a 16-in, 8-out console in my basement. What tape recorder should I buy?"
2. "Is my Fisher Z-705 receiver worth updating? Where should I begin?"
3. "Although I forgot to enclose a stamped, self-addressed envelope, please answer the following nine questions based on my experiences building your inverted RIAA kit."
4. "Please forward this (unstamped) letter to Ralph J. whose letter appeared in one of the 1970 issues—don't remember which."
5. "I have a Milhous 10W integrated stereo amplifier and a Gesundheit turntable. Which of the following six cartridges would you recommend?"
6. Queries with no stamped, self-addressed envelope or postal coupons enclosed.
7. Letters without return addresses on them whose envelopes have strayed away somewhere.
8. Illegible hand-written letters scrawled on odd scraps of paper. If you have no access to a typewriter, please try to be sure our typesetter doesn't lose his eyesight and his mind in deciphering your writing. (This is especially important if you want us to publish your classified ad.)

Since you are using four woofers in an Isobarik configuration, the total box size is the same as for a single woofer. The 3.0 ft³ meets your goal of $V_B < 4$ ft³, so calculate the −3dB point, f3:

$$f^3 = 0.28\ f_S\ (Q_{TS})\wedge -1.4 \quad f3 = 34.92\text{Hz}.$$

This meets your goal of $f^3 < 40$Hz, so calculate the box tuning frequency, f_B:

$$f_B = 0.42\ f_S\ (Q_{TS})\wedge -0.96 \quad f_B = 33.82\text{Hz}.$$

Now calculate the ripple response, R_H:

$$R_H = 20\ \text{Log}[f_B\ Q_{TS}/(0.4\ f_S)] \quad R_H = 0.079\text{dB}.$$

A ripple response of this magnitude is insignificant in this environment.

You may now calculate different parameters for smaller- or larger-sized boxes, but it would appear that an excellent trade-off between V_B, f3 and ripple has been acheived. Also, with an f_B of 34Hz you should realize good power handling with a broad range of music program material. Should you wish to use a different box size, the above-mentioned article, along with the following formula for computing box tuning parameters taken from the *Loudspeaker Design Cookbook* by Vance Dickason, should let you make the necessary adjustments.

I recommend that you place a partition in the box so that each Isobarik pair will have its own tuned enclosure.

Now calculate the ducted-port length (L_V) needed to tune a 1.5 ft³ box using a 4″ diameter port:

$$L_V = [(1.463 \times 10\wedge 7 \times R\wedge 2)/(f_B\wedge 2 \times V_B)] - (1.463 \times R)$$

(where R = Radius of port in inches and
V_B = Box volume in cubic inches).

Thus, L_V = 16.8 inches

This is rather long, so try a 3″ diameter port:

$$L_V = 8.9 \text{ inches.}$$

This length is more practical for a car and is the one I would recommend. I always use a signal generator to tune my boxes, but I have found the above formula to be quite predictable in that the port always seems to be one to two inches too long initially. So I would subtract about 1½″, or make each port about 7½″.

Assuming that you plan to use a "piggyback" Isobarik system like the one in my *SB* 3/89 article, you will need Isobarik tunnels that are 10″ in diameter and about 3″ in length. Make sure that, with a 3″ separation, the cone of the rear speaker cannot hit the magnet of the front one.

To complete the design, add 160 in³ (an approximation) for the volume occupied by the rear speaker, add 50 in³ for the port, and add 315 in³ for the Isobarik tunnel. This will yield a total gross volume of 1.8 ft³ per side of the enclosure.

Good luck with your system.

FIDELITY

continued from page 36

loud without clipping the Adcom 545 (150W/channel at 4Ω) or damaging the speakers. I used my trusty Realistic sound level meter and a record of Bach organ works. My ears gave out at around 120dB—the speakers could have gone louder.

THE SOUND. How do I love thee? Let me count the ways. This music lover's system has excellent sound stage and ambience, which is where the FFF (Formula For Fidelity) system shines. Polydax is not kidding when they claim a three-dimensional image over a wide listening domain. The stereo image goes literally from *wall to wall* and from one end of the room to the front of the speakers. I close my eyes and can see the musicians performing in my living room —silky highs, crystal clear midrange and clean, detailed, powerful bass.

I built this system last spring. After a major speaker building project every year for the last four years, I have finally built something I can live with for the long term. You can too.

REFERENCE

1. *Audax TPX System II*, Polydax Speaker Corp., (Subsidiary of Audax France) 10 Upton Dr., Wilmington, MA 01887, (617) 658-0700.

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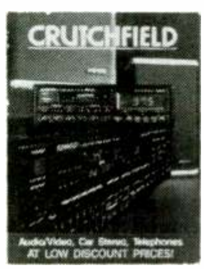

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DYNACO KIT BUILDERS—225,000 lb. buyout! Tubes, transistors, metal work, raw speakers, circuit boards, 200/200W amplifier kit, $299; manuals, any, $6. Shipping extra. Free parts list. ***SOUND VALUES***, Box 551SB, Dublin, OH 43017. (614) 889-2117, 10-4. T2/91

SPEAKER BUILDER **INDEXES FOR IBM-PC.** Find articles, corrections, letters, driver information, 1980–1989. Require dBASE or compatible (compiled with PC-FileB). $15 postpaid. Specify floppy disk size. ***RUSSELL SCHOOF***, 17777 S. Ramsby, Molalla, OR 97038. T3/90

SPEAKER DESIGN SOFTWARE for PC and Mac. **SpeakerCAD:** graphs predict performance, calculates woofer parameters, vents. **FILTERS:** calculates1-6th-order electronic crossovers. **CROSSOVERS:** 1-4th-order all-pass, constant power networks. $40 complete. ***QUBIX***, 2302 5th NE, Salem, OR 97303, (503) 363-5143. T6/90

D'APPOLITO ARIA 5 AND ARIA 7 cabinets, drivers, crossovers, etc. are available from ***WHALE COVE AUDIO***, (207) 526-4343. T6/90

