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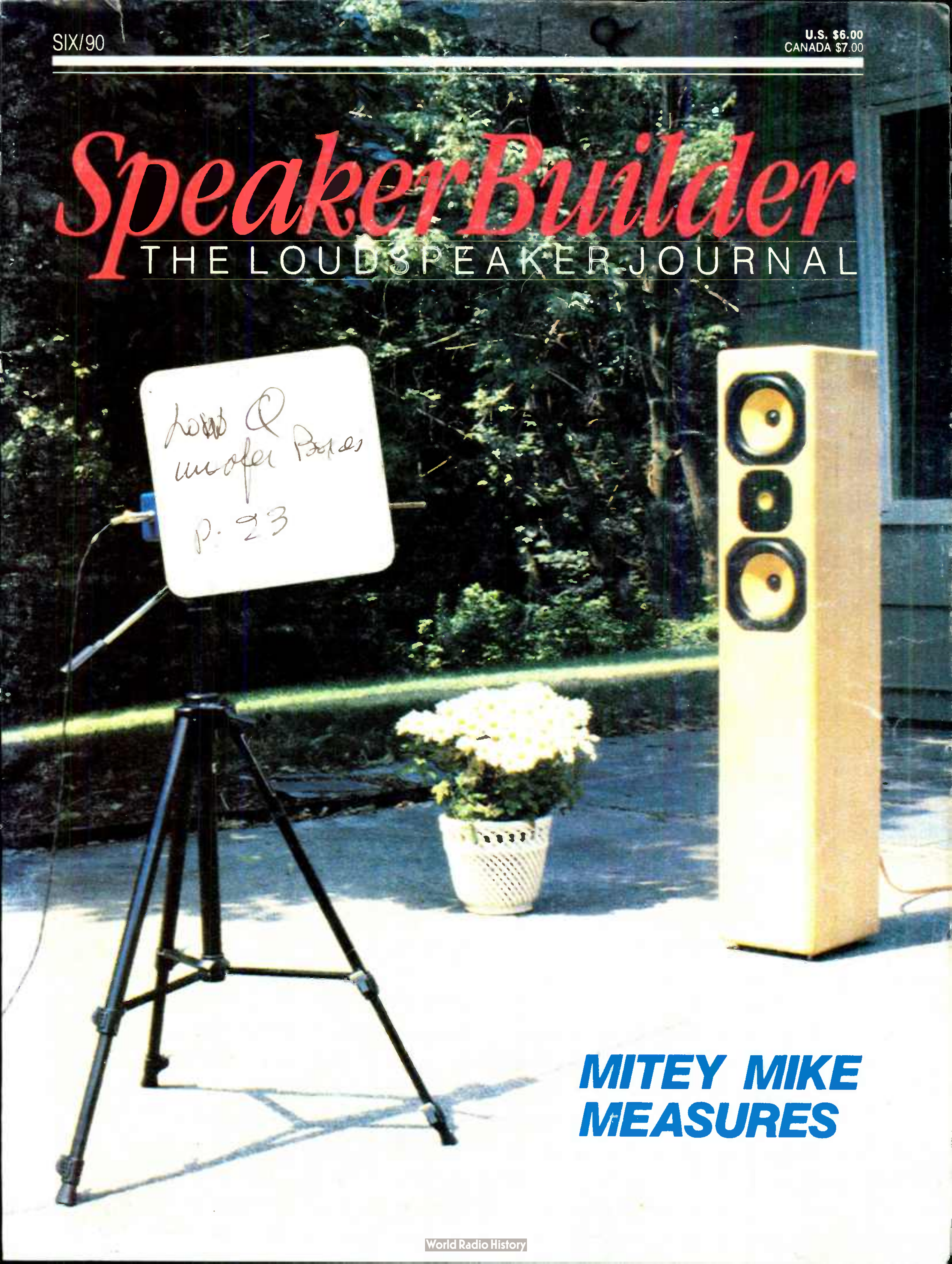
Speaker Builder

THE LOUDSPEAKER JOURNAL



Low Q
woofer Boxes
p. 23

MITEY MIKE MEASURES

SB Mailbox

ERRATA

I noticed what obviously must be a drafting typo in *Speaker Builder* 4/90, p. 39, *Fig. 4*, the crossover circuit.

The junction of C64 and R67 should be connected to the junction of R64 and R66.

Burt Cossey
Hesperia, CA 92345

VAPOR CAPACITOR

I just read the article "A Balanced Line Design" by Alan Watling (*SB* 3/90), but am unable to locate C1, C2 0.0µF ceramic discs.

Can you tell me where I might find components of this magnitude? I'm sure their quality would be unexcelled.

Rocco Santori
San Francisco, CA 94119

I wish we knew where to find them, as well. But look no further. There is at this writing no such animal, and what you read was a typo. C1 and C2 in Fig. 1 *are 0.01µF ceramic discs.—Ed.*

THEORY vs. PRACTICE

Mr. Ricart's active loudspeaker (*SB* 4/90) is very well-conceived, with excellent coverage on choices of drivers and op amps. I hope to see more articles like this which detail the concerns and compromises confronting the amateur speaker builder.

My question regards diffraction loss compensation (or lack of it) for the midrange enclosure. Mr. Ricart notes the loss occurs below the 450Hz cutoff for his 9" baffle width. Yet, the D'Appolito SWAN IV satellite begins its loss at 850Hz with a similar baffle width.

How are diffraction loss and enclosure width related? I previously believed their loss would begin at the half-wavelength dimension, or about 750Hz in this case.

Matthew Honnert
Carol Stream, IL 60188

Fernando Ricart replies:

Mr. Honnert's letter raises an interesting point. In theory, a loudspeaker radiating into free space suffers an output loss with decreasing frequency when compared to a loudspeaker radiating into a hemisphere. This loss begins at a frequency with a ½ wavelength equal to the smallest baffle dimension and approaches 6dB at low frequencies. In practice, radiating into free air is rarely achieved due to the surrounding boundaries, therefore the actual loss is somewhat less than the theoretical maximum.

It is difficult to place a loudspeaker the size of mine, and with as many wires connected to it, out in the middle of the room. Therefore, design work took place about one foot from the back wall. In this position, ⅓-octave pink noise measurements with the midrange operating at full range show a relatively flat output to about 500Hz and falling to around 2dB below reference at 250Hz.

These curves led me to ignore diffraction compensation for this design. They were also the main factor in keeping the crossover frequency at 450Hz. For designs such as the SWAN or the Linkwitz with their 200Hz and 100Hz, respectively, crossover frequencies, this effect cannot be ignored. I also believe the SWAN's designer intended his loudspeaker to be used away from walls since this is the way I heard it demonstrated at a hi-fi show two years ago.

Those who wish to use compensation with this design can do so by adding op amp #8 to the Linkwitz board and use the circuit (*Fig. 1*) as a starting point. If this circuit is introduced, the output to the midrange will be out-of-phase relative to the woofer and tweeter. Therefore, the midrange's polarity must be inverted when connected to the amplifier. I recommend adding a switch to short the capacitor in the circuit, and cancel the equalization to allow comparison.

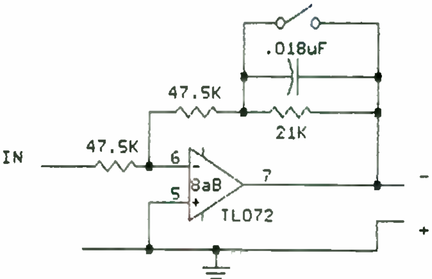


FIGURE 1: Add a switch to short the capacitor.

Cover Acknowledgment

I would like to note an acknowledgment for the *SB* 5/90 cover photo. I'd like to thank my brother, Steve Schwefel, for lending me his medium format camera, tripod, and light metering equipment. And for his invaluable pointers on proper photographic technique, without which, the fine detail of this photo would not have been possible.

Also, a note of thanks to the staff of *SB* for the fine job with processing and blow up. When I look at the photo, I want to get out my Phillips screwdriver and start dismounting the drivers!

Bill Schwefel
Jackson, WI 53037

THREE-WAY CORRECTIONS

I wish to note the following corrections to my "Modular Three-Way Active Loudspeaker" article (*SB* 4/90).

1. On amplifier 6b (*Fig. 4*) there should be a node between C64, R67, R66, and R64, not a jumper.
2. In *Fig. 5* there should be a node between C102, R104, R105, and R102, instead of a jumper.
3. In the *Table* above *Fig. 5*, F_3 should be above Hz and not above Q_{TS}.
4. Audio Concepts has significantly changed specifications for the AC12 woofer. The following circuit changes, therefore, are necessary in the table:

C101	0.33µF
C102, 103	0.056µF
C104	0.15µF
R101, 102	24.9kΩ
R103, 104	17.4kΩ
R105, 106	54.9kΩ

The unequalized resonance (f_e) is now 46Hz. The new equalized F_3 is now 32Hz with 7dB of boost. The diaphragm's moving mass seems significantly lighter than previously specified.

Continued on page 73

Editorial

WHEN ALL ELSE FAILS, LITIGATE

In a world where the achievement of peace seemed at last possible, and where, the communistic world has generally renounced an economic ideology which was the basis for forty years of "cold war," it is depressing to consider the spectacle of some of America's largest technical companies engulfed in a orgy of legal suits and countersuits. It would almost appear that since we cannot engage in dropping atomic bombs on enemies, US high tech companies, as an alternative, are attacking each other on grounds of patent infringement.

Lotus Development is suing Borland International, Microsoft and Apple Computer are suing each other over something many people suspect they both originally borrowed, without permission or royalties, from Xerox. Intel and Advanced Micro Devices, Motorola and Hitachi have been involved in suits.

I find it curious to reflect on the relative merits and shortcomings of the economic systems of state capitalism and private capitalism. The first lacks enough self interest (greed) to work and the latter is now severely threatened by an overabundance of the same commodity. We have been through a decade of loosening restraints on how private capitalistic enterprises function in this country. On balance we find ourselves with a corrupted and discredited banking system, a more and more heavily burdened class of very poor and a growing class of super rich.

I cannot refrain from noticing, since we are faced with a possible 23% increase in second class postal rates next February, that we are still attempting to operate the US Postal Service with a system of management thoroughly discredited by the USSR's abandonment of state capitalism. I certainly hope someone finally notices that it is impossible to run a business with a bureaucracy.

It is difficult to escape the conclusion that decisions about US business are made purely on considerations of profit, nothing else. The end result will be what we are already seeing, unbridled agressiveness and greed. The people who use these companies' products will not benefit from legal hassles, and if we realize that a growing portion of what we pay for products must pay legal and lawyer's fees, we ought not to be too happy about the situation. Lawyers are a lot like fire hydrants, necessary in emergencies, but fire prevention is a better answer.

It is important to differentiate here between those who sue in response to outright theft of ideas, and those who do so to retain exclusive right to patents which by law ought to be shared on some sort of royalty basis. If AT&T had refused to license others to make transistors where would we be today? If Lotus can keep exclusively for itself the "look" of the spreadsheet interface, then every spreadsheet user will be inconvenienced merely to push profits at Lotus ever higher.

Anyone who lifts his or her head for a few minutes to survey the world economic scene will realize that American businesses could hardly pick a less appropriate time for fighting with each other.

The situation now developing in our country has, classically, bred revolution. I doubt we will have mobs in the streets, although there are some cities where this has happened in our recent memory. It is not outside the realm of possibility it could happen again. But the more subtle and pervasive effect is a general sense among most people of sad cynicism about business generally, as well as deepening disenchantment with government and politicians generally. And the level of helpless anger seems to me more evident in more people every day. Agressive rudeness seems more pervasive. Just note how many more people are running red traffic lights.

I believe a large part of the economic "slowdown," that euphemism we are using instead of talking about a recession, is due to lack of confidence by the consumer. Times are bad because people generally are discouraged, frightened or both. That miasma is causing what we fear.

America has the strength and power to do wonderful things. But we won't do them if the profit-oriented managers make all the decisions. We won't do them if every person's goal is self preservation.

The best example I know of is IBM's decision to use the Intel 8088 microprocessor as the basis for their new personal computer's operating system. Programmers who understand instruction sets of the available central processing units will tell you, most of them without frothing at the mouth, that the choice was a disaster. Several other chips would have been better choices. But the decision at IBM was not made by the technical staff, it was made by the business types. The fact that the installed base of IBM and IBM-type clones based on Intel's line of processors is now in excess of 22 million bears almost no relation to the processor. The power and influence of the IBM name has sold the machine to business and individuals. But the machine could be far, far better in the opinion of most people, with Motorola's 6800 or 68000 series in it.

Somewhere in the capitalist mixture we need the enthusiast, the dreamer, the person who reaches into the unknown just out of curiosity. Many of you say nice things about this publication and how much you enjoy it. Very little of the credit for its existence is rightfully mine. Most of it belongs to the authors who make it possible. They are the dreamers, the curious, searching for answers to the puzzles, for ways around the obstacles, for better and easier answers. Unless that ingredient can find its way back into capitalism's future, in balance with intelligent, prudent, and humane managers, capitalism has no better future than did communist economics.

—E.T.D.

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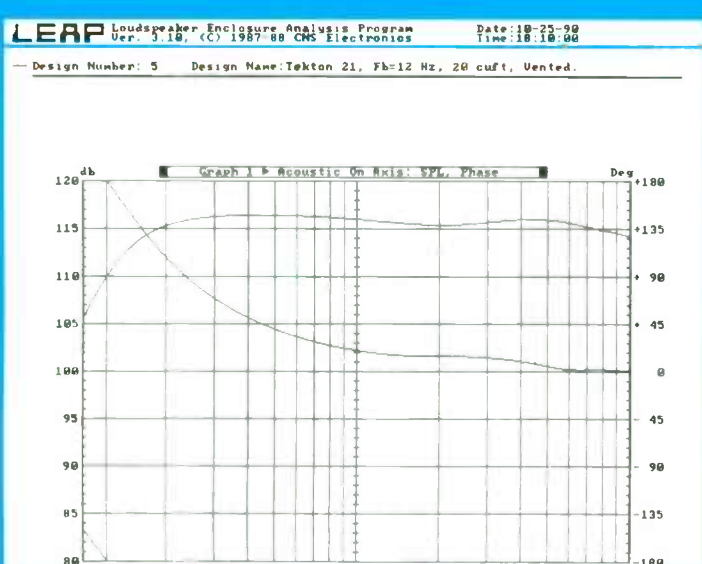

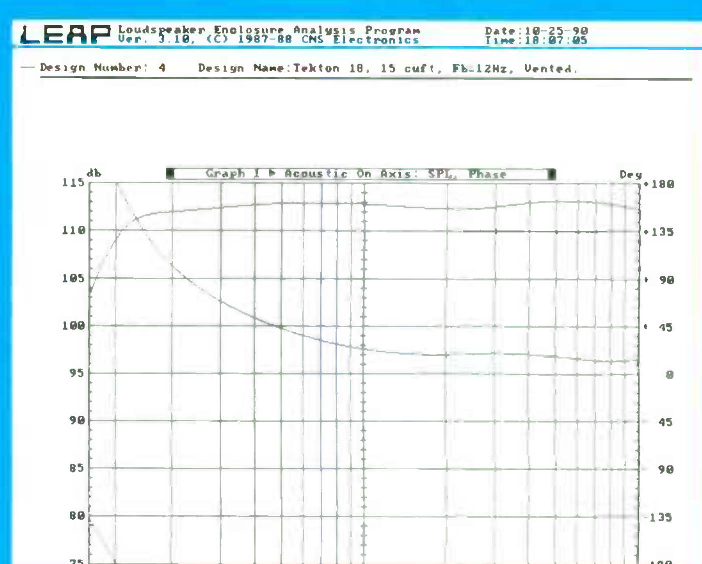

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About This Issue

This largest issue ever of *Speaker Builder* leads off with the test device every speaker builder dreams about. Where do you find a cheap way of measuring response of your new design? Bruel & Kjaer will sell you a nice one for several thousand if you are willing to stand in line for their hand-made units. As usual, one of our clever, hard-working editors comes to our rescue. **Joe D'Appolito**'s Mitey Mike adorns our cover this time—and the photo is his daughter Nina's work. You can build your very own version of the Mitey Mike for under $50 (p. 10).

Next, **Matt Honnert** shows us how to try symmetrical loading for those woofers back in the trunk or the hatch (p. 20). Contributing Editor **G.R. Koonce** unlocks the mysteries of how to use a low Q_{TS} driver in vented boxes (p. 23). Another of our Contributing Editors, **Bob Bullock**, introduces his new software BOXMODEL beginning on page 26. It does lots of new tricks, including vented, closed, and passive radiator models.

Tom Nousaine, like many readers, builds systems for friends. He shares one such project which he calls 8×2s, starting on page 38. Reviews abound this time: **Gary Galo** looks at Audio Concepts' Sapphire II kit, **Jim Frane** measures effects of Radio Shack's foam grilles, and **Dave Davenport** revisits Focal's Egg.

In the crow eating department, Contributing Editor **Bruce Edgar** will tell you about his latest adventure with a horn throat that he thought worked one way but which, alas, works differently.

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THE LOUDSPEAKER JOURNAL

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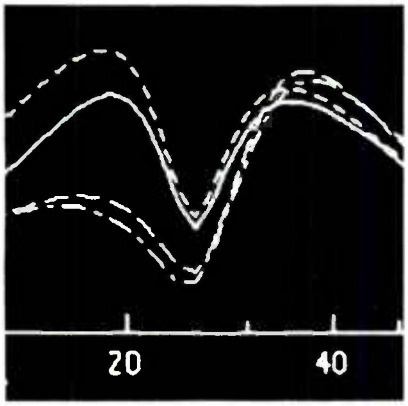

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FEATURES

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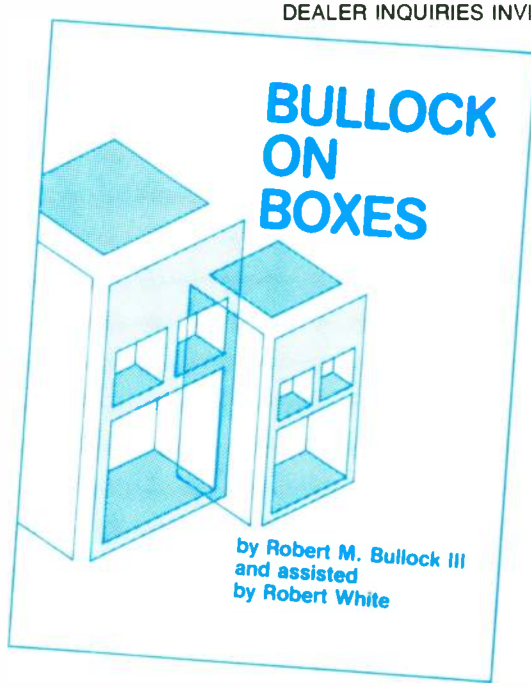

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MITEY MIKE: FOR LOUDSPEAKER TESTING

BY JOSEPH D'APPOLITO
Contributing Editor

"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of Science...."