MIT AUDIO CABLES, Van den Hul, Cardas, MAS Masterlink, OCOS, including Teflon insulated hookup wire for rewiring components; hi-flexibility tonearm sets, any custom termination; Solen polypropylenes to 200μF! WonderCaps-solder-wire; Vishay & Resista resistors; Edison Price, WBT, Odyssey, Tiffany connectors; RAM tubes; enclosure damping compounds; Simply Physics tone cones; NAVCOM isolators; spectrum analyzers, many parts and accessories. $1 catalog ($3 overseas). ***MICHAEL PERCY***, Box 526, Inverness, CA 94937, (415) 669-7181. T6/90

CLASSIFIED ORDER FORM

PLEASE FILL OUT IN CLEAR BLOCK LETTERS OR TYPE. PLEASE SPELL OUT ENTIRE WORD.

1	2	3	4	5	6	7	8	9	10
1	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50

☐ Private For Sale ☐ Private Wanted ☐ Trade If Trade please indicate # of insertions. ________

Private ads are on a one time insertion basis. Must be resubmitted for renewal. Ads cannot be taken over the phone.

Definition of a word: A series of letters with a space before and after. Please remember to include your name, address and telephone number when making calculations. In order for Private For Sale and Want ads to be **free** you must be a current subscriber. Please include your Magic Number. *Ten dollar minimum charge for charge card orders and Trade ads.*

Any words over 50, 20¢ per word; Trade ads please charge at 70¢ per word and indicate number of insertions. Deduct 10% for a 4x contract in *Audio Amateur* and a 6x contract in *Speaker Builder*; deduct 5% for a 2x contract in *Glass Audio*. Payment *must* accompany ad.

Please charge to my MasterCard/Visa:

CARD NUMBER EXP. DATE

SIGNATURE

☐ Check/Money Order enclosed

☐☐☐☐☐ MAGIC NUMBER

NAME

COMPANY

STREET ADDRESS

CITY STATE ZIP

ATC LOUDSPEAKER TECHNOLOGY, LTD. drive units for the esoteric speaker builder. Short voice coil woofers and 3" soft dome midrange drivers of uncompromised design and build quality. Professional 24dB/octave three-way stereo electronic crossover with adjustable phasing, momentary gain reduction, and balanced line in/out features, $1,500. Grover Preston, ***AUDIO ECSTASY***, 231 Elwood Dr., Rochester, NY 14616, (716) 865-9938, 7–10 p.m. EST. T3/90

ACOUSTICOAT is a specially formulated acoustical/mechanical vibration damping compound designed for loudspeakers. It is applied as a thick, viscous liquid which dries to a dense, pliable consistency. Coating all internal cabinet surfaces dramatically reduces colorations caused by internal resonances, vibrations, and standing waves. Improves imaging, midrange clarity, and bass definition. A must for speaker building! 1 gallon, $24; 5 gallon drum, $89; Includes shipping. ***R.D.V.*** 113 Knickerbocker Rd., Plainview, NY 11803, (516) 681-4675. T4/90

FALCON ACOUSTICS is one of the largest independent manufacturers of crossover networks and speaker system accessories in the UK, supplying manufacturers, retailers and export. Your guarantee is the trust our manufacturing customers put in the quality and reliability of our networks. **Inductors:** Ferrite (up to 200W), air-cored and transformer; **Capacitors:** Reversible electrolytic 50V/100V, polyester, polycarbonate and polypropylene; **Networks:** choice of over 70 for different unit combinations; **Components and Accessories:** most except for the wood! Please send for details, $2 air, $1 surface, to our mail order retail outlet. ***FALCON ELECTRONICS***, Tabor House, Norwich Rd., Mulbarton, Norfolk, England NR14 8JT. 6/90

WHALE COVE AUDIO is your source for the *SWAN IV* and for complete kits, empty enclosures, the *PEDAL COUPLER*, and Joe Curcio's new elegant rack mount version, the *PEDAL COUPLER II*. Box 356, Swan's Island, ME 04685, (207) 526-4343. T6/90

FOR SALE

Perforated aluminum stators for ESL cells per Hermeyer design, *TAA 2/77*, holes line up for maximum transparency, perfectly flat, 80 pieces, sheared 7" by 18", $250; Walt Jung WJ-1A preamp boards, parts, DC servo kit, Soundcraftsmen 20-12 equalizer, $50. Nick Mastrobuono, 50 Copperfield, Sarnia, Ontario, N7S 5K8, (519) 336-9160.

Pair JBL 124A/2203 12" Alnico bass drivers, used in L212 system. $Q_T = 0.14$ $V_{AS} = 14$cu ft. $f_S = 16$Hz, $290. Phil Boss, (505) 525-9556.

Interconnects: Apatures 3/$40 ppd.; Phoenix Gold 3/$30 ppd.; Souther tonearms: SLA, was $850, asking $300; Junior, was $550, asking $225, new, unopened; ADC cartridges PSX-30, was $150, asking $35 ppd.; Sennheiser HD-50 headphone, was $80, asking $35 ppd.; Apature A/VT Air Litz interconnects, were $90, asking $50/2 ppd. Andy, 2506 So. 20th, Sheboygan, WI 53081, (414) 458-2057.

(4) Ariston RD-80 turntables, two with arms, one shape, one profile, ready to play, $200 each; two without arms, otherwise complete, $150 each; original cartons, manuals, all under 5 hours. M. Thompson, 194 St. Davids Rd., St. Catherines, Ontario, Canada, L2T 1R4, (416) 227-4586.

Tweeters: Morel MDT-33, $75; Techniques 5HH10, $40/pr; JBL 075, $150/pr; Acoustat Spectra 22, $1200 (pickup); Yamaha SR-50 surround processor, $200; Bogen C-100B PA amps, $150; Tandberg 330 cassette, $75; KLH-27 AM/FM receiver, $50. Steve, (203) 397-3888 (CT), 7–10 p.m.