—Lord Kelvin

You have just completed your latest loudspeaker project, and you begin listening to it with great anticipation. As initial impressions fade, you are left with the growing realization that your newest jewel is "too bright," or "too forward," or "bass heavy," or...well, something is wrong.

Your ears, as wonderful (dare I say golden) as they are, cannot quite pinpoint the magnitude or the location of the problem. A good microphone could help isolate the problem, but it's too expensive. Days and perhaps weeks of tweaking lay ahead. If the preceding scenario sounds familiar, read on. We may just have the answer.

TEST MIKES. Of course, our ears must be the final judge of a loudspeaker system's quality, but ability to make accurate acoustic measurements during the system design phase, and final system tuning is invaluable. Manufacturers' response curves for drivers must be used with care. They often comprise the average of many drivers, and may not be representative of your particular samples.

These response curves are often obtained with the driver mounted on a large open-backed baffle (e.g., an IEC standard baffle). The frequency response of that driver in *your* cabinet may be very different, due to different baffle areas, edge treatment, or enclosure volume. Once your system is assembled, correct crossover network operation and proper level matching of the various drivers must be confirmed, a process best done by direct acoustic measurements.

A good microphone is at the heart of

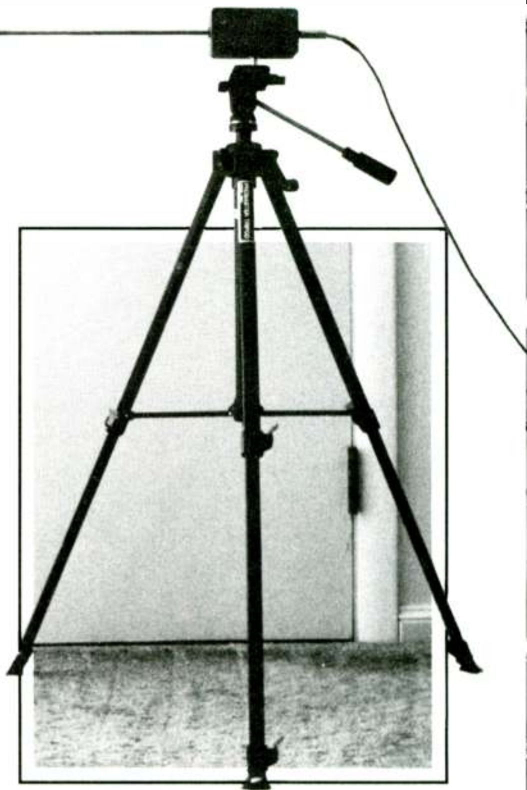

PHOTO 1: Mitey Mike mounted on a camera tripod.

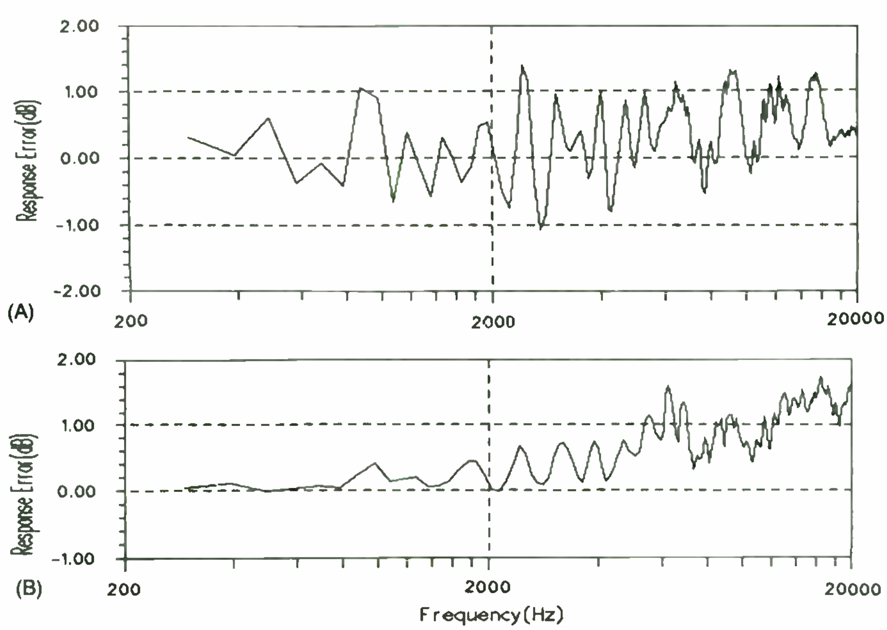

FIGURE 1: Mitey Mike calibration curves. (a) Cartridge #1, (b) Cartridge #2.

ABOUT THE AUTHOR

Joseph D'Appolito, SB contributing editor and author of many papers on loudspeaker system design, holds several degrees in electrical and systems engineering, including a PhD. He currently develops acoustic propagation models and advanced sonar signal processing techniques at an analytical engineering services company in Massachusetts. A long-time high-end audio enthusiast, he also designs high fidelity loudspeaker systems for Focal America and private label retailers in the US and Europe.

TABLE 1

MITEY MIKE SPECIFICATIONS

Response (rel. 1kHz)	±1dB, 20Hz–10kHz ±2dB, 10kHz–20kHz −3dB @ 3Hz and 25kHz
Sensitivity	39mV/Pa, ±2dB
Max Undistorted SPL	< 120dBA
Wideband Noise Level	> 42dBA
Power Consumption	5mW typ / 7mW max.

any acoustic measurement system. What constitutes a good microphone for loudspeaker testing? The four key requirements, in my opinion, are:

- Flat free-field frequency response;
- High, undistorted SPL capability;
- Good measurement repeatability;
- Long-term stability.

To meet frequency response accuracy requirements for contemporary loudspeaker systems, a test mike should have a free-field frequency response of at least 20Hz to 20kHz. Minimally, the frequency response between 20Hz and 10kHz should be within ±1dB. Above 10kHz relax this requirement to ±2dB. Of course, the more nearly flat the better. "Free-field" means the microphone's presence should not change the pressure field it is measuring. That is, the microphone should measure the SPL that would exist at the point of measurement if the mike were not there.

SMALL AND STABLE. This means the microphone cartridge diameter must be small compared to the shortest wavelength measured. For our purposes, the diameter should be no more than ½", and preferably closer to ¼". Assessing loudspeaker power response and distortion requires a test mike which can handle SPLs of 120dB, or more, without distortion.

Repeatability refers to the variation of microphone characteristics from turn-on to turn-on. We wish to make a set of measurements one day, and be able to repeat those same measurements on another day. Of course, atmospheric conditions, (temperature and humidity) affect measurement repeatability. Short-term repeatability should be on the order of ±0.3dB.

Long-term stability refers to a mike's aging traits. There may be long periods when a microphone is not in use, sitting on a shelf under varying temperature and humidity conditions. A good microphone's characteristics won't change after long shelf periods. Long-term frequency response stability should also be ±0.3dB.

NOISE AND DOLLARS. One microphone characteristic missing from my list is self-noise level. Top-quality recording and laboratory test mikes have noise levels of 15dBA or less. Since loudspeaker testing is generally conducted at reference SPLs of 90dB or more, noise levels of 40-45dBA can be tolerated.

If your budget is unlimited a laboratory grade microphone from Bruel & Kjaer is yours for $3,000 and up. Mikes from ACO are in the $1,200-$1,500 range. Below lab grade, fine test and measurement microphones from Neutrik and Josephson Engineering are available for about $200-$250. All require additional amplification and/or power supplies, adding to their cost. Incidentally, all these mikes are omnidirectional.

Surprisingly, most recording and public address mikes, even expensive ones, are unsuitable for loudspeaker testing, rarely meeting the frequency response requirement. This is especially true of directional mikes (cardioid, hypercardioid, and so forth) which display a low-frequency proximity effect. Directional mikes' low-frequency response depends upon the sound source's size, and its distance from the microphone.

ENTER MITEY MIKE. For several years Panasonic has manufactured a small back-electret, FET buffered, omnidirectional microphone cartridge (WM-063T). I purchased 10 cartridges four years ago, and tested them against a lab grade mike I had on loan. The capsules had amazingly flat response, and differed by no more than 1dB below 10kHz from unit to unit. All met our frequency response specification.

Figure 1 illustrates two typical error response curves for the complete microphone system, including cartridge and

TABLE 2

MITEY MIKE OUTPUT VOLTAGE vs SOUNO PRESSURE LEVEL

	OUTPUT VOLTAGE	
SPL (dB)	**RMS mV**	**dBm**
120	775	0
110	245	−10
100	77.5	−20
90	24.5	−30
80	7.75	−40
70	2.45	−50

supporting electronics. The curves demonstrate differences in frequency response of a loudspeaker, as measured by a reference mike (Neutrik Type 3882, Ser. No. HF883), and two WM-063T cartridges installed in Mitey Mike. Cartridge 1 has a frequency response within 1dB of the reference mike throughout the audio range. Cartridge 2 shows more peaking above 10kHz, but well within desired specifications. Cartridge 1 is exceptional, while cartridge 2 is more typical of what you can expect from Mitey Mike. Generally, the cartridges show an elevated response of 2dB or so above 12kHz.

Table 1 lists expected performance from the complete Mitey Mike system. Periodic testing over the past four years has produced worst case deviations from the original 1dB curves. The RMS deviation is less than 0.5dB, including errors from all test chain sources (mikes, amplifiers, sound source, meters, test oscillator, and environmental conditions), and implies even better long-term stability for the mike.

The Panasonic cartridge does, however, have two problems. First, its self-noise level is somewhat high at 38dBA. More importantly, its sensitivity changes with supply voltage. In *Table 1*, sensitivity is listed at 39mV per Pascal (Pa). A Pascal is a unit of pressure in the SI system equal to one Newton per square meter. In more familiar terms, this

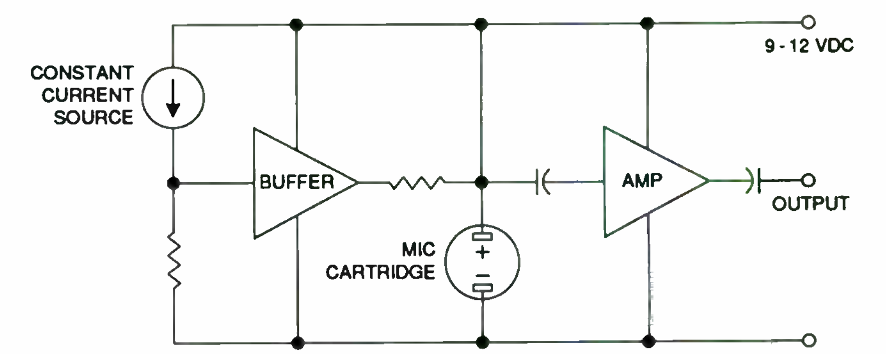

FIGURE 2: Functional diagram for Mitey Mike electronics.

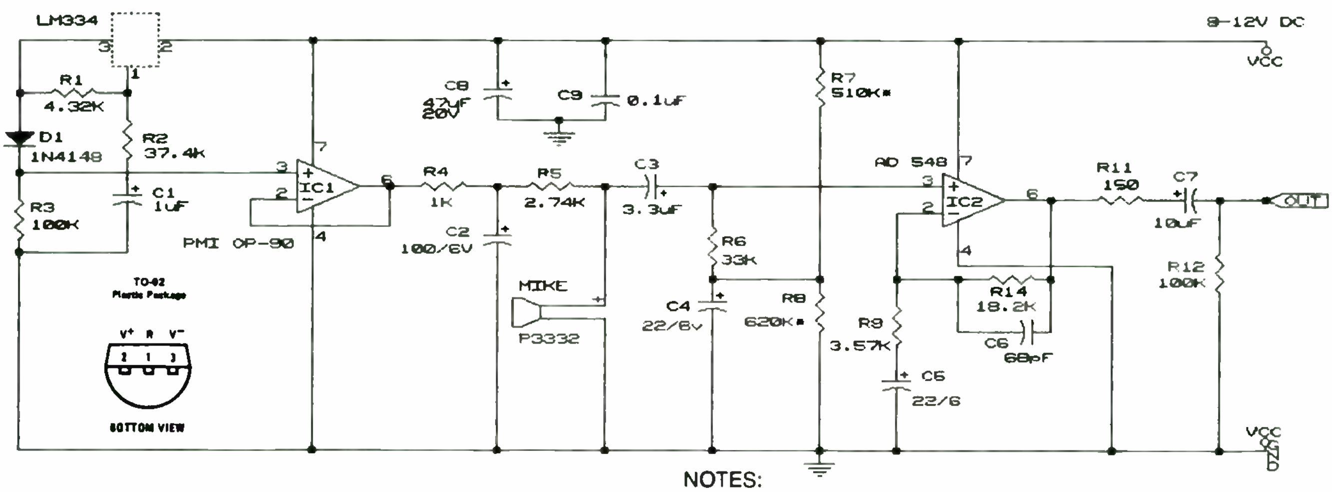

FIGURE 3: Schematic diagram of Mitey Mike electronics.

NOTES:
Resistors marked with asterisk should be at least ±5%, all others ±1%.
All polarized (with +) capacitors are tantalum types, to conserve space.
See text for alternatives to IC1 and IC2.

TABLE 3

MITEY MIKE PARTS LIST

RESISTORS

All resistors ±1% metal film unless otherwise specified.

R1	4.32k
R2	37.4k
R3	100k
R4	1k
R5	2.74k
R6	33.2k
R7	510k 5% carbon film
R8	620k 5% carbon film
R9	3.65k
R10	18.7k
R11	150
R12	100k

CAPACITORS

All capacitor values are in microfarads, and are bead tantalum unless otherwise specified.

C1	1.0
C2	100/6V
C3	3.3
C4	22/6V
C5	22 6V
C6	68pF NPO ceramic
C7	10
C8	47/10V
C9	0.1 metalized film

ICs AND SEMICONDUCTORS

IC1	OP-90 Precision Monolithics
IC2	AD-548 Analog Devices
IC3	LM334 National
D1	1N4148

Microphone Capsule:
Panasonic WM-063T available from Digi-Key, Thief River Falls, MN 56701-0677.

means the cartridge will put out 24.5mV at an SPL of 90dB. At a nominal capsule supply voltage of 3V, sensitivity changes about 3dB per volt. Therefore, a 0.1V change in supply voltage causes the mike output voltage change to exceed our short-term repeatability goal.

These problems aside, clearly the Panasonic cartridge can form the basis for a very good test and measurement microphone. Let's see what it takes to get there.

MIKE ELECTRONICS. *Figure 2* is a functional diagram of the microphone electronics. The mike is battery-powered to avoid problems and circuit complications associated with phantom or remote powering. To reduce battery size, and at the same time extend battery life, I placed my emphasis on low-power design, setting a current drain goal of one milliamp or less. With test sessions lasting four hours or more, I didn't want to be concerned with battery life.

The electronics consists of a constant current source and resistor forming a micropower voltage reference, a micropower op amp buffer powering the mike cartridge, and a low-power op amp buffer/gain block. The combination draws 550μA from a 9V battery, and can drive 50 feet of shielded cable with no loss in frequency response. Complete specifications for Mitey Mike are in *Table 1*.

POWER STUFF. *Figure 3* is a schematic diagram of the microphone electronics. At the time I began this project, no inexpensive micropower voltage references were available. However, a three terminal current source, the LM334, supplies a current directly proportional to temperature, and as such is the basis for a very accurate solid state thermometer. A few extra parts converts the LM334 into a constant current source. Passing that constant current through a temperature-stable resistor results in constant voltage.

Referring to *Fig. 3*, resistor R1 sets the LM334's current output level. Diode D1 and resistor R2 temperature-compensate the LM334. Most of the LM334's bias current passes through R1, but about 10% of it is pulled off by R2. As temperature increases, voltage across D1 drops, causing current through R2 to fall, thereby decreasing the LM334 bias current. If R2 is properly selected, the bias current decrease will be just enough to keep the LM334 output current constant with changing temperature.

R1 and R2 were selected to produce a 30μA constant current, resulting in a constant 3.0V across the 100kΩ resistor R5. C1 reduces reference voltage noise generated by the LM334's noise current. IC1 operates at unity gain to buffer reference voltage, and power the mike cartridge. This PMI OP-90 op amp supplies output currents up to 5mA, while drawing a quiescent current of only 16μA. Unfortunately, micropower op amps tend to be noisy. R4 and C2 filter the mike cartridge supply voltage; R5 is the WM-063T's load resistor; C3 serves as a DC blocking capacitor while coupling the AC mike output to IC2.

WHOSE AMP? IC2, an Analog Devices AD548 op amp, amplifies the microphone output, and provides the low-impedance, high-current capability required to drive long shielded lines. This op amp has a full power bandwidth of 70kHz in this application, while drawing only 160μA quiescent current. Resistors R7 and R8 set the DC operating point for IC2. C4 filters the bias voltage and shorts any power supply noise voltage to ground. R7 and R8 have been adjusted to obtain symmetric clipping from IC2, thereby maximizing its output swing at a supply voltage of 9V. R9 and R10 set the AC gain of IC2 to 6.12, while C5 returns the IC2's

Continued on page 14

The Recipe for the Finest Speakers...

The Xennon 3-100 resembles a traditional 3-way system; but its awesome power and precise reproduction soon makes the listener compare the Xennon to the very best systems in the world. As with all Dynaudio products, it is the dynamic range that makes the first favorable impression; other speaker systems play loud, but only Dynaudio can reproduce all output levels with an identical sonic balance and no evidence of compression. The Xennon 3-100 is a good choice for the listener who listens to large symphonic works but also wants the intimacy of small ensemble pieces.

The Xennon 3-100 is available in kit form with cabinets for under $1000. Drivers, crossovers and plans are available for under $700.

The MYRAGE is a superlative system. It has multiple chambers with two 100 mm voice coil woofers, two advanced three inch dome midranges, and the legendary ESOTAR limited production high frequency transducer. The bass is awe inspiring; vocals are silky; the imaging is well defined. The dynamic range can approach 125 db, yet the MYRAGE responds effortlessly. If you wish to own the best, and you want the satisfaction of assisting in the creation, the MYRAGE is the system for you.

The Myrage system is available in kit form with cabinets for under $1700. Drivers, crossovers and plans are available for $1300.

The IMAGE II is a state of the art system designed especially for audio enthusiasts who have space limitations or budgetary restraints. If you are willing to give up a half octave of the the deepest bass (from 35 to 50 Hz), you may experience the wonder of Dynaudio for a price so modest it borders on the miraculous. With the IMAGE II, you have superb imaging, a result of precise phase and time delay, refined in a very sophisticated 12 element filter. The dynamic range and lack of compression will startle you. After assembly, you will enjoy the overall smoothness and clarity which has earned Dynaudio drivers a world-wide reputation for excellence.

The Image II is available in kit form with cabinets for under $500. Drivers, crossovers and plans are available for under $350.

Begins with the Finest Ingredients

Model	D28AF	17W75	Esotar T330	D52AF	30W100
Diameter mm	110	177	140	145	300
Voice Coil Diameter mm	28	75	28	54	100
Frequency Range Hz	1.8K—20K	45—3.5K	1.8K—22K	600—7K	25—900
Resonance Freq. Hz	700	42	800	350	24
Sensitivity 1w/1m db	91	89	91	91	91
Power Capability DIN w	300@3K	150	300@3K	200@800	450

Model	24W100	D21AF	15W75	D76AF	Variovent
Diameter mm	240	110	145	145	Aperiodic damping device. Used for sealed box alignments to lower system Qtc, effectively allowing the use of a smaller box. Diameter 125mm.
Voice Coil Diameter mm	100	21	75	75	
Frequency Range Hz	35—3K	2.5K—30K	60—5K	500—5K	
Resonance Freq. Hz	32	600	55	180	
Sensitivity 1w/1m db	90	91	88	88	
Power Capability DIN w	120	600@5K	120	180@600	

Available from your Dynaudio Specialist:

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

Fast Reply #KE20

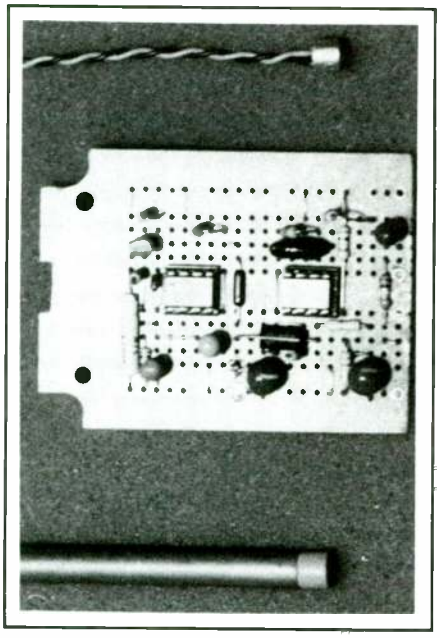

PHOTO 2: Microphone cartridge, wand and electronics board.

Continued from page 12

gain to unity at DC so that its DC operating point is solely a function of the bias divider resistors R7 and R8.

At first glance, a 6.12 gain for IC2 may seem a bit odd. Mitey Mike is designed for use with wideband AC voltmeters having calibrated dB scales. It is common practice to set these meters' 0dB reference point to a voltage corresponding to one milliwatt into 600Ω, i.e., 0.775V. When referenced to this power and impedance value, voltage and power ratios expressed in decibels (dB) are given the special suffix "m", i.e., dBm. With a 6.12 gain, a 0dBm reading corresponds to an SPL of 120dB. Meter readings and their corresponding SPLs are listed in *Table 2*. As you can see, the odd gain of 6.12 provides a direct and convenient correspondence between meter readings and sound pressure levels.

If the PMI OP-90 and the Analog Devices AD548 are not available, you may substitute TL061s for both ICs with no sacrifice in performance. Current drain will increase, however, to about 750μA. If you don't mind the extra drain, you can make the board smaller by using the dual TL062. As an alternative to the PMI OP-90, use one of the programmable "LINMOS" CMOS op amps from Texas Instruments. The TLC271 programmable op amp draws only 50μA quiescent current in the "medium" bias mode with noise specs just a little worse than the OP-90.

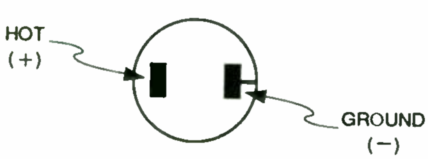

FIGURE 4: Microphone cartridge terminals.

MIKE CONSTRUCTION. The completed microphone measurement system is shown in *Photo 1*. As I mentioned, our mike's presence must not disturb the sound pressure field we are trying to measure. The microphone cartridge must not only be small, its supporting structure must not produce undesirable reflections, which could cause measurement errors. I lacked the facilities to construct a streamlined case for the microphone. I chose to distance the cartridge from the electronics package by mounting it in the end of an 18″ wand, assembled with rigid brass tubing available at hardware stores and hobby shops.

Look at *Photo 2* before reading how the wand is put together. First we must solder appropriate leads to the cartridge. With a diameter and length of only 6mm, the cartridge is small, difficult to handle, and easily damaged. The easiest way to hold the cartridge while soldering wires to it is to drill a ¼″ hole in a ¼″ thick piece of plywood or Masonite and place the cartridge in the hole with the solder pad terminals facing upward.

Next, take two 30″ lengths of #24 AWG hookup wire, one black, and carefully twist them together. After tinning the wires, solder them to the cartridge pads using a conical tip in a soldering iron of no more than 25W. Solder the black wire to the ground terminal pad, the one that connects to the cartridge case (*Fig. 4*). Slip a 1″ length of ¼″ diameter heatshrink tubing over the cartridge body and wires.

Then apply heat only to that portion of tubing covering the wires. Be careful not to heat the mike cartridge. The heatshrink tubing electrically isolates the mike cartridge from the conductive brass wand. *Photo 3* shows the cartridge, with wires connected to it.

TEST AND TUBE. It's a good idea now to test the cartridge before continuing. Use *Fig. 5*'s test circuit. Connect an oscilloscope with a sensitivity of at least 0.1V/cm or sensitive AC voltmeter to the indicated output terminals. Whistle loudly into the mike. You should get a strong indication on either the scope or the meter.

You need two brass tubes to build the microphone wand if you can find only the common 12″ lengths in hobby shops and hardware stores. These are available in graduated diameters. I used one with an outer diameter (OD) of ¼″ and another with a 9/32″ OD. Cut an 8″ length off the larger diameter tube and carefully deburr the cut end.

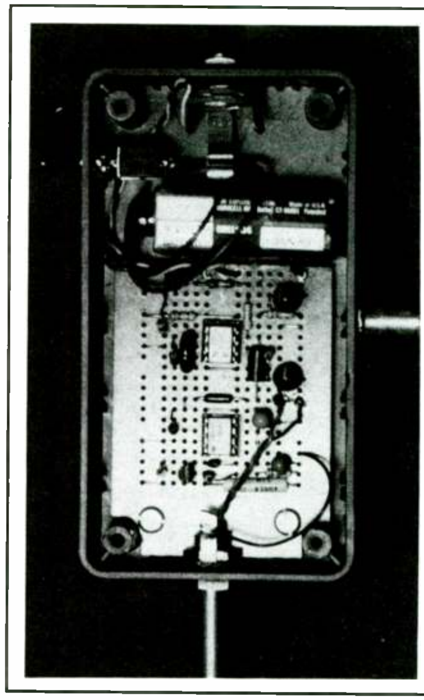

PHOTO 3: Complete microphone electronics package.

Place a small amount of soldering flux on one end of the smaller tube, and insert it into one end of the larger tube to a depth of 1″. Heat the joint with a 25–50W iron and flow rosin core solder into the joint. Wipe away any excess and let the assembly cool.

The cartridge leads now can be inserted into the larger tube's open end, and fed through to the opposite end. The cartridge should be held in place with silicone rubber glue at the large end of the wand. Although not necessary, you may wish to fill the entire wand with silicone rubber to damp sound-induced vibrations. First feed the twisted pair of microphone cartridge leads through the wand, leaving the cartridge dangling at the end of a few inches of lead. Then fill the wand with damping glue, and pull the leads through so the catridge fits snugly in the end of the wand. *Photo 3* shows a completed microphone wand.

ELECTRONICS PACKAGE. I mounted

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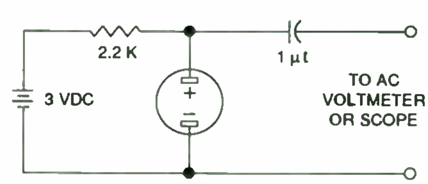

FIGURE 5: Microphone cartridge test circuit.

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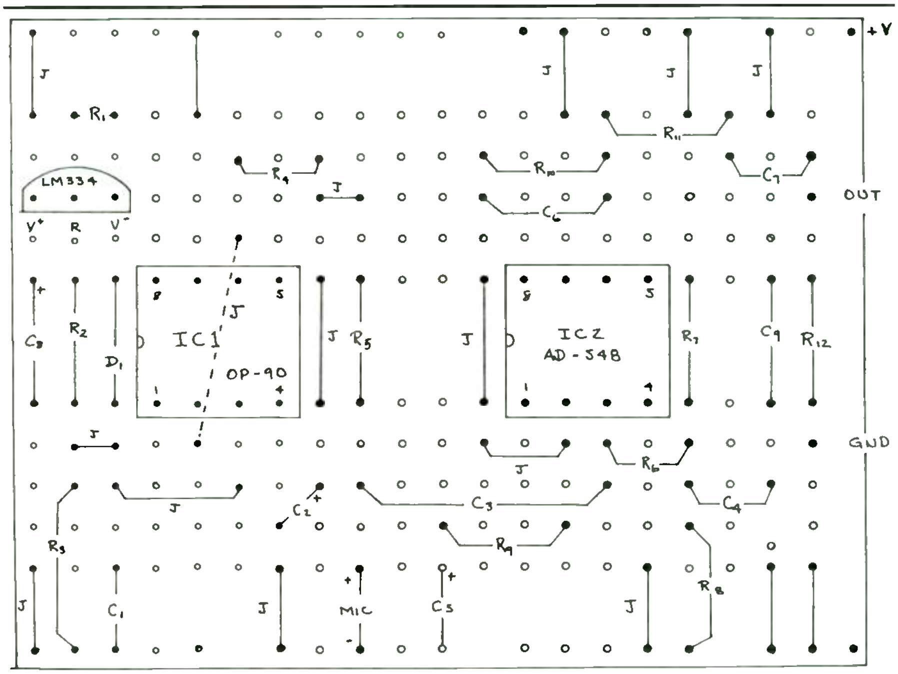
the microphone electronics in a Radio Shack plastic project case (Cat # 270-222) which is 4⅝″ × 2⁹⁄₁₆″ × 1⁹⁄₁₆″. The brass wand supports not only the microphone cartridge, it also shields the microphone leads. The wand support bushing, a ¼″ ID threaded bushing, is mounted in the center of one end of the case. Place a solder lug under the bushing nut, and use it to return the brass wand to ground.

If you do not have a ¼″ ID bushing, a ¼″ phone jack will work just as well. Remove all lugs and tines from the jack assembly, except the ground lug which you can use to ground the wand. At the other end of the case are an output jack and a miniature on/off toggle switch. I glued a ¼″-20 tee-nut to the bottom of the case so I can attach the mike to a camera tripod (*Photo 1*).

The microphone electronics are in *Photo 3*. I didn't draw a printed circuit layout. The circuit is simple, however, and easily laid out on a 3″ length cut from a Radio Shack experimenter printed circuit board (#276-170). The suggested component layout is given in *Fig. 6*. Note many resistors are mounted on-end to save board space. All electrolytic capacitors use bead tantalums to conserve board space. I used sockets for IC1 and IC2. The recommended 9V alkalin battery is held with a Radio Shack battery clamp.



TOP VIEW

FIGURE 6: Component layout for Mitey Mike electronics perforated board.

• CONNECTION
○ NO CONNECTION
Ɨ JUMPER

TESTING, TESTING. The circuit is straightforward, and rarely needs special trimming or adjustment. The first time you power up, however, check a few critical voltages to ensure everything is working correctly. First check the output of IC1's voltage, pin 6. It should be 2.8–3.2V. Outside these limits, check the voltage across R5 with a high impedance voltmeter for proper operation of IC1.

Voltage across R5 should be the same as that at pin 6 of IC1. If IC1 is working correctly and voltage is still low, R1's value may be decreased slightly to increase LM334's output current. Similarly, if the voltage is too high R1 should be increased. Voltage across the mike cartridge should be 1.8–2.2V, depending on the amount of current it draws. Of the 10 units I measured, mike current was 150–300μA. Finally, with a 9V supply, the DC level at IC2's output should be 5V.

USING MITEY MIKE. One could write a book on loudspeaker response measurement techniques. I'll stick with two procedures you can use in your listening room, namely, near field and one meter frequency response measurements. You will only need a wideband AC voltmeter with dB scales, a power amp to drive the loudspeaker, a warble tone oscillator such as that Dick Crawford described, (*TAA* 1/79) and, of course, Mitey Mike. More on the reason for a warble tone oscillator later.

There's a widespread belief among audiophiles, and even experts, you cannot make accurate response measurements in typical listening rooms. It's not necessary to hang your latest creation 25 feet in the air, or bury it in the back yard with its baffle flush with the ground, to get good data. Understanding room limitations, using the right instrumentation, and keeping your microphone relatively close to the drivers you are measuring, can produce very good results.

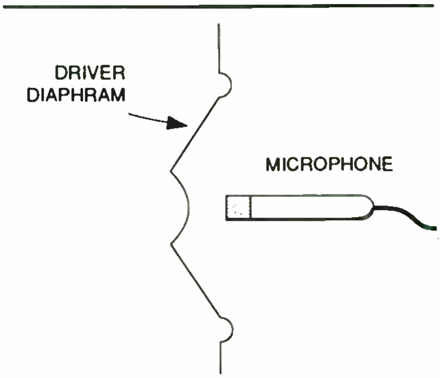


FIGURE 7: The near field frequency response measurement technique.

Let's talk a little about room acoustics first. At low frequencies where wavelengths are comparable to room dimensions, standing wave modes are widely and irregularly spaced in frequency, producing gross variations in loudspeaker/room response. At higher frequencies, where wavelengths are much smaller than room dimensions, standing wave distributions are very dense in frequency—numerous and very close together. Under these conditions, loudspeaker/room interaction is smooth as long as speaker and microphone are far from reflecting surfaces.

TERMS & TECHNIQUES. In technical terms, the low-frequency region is referred to as the "discrete standing wave" region because standing waves are widely spaced and easily observed. The high-frequency region is called the "statistical standing wave" region, because standing waves are so numerous and so closely spaced in frequency they are better described by a statistical distribution than by a direct enumeration. In typical home listening rooms with volumes of approximately 2,500 ft³ the transition between discrete and statistical standing wave regimes occurs somewhere between 300–400Hz. Below 400Hz, I use the near-field technique. Above 400Hz, I prefer one meter measurements.

I should define the term "near field" before proceeding. It's most easily de-

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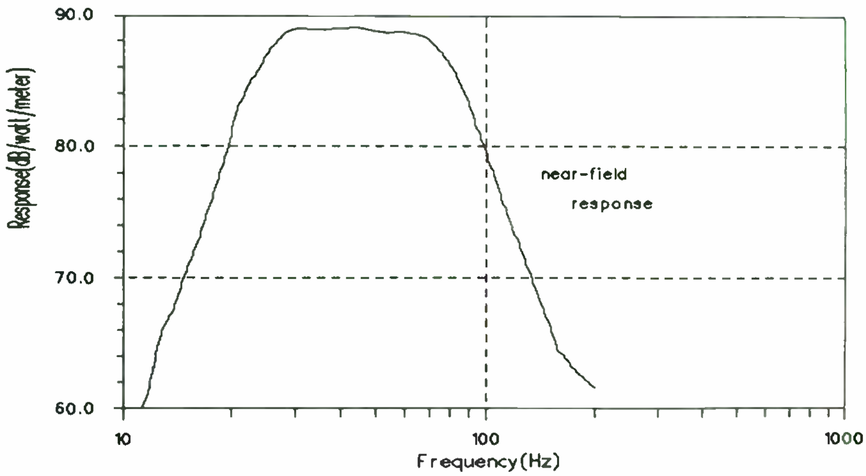

FIGURE 8: The Aria Ten near field frequency response.

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fined, perhaps, by saying what it is not. In a driver's far field sound pressure level falls off inversely with distance, and the driver looks like a point source. As the distance between the microphone and the driver shrinks compared to the driver diaphragm diameter, the axial sound pressure distribution at higher frequencies varies rapidly, because sound pressure contributions from different parts of the diaphragm arrive at the microphone with differing phases.

The distance from the driver where the transition between near field and far field response occurs is a function of driver size and frequency. For all midrange and tweeter drivers, and for most woofers, you are well into the far field at one meter.

We use the near field measurement technique to overcome the effects of low-frequency discrete standing waves. D.B. Keele describes this technique in his excellent paper.[1] I shall only highlight his approach here. Referring to *Fig. 7*, place a microphone very close to the driver diaphragm's center (less than ½″), so the sound pressure level produced dominates any energy which has been reflected from room boundaries. Keele shows that a direct mathematical relationship exists between near field sound pressure and the half-space far field anechoic response.

NEAR AND FAR. Near field measurements produce the true anechoic response of a driver for frequency wavelengths which are long, compared to the diaphragm's diameter. Pressure waves created at the cone's outer edge must travel a longer distance to reach the microphone than those coming from the cone center. They may, at higher frequencies, arrive out of phase causing near field response cancellation not observable at normal listening distances, that is, in the far field. Equation 1 gives a practical upper-frequency limit to the near field technique in terms of driver diameter

$$f_{MAX} > 4300 / D \quad (1)$$

where f_{MAX} is in hertz and the driver diameter, D, is in inches. For a typical 12″ woofer with an effective cone diameter of 10″, the upper-frequency limit is 430Hz. Equation 1 shows near field measurements are valid throughout the entire discrete standing wave frequency range for woofers of 12″ diameter or less. The near field technique is not limited to woofers. For a typical 5″ midrange driver with an effective cone diameter of 4″, near field response measurements are valid up to roughly 1kHz, while 1″ tweeter's can be made out to 4kHz.