New bass drivers: Dynaudio 24W100, $89 each; Peerless TA305FSW, $38 each (dual voice coil, lower F_S version of TA305F). Fred Janosky, RD 2 Box 3502, Wernersville, PA 19565, (215) 693-6167.

(3) new SM120A Electro-Voice midrange horns, drivers not included. Electro-Voice uses in all horn Sentry IVB studio monitor systems. Usable lower frequency limit 300Hz. Can be used in high quality home or PA system. New $180 each, will take $100 each; new 1824M Electro-Voice midrange driver, $60; Hafler DH160 equalizer, $250; Thorens TD147 turntable with Shure V15 V cartridge, $350. All like new with original boxes and instructions. Michael Beasley, 332 S. Calderwood, Alcoa, TN 37701, (615) 984-0748 Mon-Fri. before 5:30 p.m., (615) 983-6414 afternoons and weekends.

ESS AMT, $600 or best offer; JBL three-way, $400 or best offer; Speakers in excellent condition. Victor, 10176 Bonita Ave., Riverside, CA 92503, (714) 688-9749.

Rapid Systems R340 PC based FFT spectrum analyzer and one channel digital storage oscilloscope. complete and excellent, requires full slot, $700, I ship. Pat, (619) 439-3666.

Decca Kelly ribbon tweeters. Type PK-30-R with original crossovers and acoustic lenses, new in original boxes, $200/pair or best offer. Tim Bates, 314 North First, Brighton, MI 48116, (313) 227-7344.

Pair 12" Pyle W12C600F F_S = 19Hz 95W 2" VC 60 oz., $50; pair crossovers 800Hz, 5,000Hz 12dB 150W, $25; Realistic under dash tape player, metal Dolby, $30; Denison Polaris indoor antenna, $20; Polydax tweeter HD100D25A, $12; 8" Realistic woofer, $8. Rocky, (815) 657-8488, before 8 p.m. or weekends.

IQS 401 FFT analyzer with Apple computer system, monitor, printer, many extras. Ideal for testing loudspeakers, $995 or separate. All like new. John Miller, (818) 706-9864, 7–10 p.m. PST.

MacIntosh 60, $100; Dynakit ST-70, $200; ReVox F36, excellent condition, service manual, new half-track heads, spare new Kapstan assembly, $500; Harman-Kardon Citation 16, service manual, $200; pair mahogany Klipschorns, excellent condition, $800. Andrew Tomlinson, 1126 Guinda, Palo Alto, CA 94301, (415) 327-9170.

Eton 4" driver mounted in 20" long transmission line enclosure made from 6" I.D. P.V.C. pipe ⅜" wall, foam lined and filled with Dacron polyester, front mount flush inset ¾" particle board, 2 for $200, 4 for $380. Scott Freimann, 309 Luger Ct., West Palm Beach, FL 33415, (407) 686-1588 before 7 p.m. EST.

dbx 3BX Series III dynamic range expander and impact restoration, $200; 224X Type II tape noise reduction, $150; 120X subharmonic synthesizer and sub-woofer crossover, $150; All 3 for $400. Gary, (301) 598-5780, call before 9 p.m. EST.

Pedal Coupler printed circuit board, dual channel, for Swan system. I have several of these left over from my Swan Project to sell for $15 each. Pat Bunn, 171 Spring Lake Dr., Spartanburg, SC 29302, (803) 583-1304.

H-K Citation 23 active tracking digital tuner, $700 Canadian; Audiolab 8000, British 100W/ch power amp, $750 Canadian; new, sealed Linn Basik cartridge, $50 Canadian. Mike, 4968 Walden, Vancouver, BC V5W-2V7, Canada, (604) 322-5493. Leave message.

Conrad-Johnson MV-75A-1. Includes cage in perfect condition. Great tube sound, $900 or offer. Rion, (206) 285-7918, machine.

Focal system 600 (Onken boxes with Eggs), immaculately built, 10C01, 7N303, T120FC. Including active three-way crossover, Madisound 24CX-4, and passive crossover, $1,500. Excellent but too big for my livingroom. Ruud van Wynen, (415) 924-2950.

Need veneers for your system? Do I have them for you! Genuine Macassar Ebony, highly figured, black with earth tones, flame swirls, striped marble pattern. Simply spectacular, imported from East Indies, a true value. 50 square feet book matching set for $148, money order. Jose Marengo, 3408 Irwin Ave., Riverdale, NY 10463-3707.

WANTED

I want to buy one or sell one. Altec 808-8H series 2; Altec 808-8A driver; Altec 811 B horn with stock crossover. Call and we'll talk price. Don Fagerstone (303) 986-9532.

Caltech Music Lab needs gifts of transformers (UTC LS-12X, LS-10X and other models); and tube gear. Write: James Boyk, Director, MLAF, 102-31 Caltech, Pasadena, CA 91125 or call (818) 356-4590 or 356-6353.

Altec 411, 416, 515, woofers; 604 coaxial speakers; 800, 1200, 1500, 500Hz crossovers; JBL Alnico tweeters; large Altec speaker cabinets; Audio Research rack ventilator; Mastering Lab crossovers; information on Mastering Lab electronic crossover, Red series. Will pay cash for schematic. Rubenstein, Box 125, Mt. Tremper, NY 12457, (914) 688-5024.

AR stereo remote control. Jack Rumora, PO Box 368, Senecsville, OH 43780, (614) 685-2612.

Four Gold Sound GS1248 woofers F_S = 16Hz, Q_T = 0.39, efficiency 93dB. Will buy or trade. If you have these, give me a call, we can make a fair deal. Dan Martin, 2605 Woodview, Greensboro, NC 27408, (919) 282-5447 or 279-7176.

A copy of the owners manual and information on Stax ELS-F81 electrostatic speakers. Dale Shore, 220 Henthorne Dr. B-19, Palm Springs, FL 33461.

Wood cabinets for Dynaco equipment, single or double (tuner-preamp); need original manuals for ST-80 and ST-120; also want unused circuit boards for Dynaco equipment as well as circuit boards by Old Colony Sound Lab. Must be reasonable. Rich Holmes, 4085 Harlan St. #5B, Wheatridge, CO 80033.

Old Klipsch catalogs, components; *Audio Engineering* volumes 1-5; diaphragm for International Projector LU-1000 high frequency driver; JBL 12" circular perforated plate horn/lens; early Poloroid polarizing film ads, literature; book, The Throne of Merlin, by R.C. Schaller; *High Fidelity* volumes 1–5. D. R. Schaller, 6704 Schroeder Rd., Suite 6, Madison, WI 53711.

Tube amplifiers for modification project. 35W per channel stereo and pair of 60W per channel or greater mono amplifiers. Cosmetics or working condition not important, but must have sound transformers. Please state condition and price. George Koslow, 200 Commercial Ave., New Brunswick, NJ 08901, (201) 828-7737, 6–9 p.m. EST.

Focal 5N312, 5N411-L, 8K412, 90KF, 120KF; Eminence DR820; Scan Speak 21W-8553; Morel 29, 30, PP8; Peerless 1534, 1593, 1709, 1727, 1732; SEAS 14RC; Vifa 17WJ, 25-85, 26-35; Eclipse 6", 8"; Dynaudio 21AF, 76, 17W-75XL 8Ω; Bandor 0.75 8Ω. M. Thompson, 194 St. Davids Rd., St. Catherines, Ontario, Canada L2T 1R4, (416) 227-4586.

Data on University M15T and crossover; pair of the tube; improvements on Karlson 15; data on Jensen G610. R. Fabreguettes, Lot Pre Vescal Rambaud, 05000 GAP, France.

CLUBS

AUDIOPHILES IN THE DAYTON/SPRINGFIELD, OHIO AREA: We are forming an audio club. Please contact me if you're interested in construction, modifications, testing, recording or just plain listening to music. Ken Beers, 462 Blose St., Tremont City, OH 45372, (513) 969-8402.

THE CATSKILL AND ADIRONDACK AUDIO SOCIETY invites you to our informal monthly meeting. Join our friendly group of audio enthusiasts as we discuss life, the universe and everything. No matter what your level of interest, experience, or preferences, you are welcome. Meetings are generally held once a month, on a weekday evening. Contact CAAS at 756-9894 (leave message), or write CAAS PO Box 144, Hannacroix, NY 12087. See you there!

THE INLAND EMPIRE AUDIO SOCIETY our former name, has now been changed to the **SOUTHERN CALIFORNIA AUDIO SOCIETY** (SCAS). Our effort is now inviting music lovers, audiophiles, hobbyists and other interested parties throughout the southland to join us in our pursuit for that elusive sonic perfection and truth at our meetings and seminars and through our official speaker, *The Reference* newsletter. For information write or call: Frank Manrique, President, 1219 Fulbright Ave., Redlands, CA 92373, (714) 793-9209.

MEMPHIS AREA AUDIO SOCIETY being formed. Serious audiophiles contact J.J. McBride, 8181 Wind Valley Cove, Memphis, TN 38125, (901) 756-6831.

AUDIO SOCIETY OF MINNESOTA. Audiophiles, music lovers, scratch builders, record collectors, tube freaks, digital freaks—we've got 'em all! Monthly meeting, tours, audiophile concerts, special guests, etc. Now in our 12th consecutive year! Write ASM, PO Box 32293, Fridley, MN 55432.

THE COLORADO AUDIO SOCIETY is a group of audio enthusiasts dedicated to the pursuit of music and audiophile arts in the Rocky Mountain region. We offer a comprehensive annual journal, five bimonthly newsletters, plus participation in meetings and lectures. For more information, send SASE to: CAS, 4506 Osceola St., Denver, CO 80212, or call Art Tedeschi, (303) 477-5223.

CONNECTICUT AUDIO SOCIETY is an active and growing club with activities covering many facets of audio—including construction, subjective testing, and tours of local manufacturers. New members are always welcome. For a copy of our current newsletter and an invitation to our next meeting, write to: Richard Thompson, 129 Newgate Rd., E. Granby, CT 06026, (203) 653-7873.

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

ORGAN MUSIC ENTHUSIASTS: If live recordings of fine Theatre Organ Music are your thing, SFORZANDO has room for a few new members. We lend you the music on cassettes. All operation is via the mail. SFORZANDO, c/o E.A. Rawlings, 5411 Bocage St., Montreal, Canada H4J 1A2.

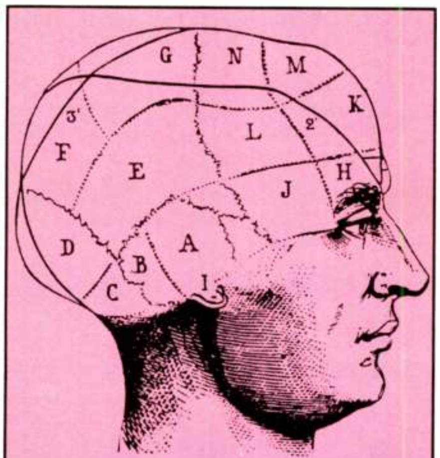
PACIFIC NORTHWEST AUDIO SOCIETY (PAS) consists of 60 audio enthusiasts meeting monthly, second Wednesdays, 7:30 to 9:30 p.m. at 4545 Island Crest Way, Mercer Island, Washington. Be our guest, write Box 435, Mercer Island, WA 98040 or call Bob McDonald, (206) 232-8130.

PIEDMONT AUDIO SOCIETY. Starting an audio club in the Raleigh-Durham-Chapel Hill area of North Carolina. Interested in designing, building, and modifying speakers and electronics (solid state and tube). Beginners and old hands both welcome. Kevin Carter, 9009 Langwood Drive, Raleigh, NC 27612, (919) 870-5528.