Although you can use the near field technique with midrange and tweeter drivers, it does not yield a driver's one meter sensitivity directly. Thus, it's not as useful as one meter measurements for matching driver levels. Since midrange and tweeter units operate exclusively in the statistical standing wave regime, you can make reliable far field measurements at microphone/loudspeaker separations of one-half to one meter.

PUT IT WHERE? When making far field measurements, place the driver or loudspeaker system as far as possible from reflecting walls, while ensuring the distance from any two or more walls is not identical. Dominant reflections will be from the floor. Above 300-400Hz, you can eliminate these reflections by placing thick fiberglass bats on the floor between the speaker and the microphone. Any residual room effects irregularity can now be smoothed out using the warble tone test signal to average through the ripples.

I have not distinguished between individual driver testing and system testing. Individual driver testing is simpler because the driver axis is clearly defined, and microphone placement relative to that axis is unambiguous. Because of the separation between multiple drivers, however, path lengths between each driver and the test mike will be different. System response will change, often drastically, with mike location. In system testing, one must define the listening axis, *and* the location along that axis where response is measured.

Systems with widely spaced drivers may not integrate well at one meter. Unfortunately, if the mike is placed much farther away from the system under test, the ratio of direct to reflected sound will decrease, and wall, floor, and ceiling reflections will begin to distort the measured response. Under these conditions I have found system response often can be more accurately predicted with a computer program, such as LMP, CALSOD or XOPT, than it can be measured. Individual driver responses, including the effect of their crossover, are measured and used with one of the programs to compute system response on any desired axis.

RESPONSE MEASUREMENT. I'll conclude with two examples. If you have ever tried measuring the subwoofer's frequency response in your listening room with conventional techniques, you know it's an impossible task. However, near field measurements are a piece of cake. *Figure 8* shows the ARIA TEN's

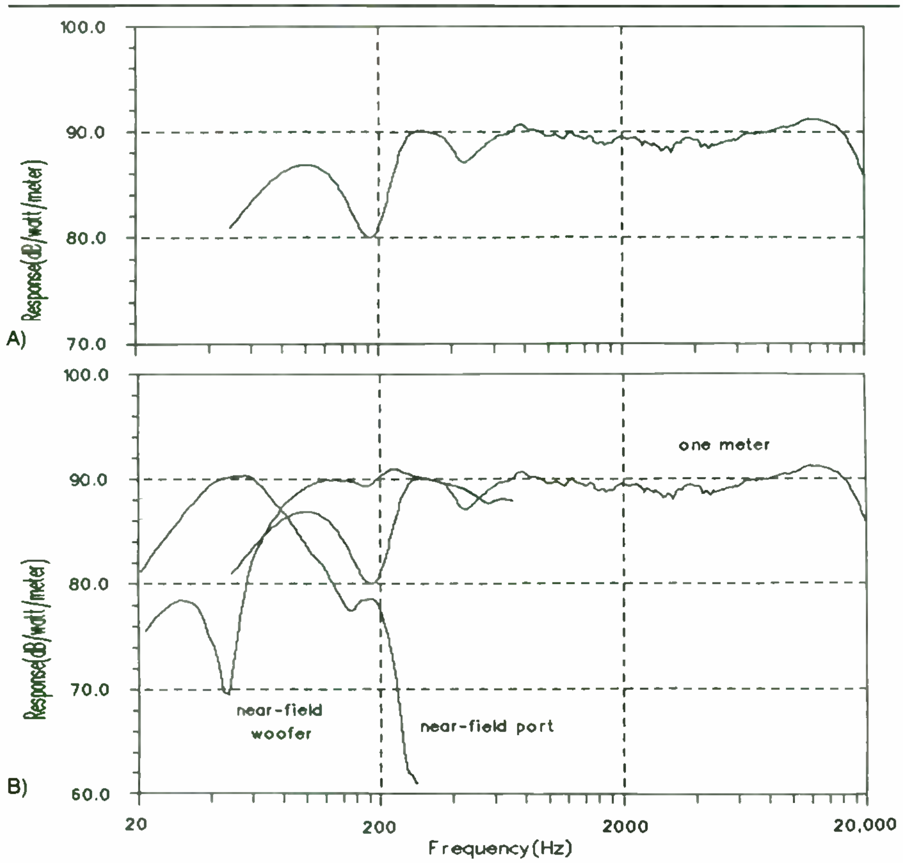

FIGURE 9: The Signature 717 frequency response; (a) One meter response; (b) Combined near field and one meter responses.

near field response to a swept ⅓-octave warble tone. The ARIA TEN, which I designed for Focal America, is a sixth order band-pass subwoofer in which all radiation comes out of a slotted port.

I obtained the measurement by placing Mitey Mike at the port exit's center in line with the enclosure's outer wall. The plot shows a smooth anechoic response with 3dB down points at 24 and 82Hz. Above and below these points, response falls off at 18dB/octave. Incidentally, the measured near field response agrees perfectly with computer model predictions.

Figure 9 shows the Signature 717's frequency response, a compact, stand mounted system designed for A&S Speakers of San Francisco. The data for *Fig. 9a* were taken at one meter in my living room using a swept ⅓-octave warble tone. Notice the response data are quite smooth down to about 400Hz, where the first room induced response dip, a mild floor dip, occurs. A second, more pronounced dip is seen at 160Hz, so 400Hz seems to be the lower limit for one meter measurements in my living room.

Data below 400Hz was obtained via a slight modification of the basic near field approach. The Signature 717 uses two closely spaced 7″ mid-bass drivers in my 3/2 geometry. To get the contribution from both drivers simultaneously, the loudspeaker was placed on 2″ spacers facing downward on a concrete floor. This created an acoustic center on the floor between the two drivers. I placed Mitey Mike at the center point and took a frequency response to get the dual mid-bass driver's contribution to the overall curve from 400Hz downward. This procedure is sometimes referred to as the "ground plane" approach.

Finally, I placed Mitey Mike at the center of the rearward firing port to get its contribution. All three curves are shown in *Fig. 9b*. Notice the near field woofer response has a deep notch at 42Hz, which is the box tuning frequency. At this same frequency, the port output has reached a maximum (I guess, the bass reflex principle really works.) Port and woofer contributions are equal at about 80Hz. *Figure 9b* shows low-end port response, and therefore the low-end system response, is down 3dB relative to 1kHz at 36Hz.

REFERENCES

1. Keele, D.B. Jr. "Low-Frequency Loudspeaker Assessment by Near Field Sound Pressure Measurement," *Journal* of the Audio Engineering Society, Vol. 22, No. 3, April 1974.

SYMMETRICAL LOADING FOR AUTO SUBWOOFERS

BY MATTHEW HONNERT

I was enthused with Jean Margerand's article, "The Third Dimension: Symmetrically Loaded," (*SB* 6/88) and have designed and built several versions for automotive use. My development work, and on-the-road experience may help fellow speaker builders.

Symmetrical loading offers many automotive advantages, such as:

1. High-power handling capacity using relatively small drivers. Reduction in cone excursion and distortion this loading technique offers, allows reduction in driver and enclosure size.
2. Minimal (or no) crossover requirements. The 12dB/octave acoustic roll off is adequate for most automotive applications due to occupants' proximity to the speakers. An electronic, even passive, crossover is helpful but not necessary. In most basic systems, the subwoofer is simply wired in parallel to the main full-range speakers.
3. Compact size and flexible dimensions. Low-profile or irregularly shaped enclosures can be built for any hatchback, sedan, or van.
4. Cost. Small drivers and enclosures are generally inexpensive. A simple crossover network reduces cost even more.

I recently built two subwoofers, one for a mini-van, the other for a hatchback coupe. Both use dual 6″ woofers, yet design parameters and installation were unique.

For the Voyager Van, dual Peerless TP165F drivers occupied a common back chamber, with a single 3½″ I.D. duct venting the front chamber. It is driven by an 80W bridged amplifier via a 140Hz Linkwitz-Riley low-pass filter. Covered in matching carpeting the enclosure resides under the middle bench seat for near-factory-look.

I was less concerned about size in my VW Scirocco commute car, but I wanted good performance and low cost. Twin Becker 906A171 drivers are mounted in separate back chambers, cones mounted push-pull. The common front chamber vents to the top through dual 3″ ducts. The enclosure is long and sloped to fit directly behind the back seat. Originally, I amplified this design as a stereo subwoofer, each woofer in parallel with its respective full-range main speaker. For more power and flexibility, I now drive it in mono with a bridged 50W amp via a dash-mounted electronic crossover.

Comparing the two designs yields some interesting notes. Both are tuned to about the same center frequency with equivalent bandwidths of 40–170Hz. The van system, admittedly less efficient, seems more strained even with the larger power amp. The VW system "pressurizes" the vehicle with solid bass. On-the-road experience and bench testing yielded practical guidelines for high performance, and low-cost, automotive designs:

- Use woofers with moderate or low f_S/Q_T values, under 100 if possible. A low V_{AS} will also reduce box size and/or allow a higher efficiency design alignment. Small woofers with small magnets and loose suspensions work well, and cost less.
- Try using woofers with long mechanical excursion limits. The Peerless drivers I used, as well as Dynaudio and others, tend not to bottom out when overdriven. Their excursion peaks at some limit, but no rapping sound occurs. I have successfully used other drivers that do bottom, but you'll appreciate the extra margin, especially with some power amplifiers which pulse the woofers at turn-on or turn-off.
- Duct diameter is important, and must be considered for its effects on annoying wind noise and ultimate sound-level. I use the formula:

$$\text{Minimum Area (inches)} = 0.02 \times \text{Vent Freq. (Hz)} \times \text{Cone Displacement (in}^3\text{)}$$

For typical tuning frequencies and drivers, see minimum vent diameters (*Table 1*).

You will find it is often difficult to design the minimum vent diameter into com-

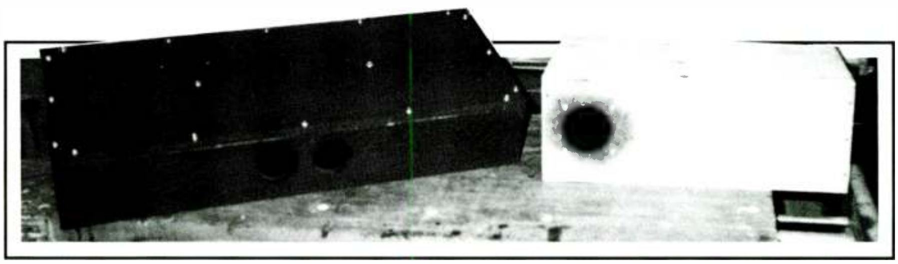

PHOTO 1: The assembled enclosures. Finishing touches are up to the builder.

TABLE 1

WOOFER	CONE DIS.	VENT FREQ.	VENT DIA.
6″	6 in³	60–80Hz	3″
8″	13	60–80Hz	4.5″
10″	25	50–70Hz	6″
12″	42	50–70Hz	2 × 6″

ABOUT THE AUTHOR

Matthew Honnert has a BSEE degree, and is Senior Applications Engineer at Syntronic Instruments, Inc., a manufacturer of precision deflection yokes. He has designed and built more than 60 speaker systems, including Strathearn and Swan IV derivatives, over the past 20 years. He is married and has two young sons.

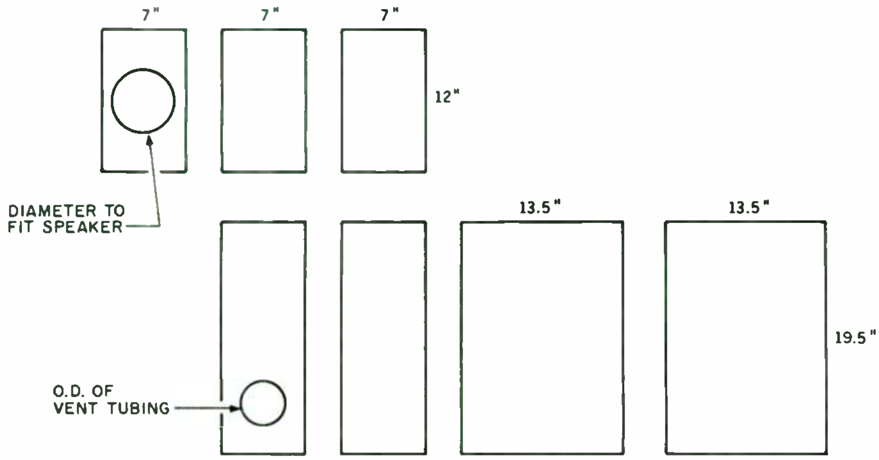

FIGURE 1: The finished pieces with speaker and vent apertures.

pact enclosures. For best results, even a 6" woofer requires a front chamber of more than 0.25 ft³ for a manageable duct length. If you use dual drivers, dual ducts (or equivalent duct area) must be engineered as well. It is likely drivers with large magnets, or small equivalent air volumes (V_{AS}) will perform best with higher "S" alignments.

• Power bandwidth influences efficiency, and power handling. I usually set f_L at 40Hz as a start, knowing that typical program music has little energy below that. It's fruitless trying to reproduce lower frequencies in a moving vehicle. Cone excursion, however, dramatically increases beyond half-power frequencies f_L and f_H. Smaller drivers, and short-throw voice coils, can be coaxed into high power applications by setting f_L considerably lower, perhaps 30Hz, since improved cone loading reduces cone excursion in the useful frequency range. Efficiency will suffer, but amplifier power is getting cheaper nowadays.

• For automotive applications, the upper half-power frequency, f_H, can be significantly higher than in quality home systems. A vehicle has many surfaces close to the subwoofer, and even at 180Hz, a rear mounted subwoofer isn't readily detected unless it is 8-10dB louder than the full-range speakers. When used without a complementary low-pass filter (crossover network), I would limit f_H to about 140-150Hz, with a filter, 180-200Hz is satisfactory.

A simple series inductor is useful in crossovers when the subwoofer is to be strapped (in parallel) across the full-range amplifier outputs. The 6dB slope is mild, yet it reduces wasted power at frequencies above f_H. Series resistance must be accounted for in subwoofer design, yet low-impedance power amplifiers may enjoy the reduced load.

I prefer electronic crossovers for various reasons. They improve system clarity by relieving the full-range speakers from the low frequencies; they allow easy balance adjustments between subwoofer and full-range speakers; and they increase sound levels dramatically, even with relatively small power amplifiers.

The latter results from summing the amplifier voltages. Assuming the midpoint of acoustic power is about 200Hz in a moving vehicle, if we use two similar power amps via an electronic crossover (for frequencies above and below this) we essentially double available amplifier output voltage to the total system. Since power is proportional to voltage-squared, we *quadruple* to equivalent power. This "totem poling" of amplifier voltage swings often allows multi-amped systems to outperform larger single-amp systems. Even using a simple low-pass *only* filter (as found in accessory equalizers), you still get balance control and significantly improved clarity. The full high-pass/low-pass filters are icing on the cake.

A LOW-COST DIY DESIGN. I've evaluated drivers from Polk, Radio Shack, Peerless, Becker, Focal, Dynaudio, and Universal. The Dynaudio is good, very costly, and has a fairly short linear excursion. The Becker is also very good, if you can find one. The others, except the Radio Shack, have too high an f_S/Q_T for efficient and practical design. We'll use the Radio Shack 40-1011. The cost is reasonable and it is widely available.

After several hours of break-in, the Theile parameters were considerably different from those Radio Shack advertised. This is not surprising, but I hope my test speakers are representative of those found nationally in stores. Measured versus advertised parameters were:

RADIO SHACK 40-1011

PARAMETER	TESTED	ADVERTISED
f_S	36	50Hz
Q_T	0.35	0.6
V_{AS}	1.7	2.6 ft³

For the enclosure parameters, I selected a moderately sized enclosure:

V_B = 870 in³
V_F = 582 in³
VENT = 3" I.D. × 9.1" long

SUIT THE SPACE. This design provides cutoff frequencies at 42 and 140Hz, with a relatively high efficiency of −2dB. All dimensions are for a single driver, and must be doubled for dual drivers (use two of the specified vents). A stereo design results from attaching together two identical enclosures.

Many dimensional ratios will suit the available space simply by adding V_B and V_F together (the volume of the vent has already been factored into V_F), and dividing the key dimensions. Since the drivers are about 7" in diameter and the

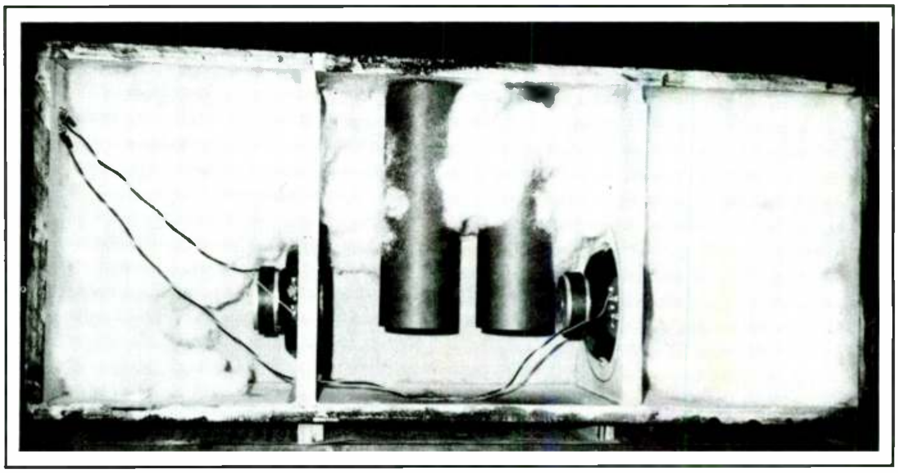
PHOTO 2: The vent can be made from materials such as cardboard, phenolic, or plastic.

vent requires about 12" internal space (vent length plus one vent diameter), I will arbitrarily use internal dimensions of 7:12:17.25". Allowing ¾" for the internal partition, the inside dimensions are about 7:12:18". Additional volume for the driver isn't necessary, as it is closely offset by the mounting aperture in the partition.

Use the following cutting list for each enclosure:

QTY.	SIZE
3	7" × 12"
2	7" × 19.5"
2	13.5" × 19.5"

These sizes are based on ¾" plywood or particle board. Using thinner material, calculate a revised cutting list. *Figure 1* illustrates the finished pieces with speaker and vent apertures. The vent duct can be made from materials such as cardboard, phenolic, or plastic. If the I.D. is 3" as specified, the enclosure's tuned frequency will be near 75Hz.