SOUTHEASTERN MICHIGAN WOOFER AND TWEETER MARCHING SOCIETY (SMWTMS). Detroit area audio construction club. Meetings every two months featuring serious lectures, design analyses, digital audio, A B listening tests, equipment clinics, recording studio visits, and audio fun. The club journal is *LC, The SMWTMS Network*. Corresponding member's subscription available. Call (313) 477-6502 (days) or write David Carlstrom, SMWTMS, PO Box 721464, Berkley, MI 48072-0464.

THE BOSTON AUDIO SOCIETY invites you to join and receive the bimonthly *B.A.S. SPEAKER* with reviews, debates, scientific analyses, and summaries of lectures by major engineers. Read about Apogee, Nytal, Conrad-Johnson, dbx digital, Snell, music criticism and other topics. Rates on request. PO Box 211, Boston, MA 02126.

THE ATLANTA AUDIO SOCIETY is dedicated to furnish pleasure and education for people with a common interest in fine music and audio equipment. Monthly meetings often feature guest speakers from the audio manufacturing and recording industry. Members receive a monthly newsletter. The society is hosting the 2-day *SUNBELT AUDIO SHOW* in Atlanta on August 18 and 19, 1990. Call: Chuck Bruce, (404) 876-5659, or Denny Meeker, (404) 872-0428, or write: PO Box 361, Marietta, GA 30061.



FILL IN THE BLANKS JOIN AN AUDIO CLUB

Learn about the latest equipment, techniques and recordings through group meetings, tours, and newsletters. Ask questions. Share viewpoints and experiences. Stretch your mind.

If there's no club in your area, why not start one? Our club ads are free up to 75 words ($.20 per word thereafter). Copy must be provided by a designated officer of the club or society who will keep it current.

THOSE INTERESTED IN AUDIO and speaker building in the Knoxville-East Tennessee area please contact Bob Wright, 7344 Toxaway Dr., Knoxville, TN 37909-2452, (615) 691-1668 after 6 p.m.

TUBE AUDIO ENTHUSIASTS. Northern California club meets every other month. For next meeting announcement send a self-addressed, stamped #10 envelope to Tim Eding, PO Box 611662, San Jose, CA 95161.

WANT TO START OR JOIN CLUB IN CENTRAL ILLINOIS (Peoria, Bloomington, Champaign, Kankakee area). Speaker building and audio in general. Trade info and parts. (815) 657-8488 evenings or weekends.

WASHINGTON AREA AUDIO SOCIETY (N. VA, MD and DC) is looking for sincere audiophiles who are eager to devote their time and get involved with the direction of the society and the publication of a monthly newsletter. Please contact: Horacio J. Vignale, 3730 Gunston Rd., Alexandria, VA 22302.

THE WESTERN NEW YORK Audio Society (WNY Audio Society) is an active and growing audio club located in the Buffalo area. We issue a quarterly newsletter and hold meetings the first Tuesday of every month. Our meetings have attracted many local and distant manufacturers of audio related equipment. We are involved in all facets of audio — from building to purchasing at discount prices. For a copy of our current newsletter and information regarding our society, please write to M.A. Monaco, WNY Audio Society, PO Box 312, N. Tonawanda, NY 14120.

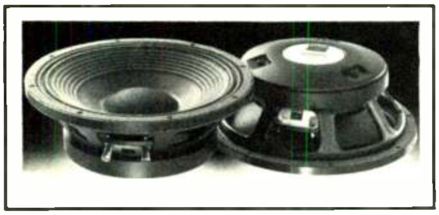
ELECTROSTATIC LOUDSPEAKER USERS GROUP is now a world-wide network for those interested in sharing valuable theory, design, construction, and parts source information. If you are interested in building, or have built, your own SOTA ESL we invite you to join our loose-knit organization. For information, send an SASE to: Barry Waldron, 1847 Country Club Dr., Placerville, CA 95667.

THE HI-FI CLUB of Cape Town in South Africa sends a monthly newsletter to its members and world-wide subscribers. To receive an evaluation copy of our current newsletter, write to: PO Box 18262, Wynberg 7824, South Africa. We'll be very pleased to hear from you.

Advertising Index

Good News

McCAULEY SOUND, INC., has begun production of their Model 6234 12″ extended low frequency loudspeaker. The 6234 features a 400W RMS power rating, 96dB @ 1W/1M sensitivity, and a frequency response from 45-3,000Hz. A 4″ edge-wound copper voice coil mounted on a Kapton Nomex former combined with a double spider—double roll surround suspension system makes the 6234 capable of handling high power.



The 6234 is designed for compact applications requiring a strong and accurate bass response for programmed music or live performances.

For pricing details contact McCauley Sound Inc., 13608 94th Ave. E., Puyallup, WA 98373.

Fast Reply #GE153

SANUS SYSTEMS, manufacturers of four lines of loudspeaker supports, announces improved performance in its premier design, the Reference Foundations.

The triangular bases, now 30% larger, utilize Fountain Head, an acoustically inert material that looks and feels like solid marble. The pillars and top plates are constructed of heavy gauge steel.

All models can be filled with sand or shot and incorporate a nonconductive speaker wire path. Adjustable downward and upward facing steel spikes are included. As an alternative to the steel spikes, Neoprene feet and isolation pads are available.

The Reference Foundations are available in 12-, 20- and 28-inch heights.

Contact Sanus Systems, 3178 Ryan Lane, Little Canada, MN 55117, (800) 359-5520.

Fast Reply #GE611

PRECISION MONOLITHICS offers the SSM-2141, a high common-mode rejection differential audio line receiver. Developed for low impedance cable runs in high performance audio systems, the SSM-2141 can be used in line receiver applications in power amps, mix consoles, tape recorders, as well as outboard signal processing devices. Capable of driving 600Ω loads, it may be used as a buffer amplifier as well.

Using PMI's thin-film resistors and laser trimming, the SSM-2141 can also be implemented as an instrumentation amp with precision resistor matching. Housed in an 8-pin plastic DIP, it can sustain operation over the industrial temperature range of −40°C to +85°C.

Contact PMI, 1500 Space Park Dr., Santa Clara, CA 95054 for complete pricing and quantity details.

Fast Reply #GE566

The Test Bench Jr. is a new pocket-size test instrument with five separate capabilities. Introduced by **B&K-PRECISION**, the Model 377 Jr. is a compact version of the popular Test Bench.

Among Jr.'s features are 39-range voltmeter/ammeter/ohmmeter/frequency counter/ and capacitance, logic, transmission, diode and continuity tester.

Its compact size, 5 × 2⅞ × 1⅜-inches coupled with triple protection of reverse polarity, overload and high-energy fusing, make it an ideal instrument for field service use.

For additional information contact your local B&K-Precision dealer or B&K-Precision, Division of Maxtec International Corp., 6470 W. Cortland St., Chicago, IL 60635, (312) 889-9087.

Fast Reply #GE386

RAPID SYSTEMS has announced a low cost, 250kHz FFT spectrum analyzer peripheral for PCs, priced at $495.

With applications geared to education, research lab and the classroom, the R411 is a perfect teaching tool for real world frequency analysis. Designed with a hardware module to capture electronic signals for transfer to the PC for analysis, the R411 captures and displays a 1024 point FFT every 2 seconds.

Other features include spectrum averaging, programmable input ranges from 1.6V to 320V P-P, and sample rates from 1kHz-500kHz.

Rapid Systems Inc., 433 N. 34th St., Seattle, WA 98103, (206) 547- 8311.

Fast Reply #GE948

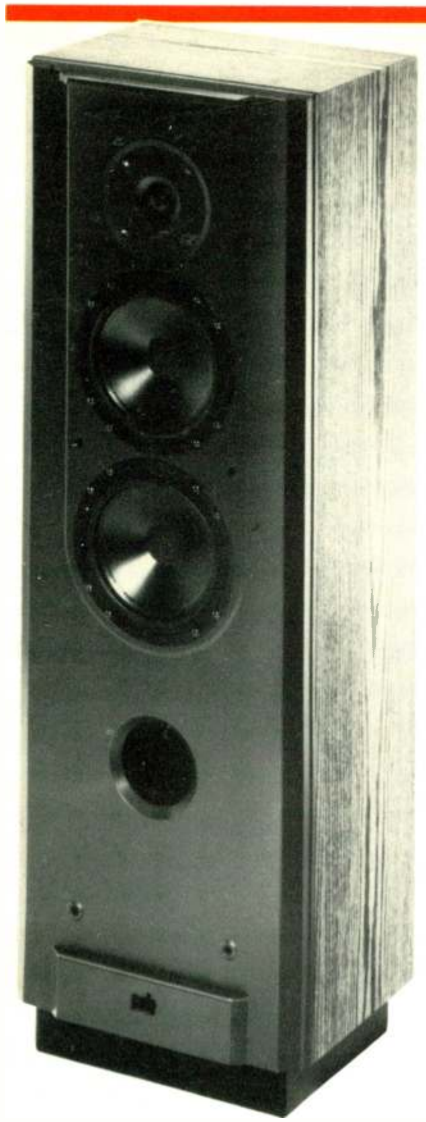
Ralph Gonzalez has informed *SB* of a new software program, ROOM, developed for the IBM PC. Co-sponsored by **SITTING DUCK SOFTWARE** and Gonzalez, this new program provides a top view of a listening room to show the present speaker and listener locations and graphs the standing wave activity at the listener position. Priced at $29.95, ROOM also finds the area of least bass energy for use as a low feedback turntable location.

For those without the IBM PC, they offer an analysis service for room characteristics for a fee.

Should you purchase ROOM in its present form, you will receive a free upgrade of the next version which is already in the works. This upgrade will deal with early reflections within the room.

Sitting Duck Software, PO Box 130, Veneta, OR 97487.

Fast Reply #GE404



PSB, INTERNATIONAL is offering three new speaker lines designed by Paul Barton. The MKII entry-level speaker at $225–$1,000 per pair, the CS Series, for the more upscale buyer at $900–$1,100 per pair, and the Stratus, for the critical music listener which is priced at $1,400 per pair.

Contact PSB International Inc., 633 Granite Ct., Pickering, Ontario, Canada L1W 3K1 for the dealer closest to you.

Fast Reply #GE608

AUDIO TEKNOLOGY INC., of Portland, OR will now be handling LEAP software. Full time support for technical questions and peripherals will be a highlight of the extended service department.

In addition, the new version, 4.0, is in the works. A feature of this enhanced program will be automatic use of extended and expanded memory to allow maximum capability for all users.

The people at Audio Teknology welcome your suggestions for additional features.

Audio Teknology, 7556 SW Bridgeport Rd., Portland, OR 97224, (503) 624-0405.

Fast Reply #GE253

Polydax Speaker Corporation, a subsidiary of Audax Industries in France is proud to announce that they have reached a distributor agreement with **PARTS EXPRESS** in Ohio. Based in Dayton, Parts Express carries a wide range of Speaker Products. Polydax expressed confidence that the agreement would strengthen their overall distributor base in the U.S.

For further details, please contact Parts Express, 340 E. First St., Dayton, OH 45402.

SIMPLY PLASTICS of Houston, Texas would like us to bring their ToneCones to your attention. Available in small, medium and large sizes, they also come in a variety of thread sizes and adapters. Custom thread sizes are available upon request.

Each size has its own characteristics and applications. The large ToneCone is used for heavier components, speakers and equipment racks. The medium has inner coreouts that allow the user his own choice of damping material. The small version is designed with a proprietary trough in back.

Also available is the Conecup for use in fine cabinets and floors.

All inquiries should be directed to Simply Physics, Inc., 13158 Veterans Memorial Parkway, Dept. B., Houston, TX 77014, (713) 537- 5083.