Assemble the enclosure's sides first, all pieces of 7" width. For the simple butt joints, I suggest a heavy adhesive such as paneling cement ("Liquid Nail") for its gap-filling feature and strength. Use nails or screws as well, since the adhesive requires overnight curing. The driver mounts in the larger aperture between the two chambers, while the vent is installed in the smaller chamber (*Fig. 2*).

The driver should be bolted or screwed in place, the magnet side facing the larger back chamber. Now the vent can be glued with panel cement or caulking, its end flush with the outer panel surface.

Next, install a side panel (13½" × 19½"). Bring the speaker terminals out before adding the last panel. A simple "zip cord" or a more elaborate feed-through can be used. Toss in a handful of fiberfill in the rear chamber, and seal down the last panel. A felt gasket works well if you opt for a removable panel).

Now is a good time to test the subwoofer for buzzes or air leaks. Connect it to an amplifier and play some heavy music. You won't hear much, but caulk any leaks.

Finishing cosmetics are up to the builder. I suggest paint to seal the wood. Automotive (non-backed) carpeting is easy to install with spray contact cement, and looks "factory."

This system's efficiency is slightly lower than typical automotive full-range speakers, making a simple parallel connection less than exciting. Satisfactory connections, in order of preference, are:

1. Separate monaural (or bridged stereo) amplifier and electronic crossover with adjustable gain control. Depending on the main full-range speaker's bandwidth, a low-pass *only* filter may be adequate for the subwoofer. Maximum volume is available if high- and low-pass networks are used. Gain control at-your-fingertips is recommended for exploring music's hidden lower frequencies.

2. A main power amplifier with opposite phase outputs simultaneously can drive main and subwoofer speakers, with close balance and good output. Some power amplifiers, such as Alpine and Rockford-Fosgate, have one channel inverted from the other, allowing you to connect the subwoofer across its "plus" terminals, and full-range speakers across their respective stereo outputs. This drives the woofer with twice the normal voltage, raising its relative output by 3dB, and more nearly matching the full-range main speakers.' Additional crossovers aren't necessary. A passive low-pass network may be added to the subwoofer, if wished, for reasons outlined earlier.

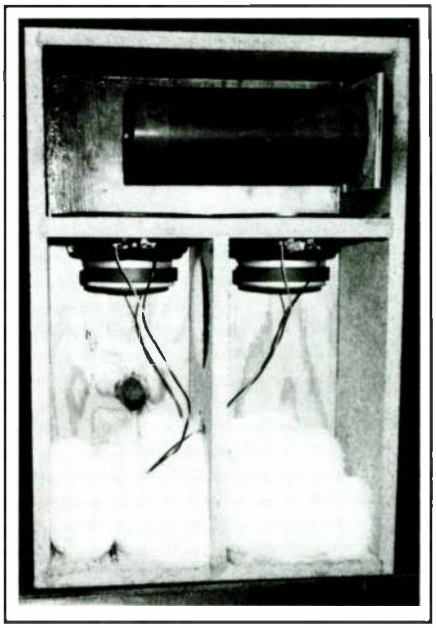

PHOTO 3: The rear chamber stuffed with fiberfill.

3. A standard stereo power amp can drive both full-range speakers *and* parallel stereo subwoofers, but requires an L-pad for the full-range speakers to match their sensitivities to the subwoofers.' Fortunately, most automotive speakers are overdamped, and not greatly affected by the L-pad's series resistance. For best results, the amplifier should have at least 40W per channel and low-impedance (high-current) capability. As noted above, a passive low-pass filter at about 150Hz would be a worthwhile enhancement.

I believe symmetrical loading provides an ideal, and cost-effective way to install a quality subwoofer into your vehicle. *SB* readers experimenting with the technique are sure to find a rewarding construction project, as well as obtaining very healthy bass performance.

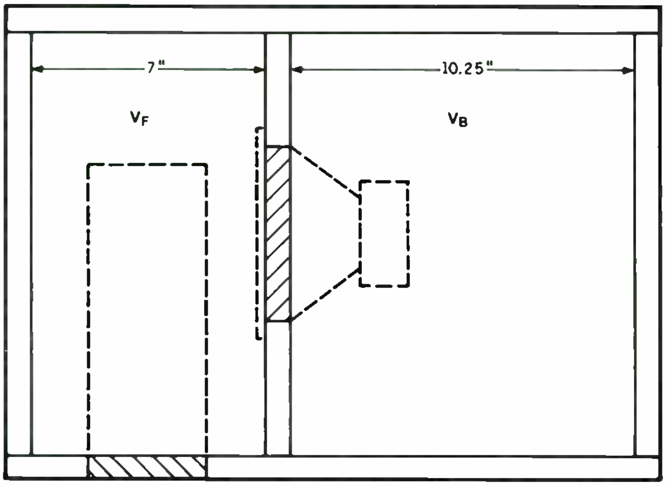

FIGURE 2: The driver mounts in the larger aperture between the two chambers.

Addendum

The problem of weak bass in my van system has been linked to inadequate enclosure rigidity. The symmetrical-loading technique generates tremendous internal pressure and requires a minimum panel thickness of ¾". (My van system used ½" for low profile.) The pressure also blew out the foam surrounds on my Becker drivers. I now recommend the woofers be rear-mounted when possible.

The van now utilizes a single Seymour Sound 8" woofer, instead of the original dual 6" Peerless drivers. Power capacity is not as high, but efficiency is better, and sound quality is equivalent.

IMPROVED VENTED BOX WITH LOW Q_{TS} DRIVERS

BY G. R. KOONCE
Contributing Editor

In "The QB_3 Vented Box Is Best," (*SB* 5/88) I expressed my preference for the sound of QB_3 aligned Vented Box (VB) speaker systems, and why they might offer superior performance. I had a problem finding drivers which offered a sufficiently low −3dB cutoff frequency (F_3) to make a worthwhile system. Small woofers, say less than 8", commonly have a Q_{TS} sufficiently low (below 0.4) to provide QB_3 alignments. It's important with small drivers to move F_3 as low as possible for acceptable system performance. The last couple of years I've accomplished this by deviating from classical alignments to enhance F_3 performance. The results have been very satisfactory.

A caveat: I have no design equations. It is purely trial and error. One requirement is the ability to plot a VB system's response. I have computer programs which do this, almost a necessity as numerous plots are required. Review Old Colony's offerings to see if software to graph VB response is available. The equations to determine VB's response are shown in the sidebar. I must, unfortunately, leave the problem of plotting VB response to the reader.

The basic approach examines the optimum QB_3 response for your driver to establish net box volume (V_B) and box tuned frequency (F_B). I have found increasing box size and modifying the tuning will drop F_3, sometimes dramatically. *Figure 1* shows the QB_3 response for a large driver with Q_{TS} = 0.258, F_S = 19Hz and V_{AS} = 12.8 ft³ in an enclosure with V_B = 3.08 ft³ net. F_3's value of 36Hz is disappointing for a driver with an F_S of 19Hz. *Figure 2* illustrates results of raising the enclosure size and playing with the tuning. Note that V_B of 6 ft³ allows an F_3 of about 27Hz, a great improvement. The penalty is a slight dip in the response (1dB), and possibly giving

TABLE 1

PERFORMANCE COMPARISON

Driver	V_B (ft³	F_S (Hz)	F_3 (Hz)	F_B (Hz)	Align.
Large—	3.08	19	35.7	28.6	QB_3
Figures	4.00	19	32	30	Mod
#1 & #2	6.00	19	27	28	Mod
Small—	0.138	62	101.9	84.1	QB_3
Figures	0.200	62	88	80	Mod
#3 & #4	0.400	62	72	77.5	Mod

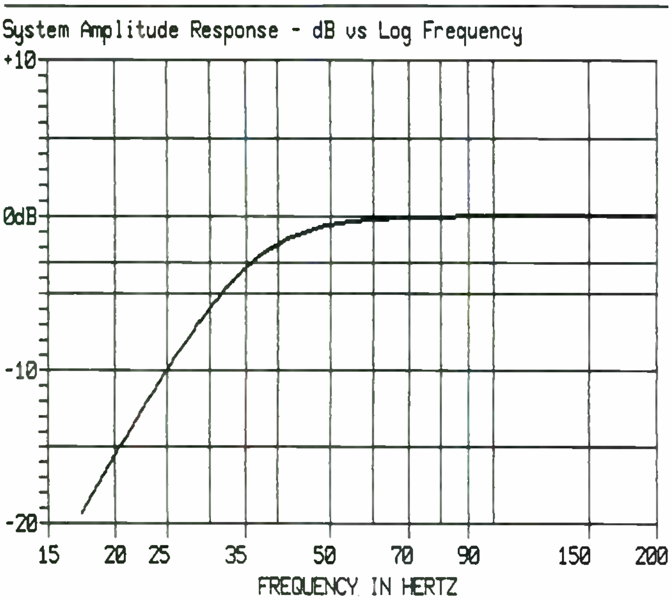

FIGURE 1: Optimum QB_3 response for large driver–V_B = 3.08 ft³

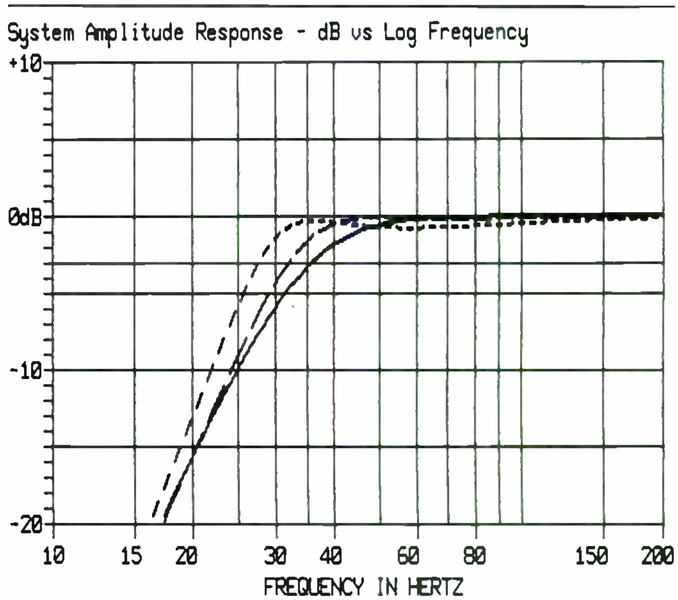

FIGURE 2: Modified responses for large driver.

Computing Response of a Vented Box System

Response in dB = $20 \log_{10}(R)$

where R is linear response as follows:

$$R = \frac{(F_N)^4}{\sqrt{[(F_N^4 - C\,F_N^2 + A)^2 + F_N^2\,(D\,F_N^2 - B)^2]}}$$

Where: F_N = F/F_{SB} F = the frequency of interest—Hz

F_{SB} = Driver resonance in V_B—Substitute F_S for design

A = $(F_B / F_{SB})^2$ F_B = Box tuned frequency—Hz

B = $A / Q_{TS} + F_B / (Q_B F_{SB})$ Q_{TS} = Total driver Q

Q_B = Box Q (Normally 7 is used)

C = $1 + A + V_{AS} / V_B + F_B / (Q_B F_{SB} Q_{TS})$

V_{AS} = Equivalent compliance volume of driver

V_B = Enclosure net volume—same dimensions as V_{AS}

D = $1 / Q_{TS} + F_B / (Q_B F_{SB})$

up some QB_3 response advantages. The slight dip occurs in a range where passive crossovers produce a slight peaking, which would somewhat offset the dip. Six ft³ enclosures are not popular these days, but any enclosure over the optimum QB_3 volume of about three ft³ would allow reduced F_3 with this driver.

Figure 3 offers a more practical application, the optimum QB_3 response for a small driver with Q_{TS} = 0.288, f_S = 62Hz and V_{AS} = 0.43 ft³ The system's F_3 frequency is about 102Hz, making construction moot. Since the QB_3 optimum V_B is only 0.138 ft³, there should be no problem considering larger enclosures. The larger you make the enclosure the lower you can push F_3, but the more severe the response dip. *Figure 4* demonstrates the performance with the enclosure volume raised to 0.2 and 0.4 ft³ With V_B = 0.4 ft³, the system has about 2dB response ripple with F_3 pushed to about 72Hz. This ripple in a small driver has not been a problem, at least in my experience. A more conservative V_B of 0.2 ft³ shows about 1.5dB droop and an F_3 of about 87Hz. Perhaps playing with the tuning could further improve performance. Playing with the tuning and enclosure size makes response curve plotting by hand unacceptable.

I proposed in "The QB_3 Vented Box" the "improved" performance I heard stemmed from the fact the system cutoff (F_3) was above the two major system resonances (F_B and f_S) so major system output did not occur at these frequencies. This technique is pushing down the F_3 point. How do these modified systems fare in keeping resonances suppressed? *Table 1* lists the results for the two driver examples. It is clear the procedure did not push F_3 down to f_S, but it certainly will put F_3 below F_B. If the enclosure size is excessively increased over optimum QB_3 then the box resonance (F_B) will be in the passband. A potential penalty is paid, not only in the response ripple, but also in moving the system resonances closer to the system pass-band. This is still better than the C_4 alignment, which has both f_S and F_B in the pass-band.

I have used this approach with moderation on large drivers, and with excess on small drivers. Final results in all cases, so far, have been good. Could this be proof the advantage of QB_3 alignment is simply the low driver Q, and thus good woofer damping, and not in any way related to the suppressed system resonances? I don't know the answer. I *do* know that systems with these low Q drivers sound better. I will continue using them, even if I can't explain the perceived superior performance.

This technique enables construction of systems with a lower cutoff frequency with low Q drivers. They may no longer be QB_3, but they sound good. Let me hear from any builders using this, or similar, technique with low Q drivers.

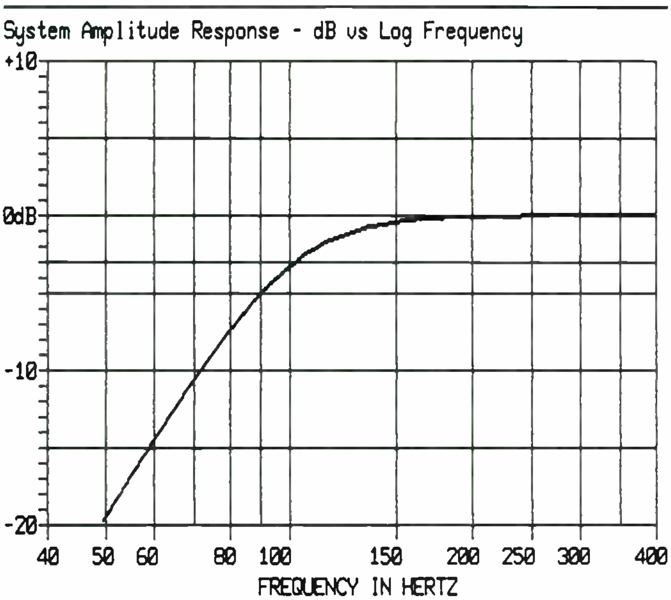

FIGURE 3: Optimum QB_3 response for small driver—V_B = 0.138 ft³

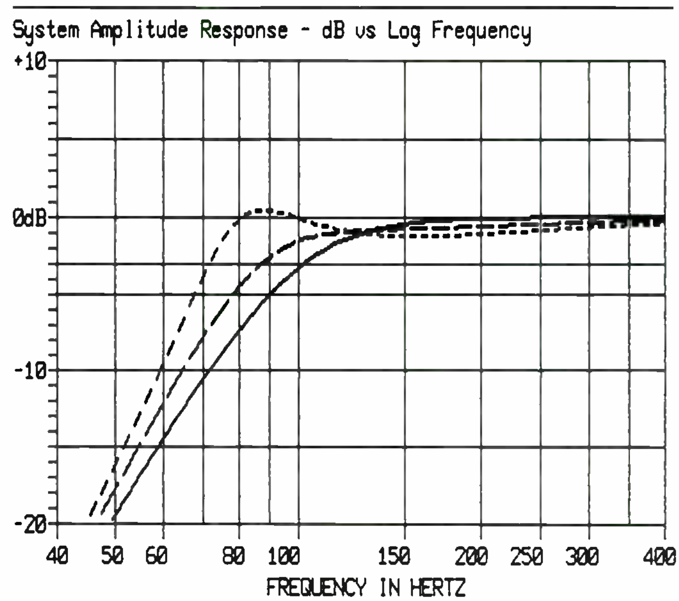

FIGURE 4: Modified responses for small driver.

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BOXMODEL—AN AID TO WOOFER SYSTEM DESIGN

BY ROBERT M. BULLOCK, III
Contributing Editor

In 1984 I wrote an Apple program called BOXRESPONSE which appeared in *SB*.[1] Its purpose was to allow the Thiele/Small model of a woofer system to be used in a practical way for the design and analysis of either a vented-box or a closed-box with or without equalization.

I had wanted to include Small's passive-radiator model[2] as well, but this proved to be more complicated than I cared to deal with. I was also interested in investigating the three box losses (absorption, leakage, port) separately rather than lumping them together in the leakage loss as is done in Small's models. These two facts led me to derive a new model that included all three common box types simultaneously and the three separate loss factors as well. The derivation of this new model was presented at the AES Convention in 1989.[3] Using this generalized model I wrote a new version of BOXRESPONSE for the IBM PC. This version is currently available through Old Colony.

Although it is a powerful program it is rather awkward to use because of the way data entry is handled. Also, there is no way to directly compare more than two alternative designs, and passive-radiator system parameters are not handled in the standard way. Because of these and other shortcomings I have written a new program for studying woofer systems by the Thiele/Small models. It is called BOXMODEL and will be offered by Old Colony. With it you can easily compare as many as four systems at once and data entry is extremely fast and easy. Overall, I think it is a great improvement over IBM BOXRESPONSE.

If you are interested in programs of this type mainly for calculating optimal alignments, then BOXRESPONSE is still the program for you. BOXMODEL does not support this capability. It was not included because I wanted to make the comparison features as convenient as possible, and because I considered alignment calculation to be of only marginal value. Why depend on somebody else's ideas of the "best alignment" when in BOXMODEL you have the capability to look at any alignment and decide whether it is appropriate for your circumstances.

The rest of this article is divided into three sections. The first explains the operation of the program in some detail. The purpose for doing this is to permit reference to the program in later discussion and to allow this article to serve as the documentation for the program. The second part discusses two topics that may not be so well known: passive-radiator systems and acoustic losses. The last part consists of a couple of examples showing how the program can be used.