Fast Reply #GE621

For those of you who have been waiting anxiously for it, the new 1990 General Catalog by **CONTACT EAST** is now available for the asking.

The 148-page catalog contains new products such as oscilloscopes, soldering supplies, test equipment and precision hand tools. They have also expanded their line of wire and cable aids, electronic adhesive products and inspection equipment.

All products are described in detail with full color photos and pricing.

Your free copy of the General Catalog plus one year of technical supplements is available from Contact East, 335 Willow St., No. Andover, MA 01845, (508) 682-2000.

Fast Reply #GE500

SOUNDSTREAM TECHNOLOGIES of Folsum, CA, has introduced two new products to their car audio loudspeaker line.

The SS 8 subwoofer, consists of an 8-inch cone made of pulp/carbon fiber materials. Because of molded concentric ribbing that prevents spurious vibrations, the SS 8 can withstand pulses of 300W @ 40Hz input without flexing.

Other features of the SS 8 are: an extra long 2″ diameter voice coil capable of withstanding 800° temperatures; a lightweight cast-aluminum/magnesium basket made to be more stable in car environments; and a rubber gasket bonded to the front of the frame to provide a seal for mounting on uneven surfaces. Mounting requirements are a 7⅛″ cutout with 3½″ of mounting surface.

The SS 4.0 full-range loudspeaker utilizes a specially treated paper main cone with a CAD/CAM designed diffuser that extends treble to 18kHz. Due to its small size, the SS 4.0 exhibits low distortion and a frequency response of 10–18,000Hz, ±3dB.

Additional features of the SS 4.0 include treatment with moisture repellant to ensure reliable operation in door-mount applications and a magnetic structure designed with a a copper-clad polepiece which lowers the self inductance of the voice coil, flattens the impedance curve and reduces second- and third-harmonic distortion in the mid- to high-frequency range by as much as 10–15dB.

The SS 4.0 comes with a perforated metal protective grille and a molded plastic mounting ring into which the driver fits.

Specifications and pricing for both these products can be obtained by contacting Soundstream Technologies, 120 Blue Ravine Rd., Folsom, CA 95630, (916) 351-1288.

Fast Reply #GE614

Fast Reply #GE401

Pox Humana

Fred, It Wasn't In There!

by Robert J. Spear

In the early 1960s, while at Ithaca (NY) College studying music, I tried to buy a speaker system that would closely reproduce the sounds I heard when playing string bass in the orchestra. Most speakers failed miserably to produce the lowest octave, so I assumed my speakers just weren't good enough. I knew the signals had to be in there. The problem was to get them out.

In my perennial search for low bass I had two important allies. First was a recording of Richard Strauss' *Also Sprach Zarathustra* with Fritz Reiner conducting the Chicago Symphony. The opening measures contain a transcendental brass fanfare underpinned by deep, 32Hz fundamentals. Second was Fred Abraham, the jolly owner of Fred's Record Shop on State Street. My goal in life was to buy speakers that could get the bass out of that recording, and Fred's goal was to sell them to me.

Fred handled Fisher, Kenwood, Marantz and Scott, among others, and was always trying to interest me in Fisher speakers. I liked them, but they weren't up to the task. I knew those low notes were in my record, but the XP-7s and -8s couldn't deliver them. Neither could the XP-9s nor the -10s when they came along.

Whenever the latest and greatest arrived from a manufacturer, Fred would call me and together we would audition the speakers. Some of those days were ghastly. We would pump up the volume, twiddle the loudness compensation, fiddle with the bass tone controls and flog the system's woofers every way we could. The session would end after any semblance of fidelity had been rolled out of existence and the woofers doubled more horribly than we could tolerate. Fred would ask, "How did it do, Bob?" And I would reply, "Fred, it wasn't in there!"

After one frustrating day auditioning speakers, I told Fred when he found a system capable of reproducing 32Hz at volumes that would make my hair stand on end I would buy it on the spot, no matter what the cost. This was a rash statement from somebody who had a part time job which paid $17.50 every other week, but I had become convinced no home audio system would ever be capable of the task.

One day Fred called, and by the tone of his voice I sensed something I had never sensed before. "They're here," he said. "Come at once." The moment I walked in the door, I knew it was something special. The entire speaker display had been moved aside to create a small stage. Fred had connected his best equipment, and the heavy lamp cord that coiled out from the amplifier taps was connected to the latest contender.

And what a formidable apparatus it appeared to be. In large cabinets with truncated, wedge-shaped faces, a pair of XP-18s oozed quiescent power. "The 18 stands for the size of the woofers," said Fred, leering confidently. "If it's in your record, these babies are gonna get it out!" Fred placed my record on the turntable and cued up the arm. There was a soft click as the stylus engaged the lead-in groove, and in another moment Fred turned the volume all the way up.

My memory is a bit hazy about what happened next. I recall the opening bass notes as the piece began, and then a tremendous cyclic and cavernous rumble belched from the XP-18s. It was the loudest, lowest tone I'd ever heard in my life. The hair on my arms began to vibrate, and wispy clouds drifted up from various parts of the room, testifying that Fred hadn't dusted the record bins in a long time!

Two old spinsters were in the store perusing recordings by Vic Damone and the Andrews Sisters. As the colossal sonic tsunami engulfed them, one screamed, "Run, Flo! It's an earthquake!" The two biddies staggered out the door to the street, shrieking. From behind the counter, a sales clerk stared at us in frozen terror.

The awful thundering continued louder than ever as the great 18-inch woofers thrashed in an ecstasy of excursion that would have rent lesser speakers asunder. I began to feel sick to my stomach, caused by the constant hammering of air against my body. My eyes watered, and I waved madly at Fred to stop. It was useless to shout. Nothing could be heard above that cataclysmic thundering.

It seemed like an eternity, but at last the notes of the fanfare echoed away. Fred turned the volume down and slipped beside me, order pad in hand. "When would you like to take delivery on a pair of these beauties?" I gasped a question about the price of the XP-18s and nearly died when told a pair cost as much as an entire semester's tuition. I begged off, telling Fred I wasn't sure the speakers would even fit in my room.

In my dormitory later that day, tape measure in hand, I learned the only way I could use a pair was to stack one cabinet on top of the other. The speakers and their cost were too big; my room and my resources were too small. It was time to lower my flag and withdraw from the field, not only beaten, but disgraced. Fred was gracious in victory. He accepted my offer of a meal at Joe's Italian Restaurant where he dined heartily on lasagna, coffee and cake. I mostly ate my words and for dessert had a substantial portion of humble pie.

I moved away after graduation, and in the years that followed I auditioned many fine speaker systems: Klipschorns, E-V Patricians, JBL Paragons and Altecs big enough to crawl in. I listened to acoustic suspension types, transmission lines, passive radiators and combinations of all kinds which raised my suspicions not about the speakers of the day, but about my recording. Once I heard my first CD I knew I had been wrong about the sonic information I had thought was on the LP disc.

I returned to Ithaca in the early '70s and went to visit Fred. The record shop was gone, replaced by a magazine and candy store. Fred had suffered financial reverses several years earlier and closed his business. He passed away not long after that.

As I stood in front of the store window and thought about that particular day, I realized we hadn't heard those vibrant fundamental tones after all. We had caused the turntable and tonearm rumble to be heard through those mighty speakers, creating a combination of music and rumble at enormous volumes. The resulting acoustic loop caused a phenomenon called "motorboating," and by some quirk we had managed to induce it at 16Hz where it substituted wonderfully for the lack of bass on the recording.

I also began to understand that Fred probably knew all along the speakers I wanted would be out of my reach, but he persisted in the search anyway. We had become good friends and shared some fine moments. The outcome was not really so important, and I think Fred would have enjoyed the irony of it. After all our efforts, Fred, it wasn't in there!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high fidelity range

The MDM 85 is a mid range 75mm soft dome unit of extremely high standard, both from a design and technical viewpoint.

It incorporates the renowned Morel double magnet and Hexatech voice coil techniques, and results in a unit of above average sensitivity with extremely low distortion and high power handling capability.

With an output level of 96dB distortion in the area of 400-800Hz is slightly over 1% falling to 0.015% from 1Khz.

There are two different types available, one with a rear enclosure and one without (MDM 85NE). The type with the rear enclosure can be fitted into a cabinet as an integral unit.

The MDM 85NE without the rear enclosure can only be fitted into a system having a separate housing to enclose the unit. A volume of 0.7 litre is recommended for this housing, which is essential to prevent inter-reaction with the bass unit compressions and expansions. This housing must be filled full with damping material, such as fibreglass or rock wool.

The Thiele small parameters are given for both types under specifications. The contribution of this unit to a suitably designed system will be evident in the clarity and detail given in the 500-5000Hz region.

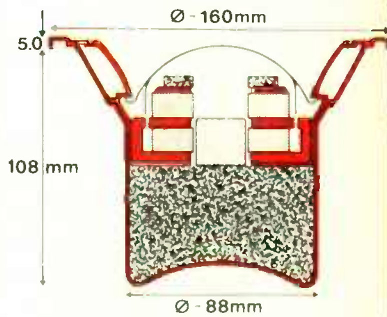
Specification

MDM 85 (with enclosure)

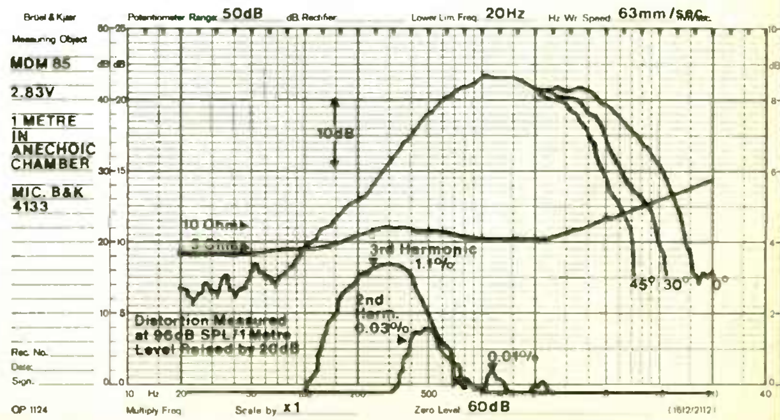
Overall Dimensions	Ø - 160mm x 113mm
Nominal Power Handling Din	300W
Transient Power 10ms	1500W
Voice Coil Diameter	75mm (3") Hexatech Aluminium
Voice Coil Former	Aluminium
Frequency Response	300-5000 Hz
Resonant Frequency	250 Hz
Sensitivity	92 dB (1W/1M)
Nominal Impedance	8 ohms
Harmonic Distortion for 96 dB SPL	<1%
Intermodulation Distortion for 96 dB SPL	<0.25%
Voice Coil Inductance @ 1 Khz	0.2mh
Air Gap Width	1.05mm
Air Gap Height	3.0mm
Voice Coil Height	6.0mm
Flux Density	1.0T
Force Factor (BXL)	4.6 WB/M
Rdc	5.2 ohms
Rmec	37.90
Qms	0.29
Qes	2.66
Q/T	0.20
Vas	0.33 litre
Moving Mass including Air Load	7.0 grams
Effective Dome Area	63.50 cm^2
Dome Material	Chemically Treated Fabric
Nett Weight	1.25 kg

Variations to specification for MDM 85NE (without enclosure)

Overall Dimensions	Ø - 160mm x 60mm
Frequency Response	250-5000 H
Resonant Frequency	170 H
Rmec	39.3
Qms	0.1
Qes	1.8
Q/T	0.1
Vas	0.7 litr
Nett Weight	1.05 k



Specifications given are as after 24 hours of running.



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