For the most part the symbols used in the program for system data are those first used by Small in his papers on box systems. If you are a regular reader of *Speaker Builder* most of them should be familiar to you. If you are not, then you should consult my *SB* series[4] on vented-boxes where most of them are described. Some symbols related to losses and passive-radiators may be new to you, but they are described below.

I. PROGRAM MECHANICS

MACHINE REQUIREMENTS. BOXMODEL is designed for an IBM PC or compatible with at least 384K of RAM and running DOS 2.x or higher. The program will run on a machine without graphics capability, but I don't really recommend it because the graphics presentations are extremely important in making design decisions. The program will recognize and use MDA, CGA, EGA, VGA, MCGA or Hercules video

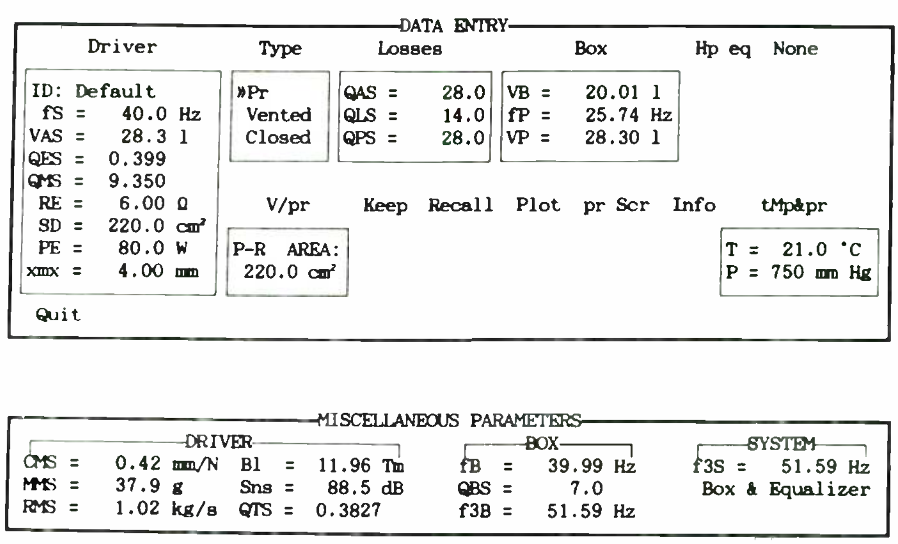


FIGURE 1: A typical display screen with no equalizer.

adapters. I believe it should also be usable with any adapter that is capable of emulating the high resolution modes of these adapters, but I have not been able to verify this. Color capability is not necessary, but it is also highly recommended.

Some of the data calculations in the program involve many floating point operations, so a co-processor is highly recommended. As a matter of fact, the program's number crunching on my 4.77MHz 8088/8087 combination is slightly faster than it is on the department's 16MHz 386 machine without a co-processor. So, if you can possibly swing it, a co-processor is well worth it for this kind of application. They are available for about $100.

To summarize, minimum requirements for the program are an IBM PC or clone with at least 384K running DOS 2.x or higher. To get the most out of the program you should have a graphics card of one of the types mentioned above. To avoid waits of one to two minutes you should have a co-processor. Color makes for a pretty screen.

```
                              DATA ENTRY
      Driver            Type        Losses              Box          Hp eq  Order = 2
                                                                          Eqdata
 ID: Default          Pr          QAS =    28.0   VB =   20.01 l
  fS =   40.0 Hz      Vented      QLS =    14.0                    Cnr =   42.00 Hz
 VAS =   28.3 l       »Closed                                      Dmp =  0.4400
 QES =  0.399
 QMS =  9.350
  RE =   6.00 Ω                  Keep  Recall  Plot  pr Scr  Info   tMp&pr
  SD =  220.0 cm²
  PE =   80.0 W                                                    T =  21.0 °C
 xmax =   4.00 mm                                                   P = 750 mm Hg

 Quit
```

```
                        MISCELLANEOUS PARAMETERS
            DRIVER                              BOX                  SYSTEM
CMS =  0.42 mm/N  Bl  =  11.96 Tm     fC  =  62.15 Hz      f3S =  40.49 Hz
MMS =  37.9 g     Sns =  88.5 dB      QBS =    9.3         Box & Equalizer
RMS =  1.02 kg/s  QTS =  0.3827       f3B =  79.39 Hz
```

FIGURE 2: A typical display screen with an equalizer active.

PROGRAM OPERATION. The program starts with a title screen. Hitting any key will take you to the main work screen for the program. This screen is divided into two windows as shown in *Fig. 1*. All of the data entry you (the user) do occurs in the top window called "DATA ENTRY." The bottom window is called "MISCELLANEOUS PARAMETERS" and contains various program calculated parameters of interest. You never work in this window.

DATA ENTRY. All units are in the meter-kilogram-second system. If you are used to working in the foot-pound-second system, the HELP facility will usually provide you with an appropriate conversion factor.

The data entry section consists of two menus and several data windows. The main program menu is free form and consists of the items DRIVER, TYPE, LOSSES, BOX, HP EQ, KEEP, RECALL, PLOT, PR SCR, INFO, Tmp&Pr, and QUIT, which are always displayed, as well as the items Eqdata and V/PR, which appear only when needed. Items are selected by pressing the capitalized letter of the item. You can also move from item to item with the Left arrow and Right arrow keys and select an item by pressing the Enter key. You can also quit the program by pressing the Esc key.

If you select DRIVER, TYPE, LOSSES, BOX, V/PR or Tmp&Pr, then the cursor will move into the window below the selected item and you can either make a menu selection in the TYPE menu or enter new data in any of the other windows. Note that one item in the TYPE menu is marked with an » to indicate that it is the current selection.

To enter data, first move the cursor to the data item you want to change by using the Up and Down arrow keys. Then move into the data field with the Right arrow key. The cursor will move to start of the data item. Then the overwrite mode is active and you can simply write in what you want. The Left and Right arrow keys let you move to any field position. The Space Bar and Back Space keys delete characters. Once you have edited to your satisfaction, striking the Enter key will take you out of the field and you can move on to another field with the Up or Down arrow keys or move back to the main menu by hitting the Enter key again.

If you are in a data field and have modified it, but then decide you want to keep the original value, hit Esc. This will move you out of the field but preserve the original value. If you decide you really didn't mean to edit any of the fields in a window, hit Esc rather than Enter and the cursor will move back to the main menu and all of the fields in the window will be returned to the values they had on entry.

Any other main menu selection will cause a window to pop up. With KEEP, RECALL and PLOT the window will contain a menu. Move to your selection with the Up and Down arrow keys and select with Enter. To cancel the menu, use Esc. Selecting the PLOT main menu item will cause a menu to pop up in which you choose how many systems are to be displayed. After you select from this menu there is a delay during which extensive calculations are done. Then another menu appears from which you pick the type of plot you want. This menu also has a choice to allow you to turn the coordinate grid on and off. Plotting is faster without the grid, but the grid makes it easier to estimate values. After a plot is done, striking any key will return you to the plot type menu and you can select any other type. When you are done plotting, hitting Esc in this menu will return you to the main menu. As always, Enter selects an item and Esc backs you out of the menu.

INFO. The INFO item supplies help information of a general nature. You can page through five screens of information before returning to the first page. You return to the main menu anytime by hitting Esc.

PR SCR. The selection PR SCR is provided for machines without a PrtScr key. It will send the system data currently on display to an attached printer if it is on line. Otherwise, nothing will happen. The window borders may look somewhat strange if your system doesn't support the IBM higher order character set, but all of the data should be sent correctly. This PR SCR function is not capable of dumping graphics screens to a printer. For this purpose you will need your own utility.

TMP&PR. The Tmp&Pr selection is provided for those who prefer to use their own values for ambient temperature and barometric pressure. The default values are in the window when the

```
                              DATA ENTRY
      Driver          Type       Losses            Box           Hp eq  Order = 2
                                                                        Eqdata
 ID: Default        Pr         QAS =    28.0   VB =    20.01 l
  fS =    40.0 Hz   »Vented    QLS =    14.0   fB =    40.00 Hz  Cnr =    40.00 Hz
 VAS =    28.3 l    Closed     QPS =    28.0                     Dmp =   0.5000
 QES =  0.399
 QMS =  9.350
  RE =    6.00 Ω      V/pr      Keep  Recall   Plot   pr Scr   Info     tMp&pr
  SD =   220.0 cm²
  PE =    80.0 W    VENT DIAM:                                   T =   21.0 'C
 xmx =    4.00 mm    7.62 cm                                     P =  750 mm Hg

  Quit

              Losses due to enclosure leakage.  Typical range is
              3 ≤ QLS ≤ 80.  QLS ≥ 99999 sets QLS = ∞(lossless).
              Related to Thiele-Small QL by QLS = (fS/fB)QA.
                            any key continues                        SYSTEM
CMS =   0.42 mm/N  Bl   =  11.96 Tm      VL  =   37.10 cm     f3S =   35.78 Hz
MMS =   37.9 g     Sns  =   88.5 dB      QBS =     7.0         Box & Equalizer
RMS =   1.02 kg/s  QTS  =  0.3827        f3B =   46.25 Hz
```

FIGURE 3: A help message displayed while the cursor is on the Q_{LS} item in the LOSSES window.

program starts. Changing these values will alter entries in the MISCELLANEOUS PARAMETERS window only.

TYPE, LOSSES, BOX, HP EQ, V/PR. These selections enable the necessary information about the system to be entered and will be discussed in more detail below. The operation of the selection HP EQ does require a bit more explanation though. Selecting it will cause a small window to open. Use the Right arrow key to move into this window and enter the order of the equalizing filter you want to use. Picking order 0 causes the word None to appear and no further action is necessary. If you choose 1, 2 or 3 then a second window pops up below the menu item and the cursor is moved into it. Here you enter the data on the equalizer. This window will stay on view as long as an equalizer is in use. An example showing a second-order equalizer is in *Fig. 2*. It will disappear when you select an order 0 equalizer. Then the word None will reappear.

HELP. The program also has a help feature. If you are unclear about the role of a particular menu item or data field, move the cursor to the item and hit F1. If there is anything I felt needed to be said about the item, a window with a help message will pop up as in *Fig. 3*. On a color system the window will be green with yellow text. If it doesn't tell you what you want, then try the INFO selection. If there is no reference in either place, then it is not worth knowing!

KEEP, RECALL. The system description on display is referred to as system A for identification. As many as four systems can be remembered by the program. The other three are referred to as B, C and D, naturally. You can KEEP the currently displayed system as B, C or D by choosing which in the KEEP menu. If you want to recall the system later, use RECALL. This function not only redisplays the selected system, but it simultaneously stores the currently displayed system in the location freed up by the recall. In other words, if you RECALL system X (= B, C, or D) then the action actually is to exchange A and X.

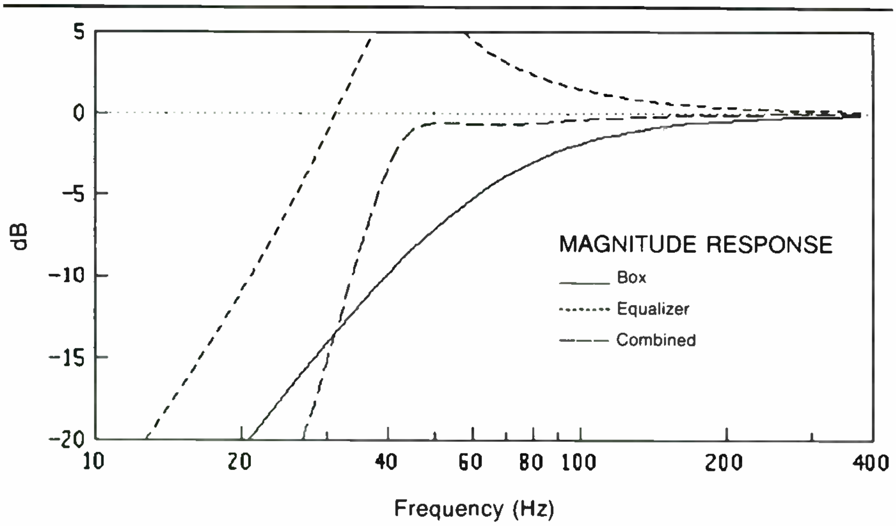


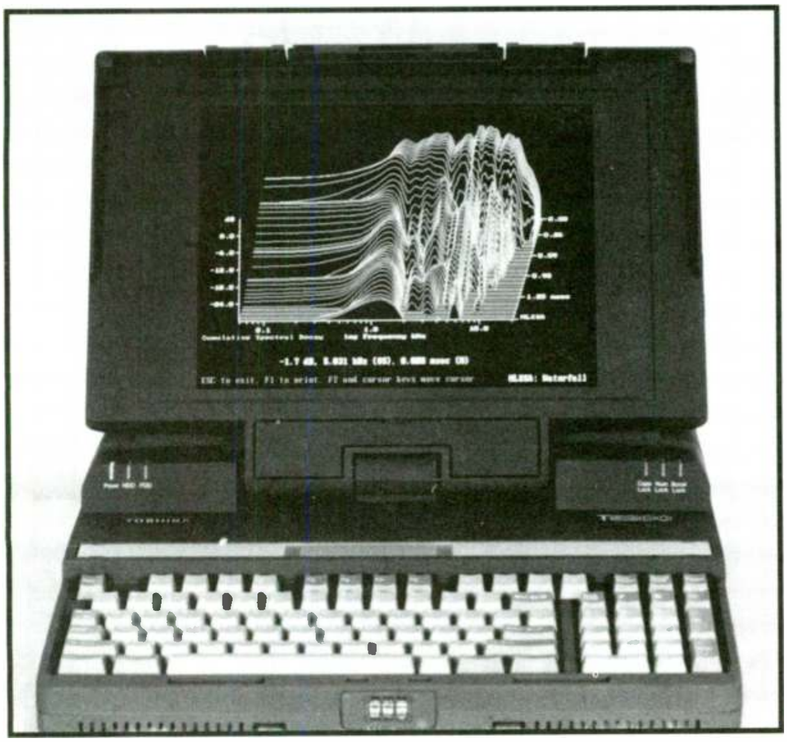
FIGURE 4: Small-signal response curves for the system shown in *Figure 2*.

PLOT. The plotting setup is quite nice, I think. You can do plots for system A alone of small-signal magnitude or phase, input impedance magnitude or phase, large-signal response, cone excursion, and PR excursion or vent air speed if either are applicable. If the system is equalized, then three graphs are shown in the small-signal magnitude plot: the box alone, the equalizer alone and the combined response. An example of this is shown in *Fig. 4*. When large-signal response is plotted, the sensitivity is also plotted for comparison. Further, the maximum excursion is plotted with the cone excursion function. Finally, for any large-signal graph, you are asked to set the input power before the graph is drawn. You can use this capability to determine how much power can be supplied before your excursion limit is exceeded. When this is determined, you can use this power input to graph SPL and find out how loud the system will play without distortion.

Large-signal graphs in BOXMODEL are not the same as they were in BOXRESPONSE. In the latter program when graphing maximum SPL, the input power was controlled to keep cone excursions at or below X_{MAX}. In BOXMODEL this is not done, so you have to look at the cone excursion plot separately to decide whether a particular input level keeps excursions below X_{MAX}. Thus the SPL plots in BOXMODEL represent valid responses.

You can also plot system A together with any combination of the other three systems on the same axes. This makes it easy to compare consequences of various design alternatives, including those of using the same driver in different box types. An example of this is shown in *Fig. 5* where A is an equalized closed-box, B is a closed-box, C is a vented-box and D is a passive-radiator, all with the same box volume. If you have sufficient color capability, each graph will have a different color. Even without color you can distinguish the

Continued on page 30



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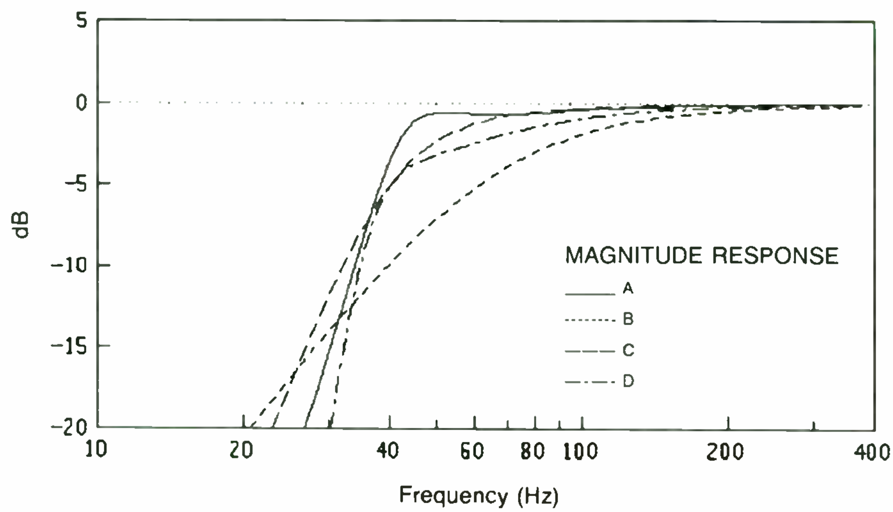


FIGURE 5: Small-signal responses. D is *Figure 1* system, C is *Figure 3* system, B is *Figure 2* system without equalizer and A is with equalizer.

Continued from page 28

separate graphs because each uses a different line style. Finally, a legend above the graph shows the correspondence between system and line style and/or color.

WINDOW CHANGES. The data entry section of the display changes depending on what type of system you are working with. *Figure 1* shows a passive-radiator system and *Fig. 3* a vented-box. Note that the BOX window changes because different information is required for these types. Also, the V/PR window changes from showing the area of the passive-radiator to showing the diameter of the vent. When a closed-box is chosen as in *Fig. 2*, the V/PR window is hidden because it is no longer needed. Also, the BOX window reduces to one row because only one parameter is needed.

MISCELLANEOUS PARAMETERS. The window is just that. Any system parameter that may be of interest is calculated by the program and displayed here. The significance of most of them is self-evident, but a few need comment.

In the list of DRIVER parameters Q_{TS} is the parallel combination of Q_{ES} and Q_{MS}, and Sns is the calculated sensitivity of the driver at 1m with input voltage $\sqrt{R_E}$. This is the usual 1W/1m specification when the load impedance is R_E, and it usually is fairly close to manufacturers' spec sheet values.

The item Q_{BS} in the BOX list is actually the parallel combination of Q_{AS}, Q_{LS} and Q_{PS}. It should be quite close to your measured value of Q_L. There may be some discrepancy because the letter S means that these Q's are referred to driver resonant frequency, while a measured Q_L is referred to the box-vent or box-passive-radiator resonant frequency. More on this below.

The next item in the BOX list is f_B for a passive-radiator system, vent length for a vented-box or f_C for a closed-box. In a PR system f_B is not an adjustable parameter, but depends on the resonant frequency of the passive-radiator f_P, which is adjustable. This is the reason f_B doesn't appear in the data entry section for a passive-radiator.

The vent length for vented-boxes is calculated from the standard formula for one flanged and one unflanged end using the speed of sound as determined from the ambient atmospheric conditions given in the Tmp&Pr window.

The final item in the BOX list is the box cutoff frequency f_{3B}. This cutoff applies only to the box acting alone, whether or not there is an equalizer in the system. The complete system -3dB frequency is listed under SYSTEM and includes the effect of any equalizer. These cutoff frequencies are calculated by a numerical procedure that can go awry. If this happens then usually the phrase 'Bad value' will appear rather than a number. Nevertheless, you should be suspicious of any extremely small number because it probably means an untrapped bad value. Usually this happens only when you have specified a really wild set of parameters. If you change to a more reasonable set, a reasonable number should reappear in this position.

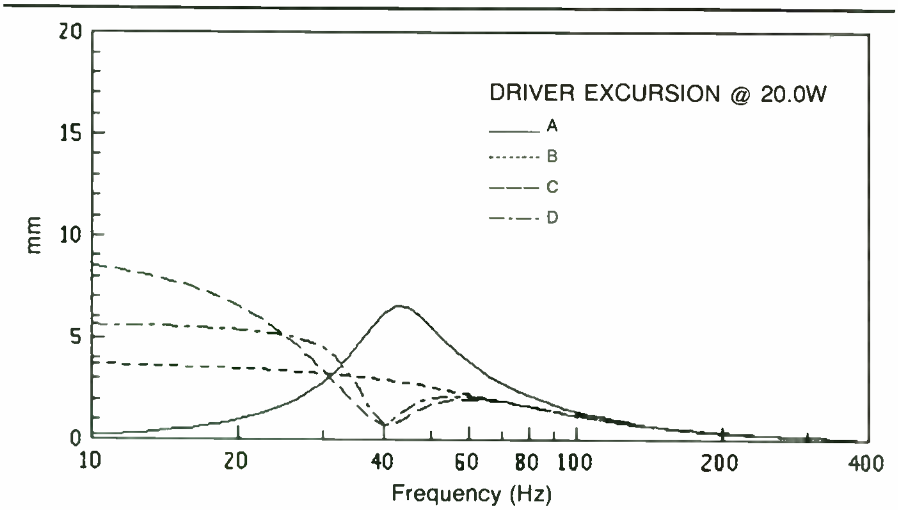


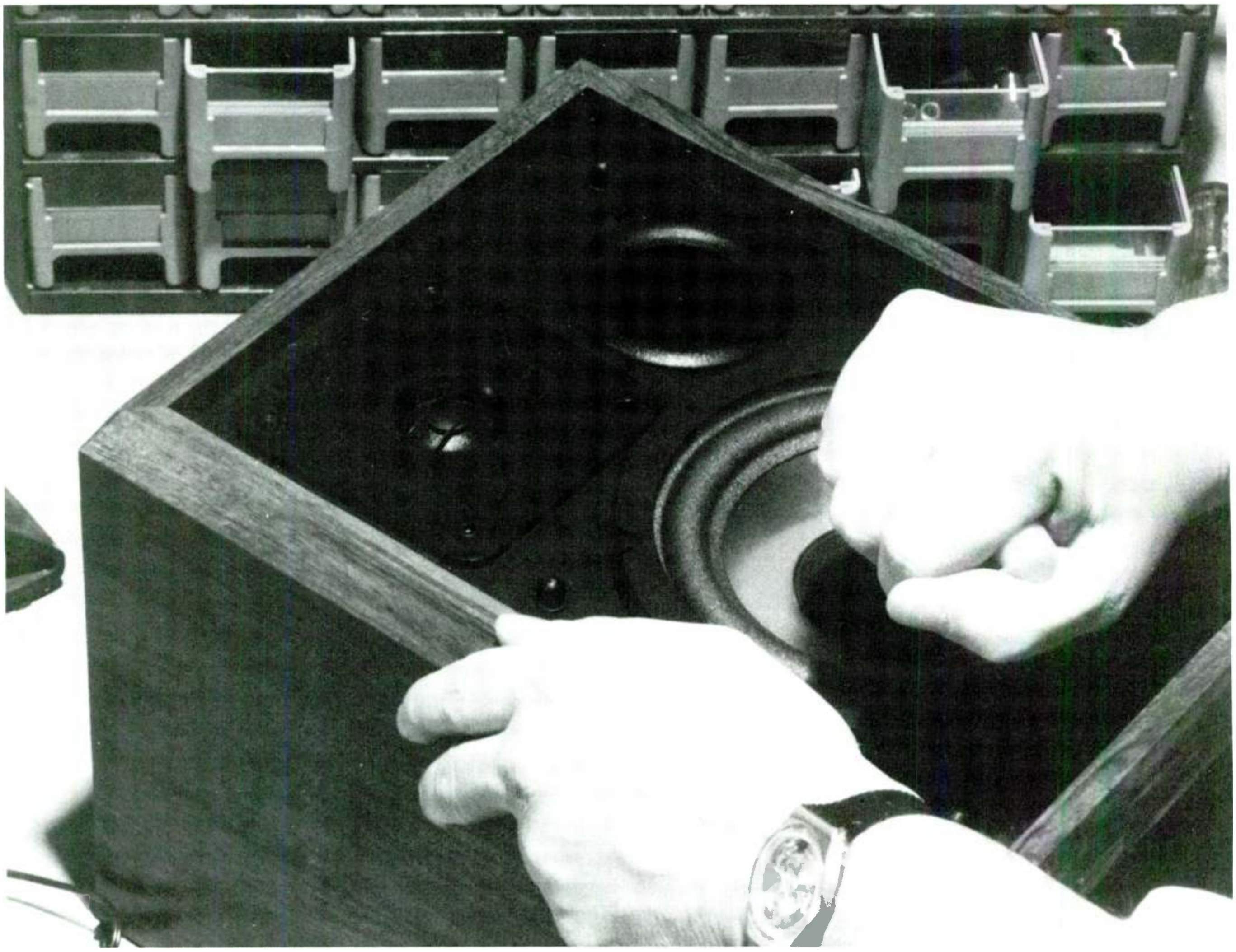
FIGURE 6: Cone excursions at 20W input for the systems in *Figure 5*.

II. NEW IDEAS. Most of the system component parameters should be familiar to you from their Thiele/Small origins. The exceptions are probably the parameters specific to passive-radiator systems and the separate system losses.

PASSIVE-RADIATOR SYSTEMS. For passive-radiator design the adjustable parameters are the box volume V_B, the volume equivalent compliance of the passive-radiator suspension V_P and the mass of the passive-radiator cone as reflected by its resonant frequency f_P. As a practical matter for the home builder, once a passive radiator has been chosen V_P becomes fixed. This means that V_B and f_P are the only adjustable parameters and f_P can only be decreased because you can increase the mass of the passive-radiator but you can't decrease it. In any case, if you are going to tackle a passive-radiator design you should consult the article by Koonce[5] for appropriate techniques for measuring V_P and f_P.

SYSTEM LOSSES. Probably the least understood data requirements are the losses. In general, a loss is the acoustic equivalent of a resistance. A Q number

Continued on page 32



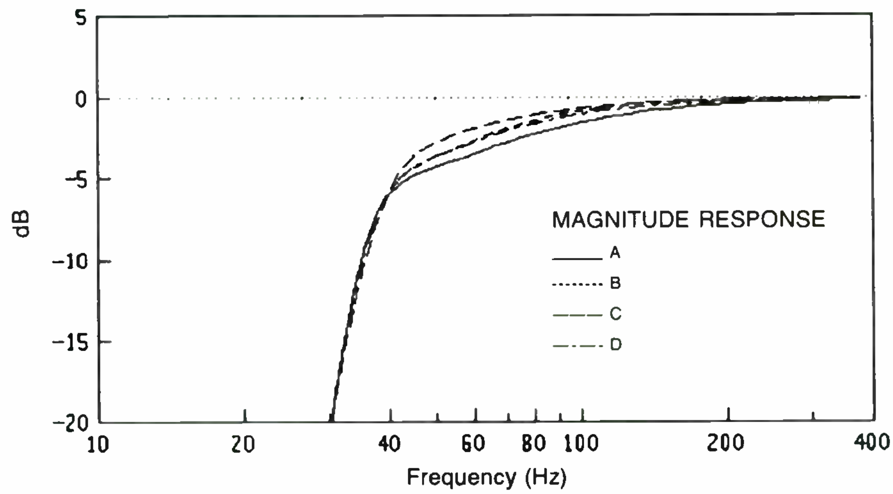


FIGURE 7: *Figure 1* system with various loss distributions. See text for details.

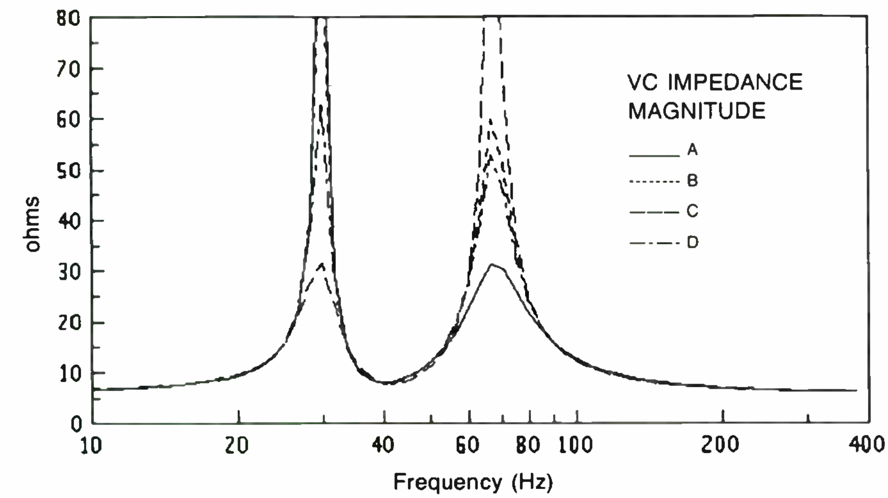


FIGURE 8: Same systems as in *Figure 7*, but showing voice-coil impedance magnitude.

Continued from page 30

is a representation of a loss at a particular frequency. Small identified three potential losses for vented-boxes and passive-radiators: Q_A related to the box lining or stuffing, Q_L related to air leakage from the box, and Q_P related to the vent or passive-radiator. In his work he always referred these Q numbers to the resonant frequency f_B. The problem with this is that f_B is usually a variable in design so that these quantities would have to be recalculated with every system change. To avoid this problem I introduced Q_{AS}, Q_{LS}, Q_{PS}, which are the three Qs related to the driver resonant frequency. This change also allows Q_{AS} and Q_{LS} to apply to closed-boxes where Q_A and Q_L are undefined.

You can convert from Q_A, Q_L, Q_P to Q_{AS}, Q_{LS}, Q_{PS} in passive-radiator and vented-box systems with the following formulas:

$$Q_L = hQ_{LS}$$
$$Q_{AS} = hQ_A$$
$$Q_{PS} = hQ_P$$

where h is the Thiele/Small parameter: $h = f_B/f_S$. The quantities Q_A, Q_L and Q_P are not defined for closed-boxes. For most reasonable systems, h is close enough to 1 so that differences between the two Q sets are negligible. Thus, in the discussion I will use the two sets interchangeably.

As you will recall, when you measure system loss in a vented-box, all you really measure is a single quantity called Q_B defined by

$$1/Q_B = 1/Q_A + 1/Q_L + 1/Q_P \quad \text{(Q-EQ)}$$

It is usually assumed that Q_A and Q_P are very large for vented-boxes so that Q_B and Q_L are approximately equal. Thus, when you say $Q_L = 7$ for a vented-box, this really means $Q_B = 7$, and box absorption and vent/PR losses are negligible.

To say that a loss is negligible means that it could be removed from the model without significantly changing the model responses. This can be accomplished theoretically by setting the particular negligible loss to the value ∞. This can be done in the program by entering the largest possible value: 99999.9. The program recognizes this as a signal to delete that particular loss, and it will replace the number in the loss window with ∞. For example, if you entered Q_{AS} = 99999.9 and Q_P = 99999.9 then the program would show $Q_{AS} = \infty$ and $Q_{PS} = \infty$. With these values you are working with Small's original model. Most alignment tables are based on his model, so if you are starting with a table alignment, this loss setting should give you a response based on Small's model. You could then compare it with responses using other values of Q_{AS} and Q_{PS}. This would give you some idea of how the actual response might vary from the intended one. When you do this remember that the value you use for Q_{LS} in Small's alignments is really Q_{BS}, so when you change the other Qs make sure that Q_{BS} stays the same by requiring that the equation (Q-EQ) is always satisfied.

The formula (Q-EQ) for Q_B also applies to passive-radiator systems. In this case, Q_A is usually assumed to be negligible. So, a measured Q_B consists of contributions from both Q_P and Q_L. Small [2, p. 600] addresses the question of how to measure Q_B for a passive-radiator, as well as how to allot the measured value between Q_L and Q_P. His recommendation is to allot about 30-40% of the value of Q_B to Q_L and the remainder to Q_P. It is possible that you may know a value for the mechanical Q of the passive radiator, Q_{MP}. If so, then you can get a reasonable value for Q_{PS} with

$$Q_{PS} = (f_S/f_P)Q_{MP}$$

The advantage of having Q_{AS} and Q_{LS} available for closed-boxes is not as clear as it is for vented-boxes and passive-radiators. The main reason is that closed-boxes are usually *filled*, while the others are *lined*. This probably makes Q_{LS} negligible and only Q_{AS} really matters. But there is a further complication because of the filling. As the amount of filling material increases, the air compressions in the box move from adiabatic to isothermal. This causes the net acoustic compliance of the box to increase and this tends to counteract the resistive loss. For the details of this mechanism[6]

When using the model for a closed-box it is probably best to set $Q_{LS} = \infty$ and work only with Q_{AS}. As you decrease Q_{AS} you may also want to increase V_B to

Continued on page 34

```
                              DATA ENTRY
     Driver          Type      Losses           Box        Hp eq  Order = 2
                                                                  Eqdata
 ID: JBL 2235H     Pr        QAS =  ∞        VB =  102.09 l
  fS =   23.0 Hz   »Vented   QLS =     7.0   fB =   24.64 Hz   Cnr =   29.98 Hz
 VAS =  340.0 l    Closed    QPS =  ∞                          Dmp =  0.6007
 QES =  0.350
 QMS =  1.182
  RE =   6.30 Ω      V/pr     Keep  Recall  Plot  pr Scr  Info    tMp&pr
  SD =  880.0 cm²
  PE =  300.0 W    VENT DIAM:                                  T =  21.0 'C
 xmx =   8.50 mm    7.62 cm                                    P = 750 mm Hg

 Quit
```

```
                          MISCELLANEOUS PARAMETERS
               DRIVER                          BOX                 SYSTEM
 CMS =  0.31 mm/N  Bl  =  19.92 Tm    VL  =  16.47 cm     f3S =   29.94 Hz
 MMS =  152.5 g    Sns =   92.7 dB    QBS =    7.0        Box & Equalizer
 RMS =  18.64 kg/s QTS =  0.2700      f3B =  47.14 Hz
```

FIGURE 9: Initial parameters for JBL 2235H based system.

```
                              DATA ENTRY
     Driver          Type      Losses           Box        Hp eq  Order = 2
                                                                  Eqdata
 ID: JBL 2235H     Pr        QAS =    28.0   VB =  120.00 l
  fS =   23.0 Hz   »Vented   QLS =    14.0   fB =   25.00 Hz   Cnr =   30.00 Hz
 VAS =  340.0 l    Closed    QPS =    28.0                     Dmp =  0.6000
 QES =  0.350
 QMS =  1.182
  RE =   6.30 Ω      V/pr     Keep  Recall  Plot  pr Scr  Info    tMp&pr
  SD =  880.0 cm²
  PE =  300.0 W    VENT DIAM:                                  T =  21.0 'C
 xmx =   8.50 mm   10.78 cm                                    P = 750 mm Hg

 Quit
```

```
                          MISCELLANEOUS PARAMETERS
               DRIVER                          BOX                 SYSTEM
 CMS =  0.31 mm/N  Bl  =  19.92 Tm    VL  =  28.57 cm     f3S =   28.76 Hz
 MMS =  152.5 g    Sns =   92.7 dB    QBS =    7.0        Box & Equalizer
 RMS =  18.64 kg/s QTS =  0.2700      f3B =  47.50 Hz
```

FIGURE 10: Minor parameter adjustment of JBL based system.

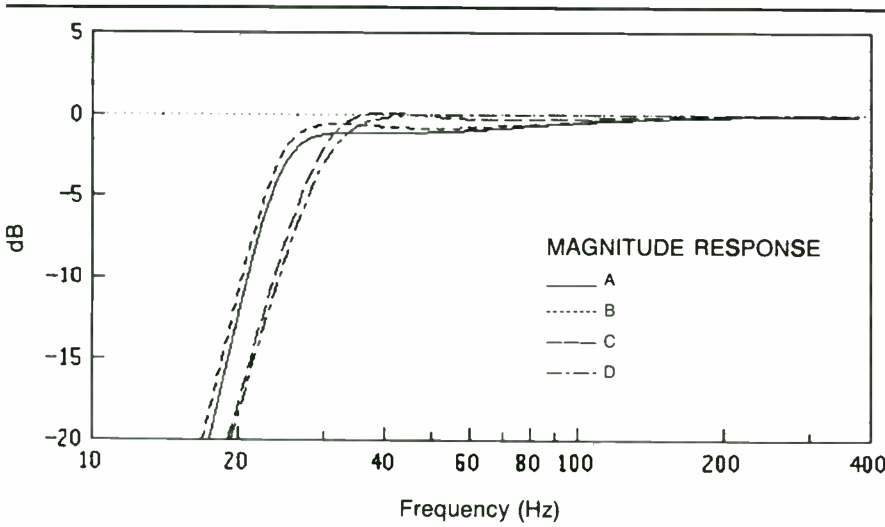


FIGURE 11: Small-signal responses of various JBL based systems described in text.

Continued from page 32

mimic the behavior just described. When you are satisfied that what you have is reasonable, you may want to assign a finite value to Q_{LS} to see how an unintended system leak would alter the response.

One final comment on closed-boxes. The use of a Dynaudio variovent is advocated by some as a good loading method. I believe you can model such a system as a closed-box with a finite value of Q_{LS} chosen to represent the variovent. I have not experimented with this to verify it, but I would be interested in hearing from anyone who does.

The real advantage of having separate Qs in this model is that you can allocate the total loss to three separate sources in various ways and see how much this changes system response. The default values for these three quantities in BOXMODEL are Q_{AS} = 28, Q_{LS} = 14, Q_{PS} = 28. This gives a total loss Q of Q_B = 7, the standard assumption. However, if you have more than the usual stuffing in your box and you believe the box is quite air tight, then you may want to assign Q_{AS} = 14, Q_{LS} = 28 and Q_{PS} = 28. (Note that the higher the Q number, the less loss it represents.) This still gives Q_B = 7, but with more of the loss in the box lining rather than the box leakage. In this way you can investigate various scenarios and see how much your system response might vary from your intended response.

III. EXAMPLES. Now that you know something about the operation of BOXMODEL, I would like to present some examples illustrating ways the program might be used.

DIFFERENT BOXES. Lets use the parameters given in *Fig. 1* and make (B) a closed-box and (C) a vented-box. Also, lets take (A) to be the same closed-box with an equalizer with Cnr = 42Hz and Dmp = 0.44. The small-signal responses are shown in *Fig. 5*. As you might expect, the simple closed-box has the poorest low frequency response. But the equalized closed-box has the best! Even so, it may not be the best choice. To see why, lets look at the cone excursions at 20 watts input shown in *Fig. 6*. The excursions of the equalized closed-box (A) are much greater than in the other two systems and exceed the linear limit xmax by a fair margin over a wide band of frequencies around 40Hz. Thus, it is more likely to produce audible distortion in this band. For a commercial system, I would tend to steer clear of it because it would be easier to damage the woofer.

When you plan to use an equalizer to shape the response of your woofer, I suggest you keep close watch on the excursion requirements it imposes. If you use a high Q filter, it is quite possible that you may wind up driving the woofer

Continued on page 36

```
                              DATA ENTRY
     Driver            Type        Losses            Box          Hp eq  Order = 3
                                                                        Eqdata
 ID: JBL 2235H       Pr          QAS =    28.0   VB =  120.00 l
  fS =    23.0 Hz   »Vented     QLS =    14.0   fB =   25.00 Hz  Cr1 =    12.00 Hz
 VAS =   340.0 l     Closed     QPS =    28.0                     Cr2 =    24.00 Hz
 QES =   0.350                                                    Dmp =   0.4500
 QMS =   1.182
  RE =    6.30 Ω       V/pr       Keep   Recall   Plot   pr Scr   Info     tMp&pr
  SD =   880.0 cm²
  PE =   300.0 W     VENT DIAM:                                     T =  21.0 'C
 xmx =    8.50 mm     12.70 cm                                      P = 750 mm Hg

 Quit
```

```
                          MISCELLANEOUS PARAMETERS
              DRIVER                            BOX                  SYSTEM
 CMS =   0.31 mm/N  Bl  =  19.92 Tm     VL  =   41.31 cm     f3S =    24.95 Hz
 MMS =  152.5 g     Sns =   92.7 dB     QBS =     7.0          Box & Equalizer
 RMS =  18.64 kg/s  QTS =  0.2700       f3B =   47.50 Hz
```

FIGURE 12: Final parameter settings for JBL system.

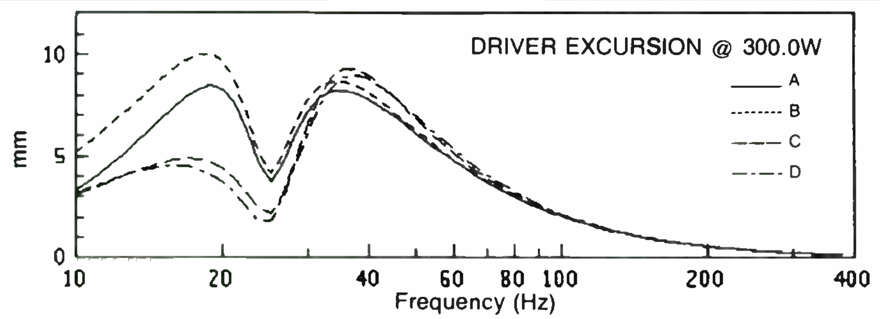


FIGURE 13: Cone excursions for JBL systems.

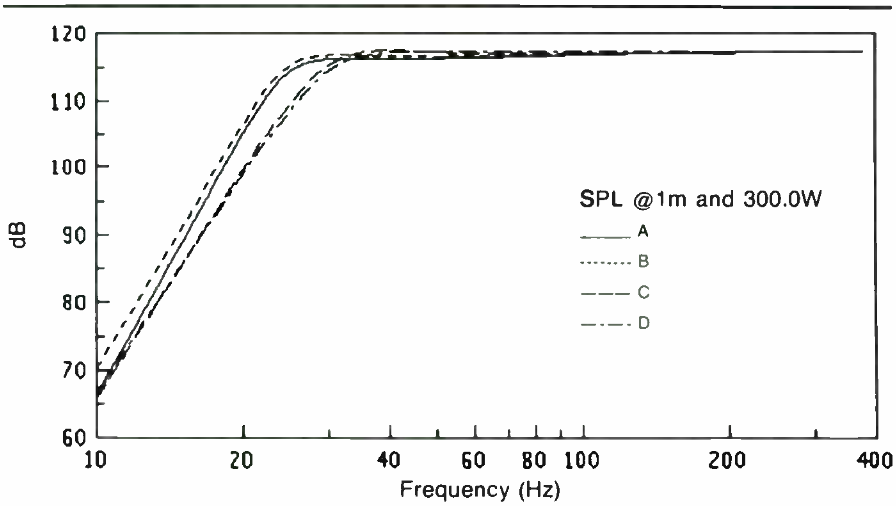


FIGURE 14: Maximum SPL graphs for JBL systems.

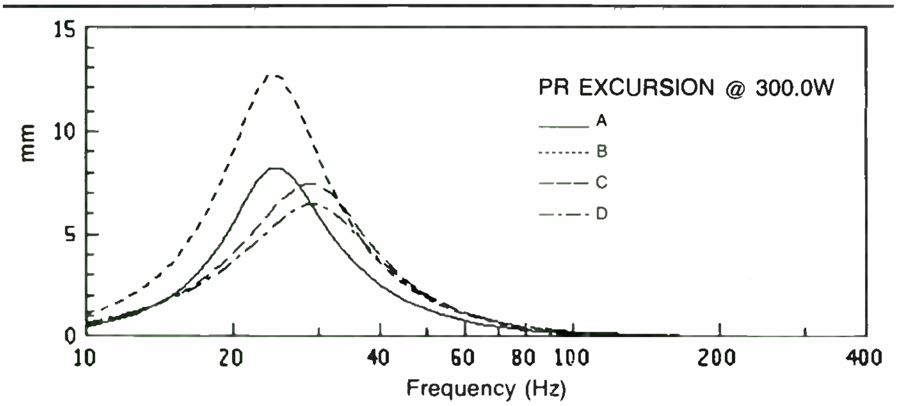


FIGURE 15: Vent air speeds graphs for JBL systems.

Continued from page 34

hard enough to damage it without even realizing it.

EFFECT OF LOSSES. Lets take the passive radiator as defined in *Fig. 1* but with Q_{AS} = 20, Q_{LS} = 10 and Q_{PS} = 20 as the basic system and call it (D). Note that Q_{BS} = 5. Now compare it with the three possible systems in which all the loss is concentrated in one Q, keeping Q_{BS} = 5. In particular, let Q_{AS} = 5, Q_{LS} = ∞, Q_{PS} = ∞ be (A); Q_{AS} = ∞, Q_{LS} = 5, Q_{PS} = ∞ be (B); and Q_{AS} = ∞, Q_{LS} = ∞, Q_{PS} = 5 be (C). The response graphs are shown in *Fig. 7*. Notice first that these variations in loss assignment have only a small effect on overall response. Also, the response of the basic system all but coincides with that of the system where all the loss is concentrated in Q_{LS}. Small[7] remarked that this is generally true and and is one of the reasons he chose to ignore Q_{AS} and Q_{PS}.

This information can also be interpreted in another way for purposes of verifying a system. Suppose the parameters above are those of a system you have measured with Q_L = 5. Then *Fig. 7* indicates that the model predicted response of your system is somewhere between the two extreme curves in that figure. So, you can set some sort of tolerance on the response due to variations in system loss distribution.

The graphs of the voice-coil impedances for these systems in *Fig. 8* are also of interest. Notice that in system (A), where the loss is concentrated in Q_{AS}, the high-frequency impedance peak is quite short, as is the low-frequency peak

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7. R. H. Small, "Vented-Box Loudspeaker Systems Part I: Small-Signal Analysis," *J.* Audio Eng. Soc., vol. 21, p. 363, 1973.

in system (C), where the loss is concentrated in Q_{PS}. This looks like it could be a signal that absorption loss or passive-radiator loss is dominant. It could also possibly indicate a physical problem in the system. For example, there may be an excess of filling material or a mechanical impediment to the free motion of a passive-radiator.

WOOFER DESIGN. *Figure 9* shows the parameters for a JBL 2235H driver for possible use in a vented subwoofer. By subwoofer I mean a system with as much high-output low-frequency-extension as possible. For this reason, I started with a sixth-order quasi-Butterworth Type 1 alignment with Q_L = 7. The relevant parameters are listed in the figure. This system is kept as D. Next, I rounded off the box and equalizer parameters and distributed the losses differently. Also, I increased the box volume to make the vent easier to design. The result of these changes is listed in *Fig. 10* and kept as system C. The response curves of these two systems can be seen in *Fig. 11*. As you will note, the small changes made do not substantially alter the response.

Next, I started lowering the equalizer corner and damping until f_2 = 24Hz and Dmp = 0.45. This configuration is kept as system B. I now have a system f_3 of about 24Hz. The final change is to go to a third-order equalizer by adding a first-order corner at 12Hz. This configuration is system A and its complete parameter set is shown in *Fig. 12*. The reason for this last change can be found by looking at the cone excursion curves at 300W input in *Fig. 13*. The excursion of system B exceeds X_{MAX} at very low frequencies. The additional filter section pulls the excursions back below X_{MAX} at all frequencies as graph A in *Fig. 13* shows. The small-signal response of systems A and B are shown in *Fig. 11*. The graphs of maximum SPL at 300W in *Fig. 14* show that system A should be capable of about 115dB at 25Hz without exceeding its X_{MAX} at any frequency! System B excursions would have exceeded X_{MAX} in order to play equally loudly.

The only remaining problem can be seen in *Fig. 15* where system B using twin 3″ vent tubes has a vent air speed

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FOUR EIGHT BY TWOs

BY THOMAS NOUSAINE

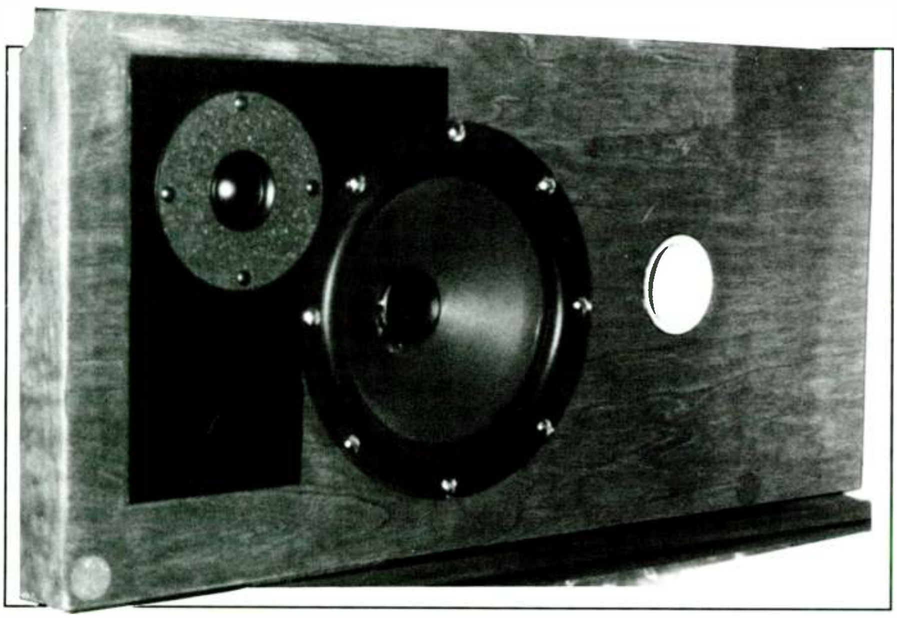

PHOTO 1: Finished system, installed without grille.

When my friend LeRoy Murphy asked me to help him design a speaker system for his home, I'd heard it all before. It had to go "here," it could only be "so big," it had to sound great but he "couldn't spend more than $300," and can you top this, it had to "match his birch furniture." Sound familiar? Murphy wanted an 8″ two-way system with good sound, reasonable cost, and manageable size. State of the art? No way. The 8 × 2 format does, however, offer an excellent compromise on size, performance, and cost. The blue plate special on the luncheon menu!

ABOUT THE AUTHOR

Tom Nousaine is director of Capital Recovery for Ameritech in Chicago. He has worked in telecommunications for nearly 20 years. He is also a contributing editor to Car Stereo Review, *writes product reviews for* The Sensible Sound, *and is secretary of the Chicago AES. He has been active in loudspeaker design and construction since joining SMWTMS and subscribing to TAA in the mid 1970s.*

Commercial two-way designs with 8″ woofers are popular, and with good reason. They offer true 50Hz low-end potential in a 1–2 ft³ box, and excellent price to performance ratios. An 8″ woofer is the smallest size which can deliver good, believable bottom end. Sorry, I don't believe 6″ woofer systems can deliver adequate loudness without high distortion at frequencies below 80Hz.

An 8 × 2's economics are great because few parts and minimal materials are needed. Only two drivers, woofer and tweeter, and one crossover per side are required. The reasonably-sized cabinets mean a pair usually can be cut from a single piece of 8 × 4 ft. stock, and a maximum of 30 ft² of veneer or plastic laminate will cover an enclosure's six sides. A 1–2 ft³ box easily can be slipped inside the UPS size limit. It's no wonder so many commercial systems use this format.

Of course we all know there are shortcomings. So what's the price of an 8 × 2? An 8″ driver cannot provide true subwoofer performance. All you can expect is 40–50Hz low-end at best. On the other hand, 50Hz is usually as much as most people need or want. Upgrading to full bandwidth (20Hz–20kHz) is easy, however, with a separate subwoofer.

Other compromises are required with this format as well. Most tweeters cannot handle much power below 2.5kHz. When used above 1kHz or so, most woofers exhibit narrowing dispersion and a frequency response peak. Therefore, a typical 8 × 2 will have a 3kHz crossover, a pinched dispersion pattern above 1kHz, and a nasty frequency response peak somewhere around 2kHz. Commercial designs often ignore this peak. It requires a passive equalization network to fix it, adding to the parts count and cost.

MURPHY'S SYSTEM. I tried to capitalize on the format advantages and *minimize* the disadvantages while working inside the alloted speakers' 11½″ × 12″ × 25″ bookshelf space. I've had plenty of firsthand experience building 8″ two-way speakers, and felt the thrill of great sounding, simple to build, and economical home-brew systems so I knew we had a good chance for success. I will outline the Murphy system from start to finish, however, I've listed important parameters for three other successful 8″ two-way systems in *Table 1*. They all work well, providing a good spread of box styles, drivers, and performance options available to the home builder.

A great 8 × 2 begins with a large diameter tweeter, which can be crossed over at 2kHz to avoid as much of the woofer response peak as possible. The SEAS H297 1¼″ soft dome tweeter fits the bill. The tweeter was crossed over to an exceptional Carbonneau 8″ (29-905) al-

TABLE 1

8″ TWO-WAYS: SEVERAL GOOD ALTERNATIVES

	RS-1	RS-2	LG-1	Murphy 1.1
Woofer	KEF B200 SP1054	KEF B200 SP1039	Peerless TD205R	Carbonneau 29-905
Tweeter	Polydax HD10025	Polydax HD10025	Morel MDT28	SEAS H297
Crossover	KEF 104aB	Custom	Custom	Bigfoot
High-pass	3-pole 3kHz	3-pole 3.1kHz	3-pole 2.85kHz	3-pole 2.1kHz
Low-pass	2-pole	3-pole	3-pole	3-pole
Notch Filter	2kHz	2kHz	2kHz	none
Cabinet				
Style	Ported QB_3	Sealed w/EQ	Ported w/ripple	Ported B4
V_B	1 ft³	1 ft³	1.4 ft³	1.05 ft³
F_B	41Hz	48Hz	42Hz	40Hz
F_3(est)	48Hz	40Hz	47Hz	40Hz
(act)	50Hz	40Hz	50Hz	45Hz
		Bass EQ +6dB 40Hz		
Stuffing	no	1 lb. polyester fiberfil	no	no

ready on hand, and mostly free of the above-1kHz response peak I've found in all other 8″ drivers.

I also used a Madisound Bigfoot 3-pole 2kHz passive filter. A word about passive filters: I had been in the habit of brewing my own crossovers for some time. My normal routine included winding my own inductors, making precise capacitor values by paralleling caps, wiring the crossover, hooking the drivers to it, measuring the voltage drive at the speaker terminals and then tweaking the values to get the right slopes.

On my last few projects, however, I purchased Madisound Bigfoot networks built to spec, specifying a slope and turnover frequency, and telling them which drivers I'd be using. Within a week I receive a completed network which works exactly as specified—and each for $20 or less. That was a deal I couldn't afford to pass up. Even if the network didn't function exactly as I wanted, they would be easy to tweak and I would be spared the drudgery of winding coils, measuring a bunch of capacitors, and building up a circuit board.

Next we had to choose a bass cabinet alignment which would optimize the system within the enclosure size limititation the bookshelf imposed. This meant the box could have a maximum of 1.05 ft³ internal volume for a ported enclosure, and a 1.4 ft³ equivalent for a stuffed sealed enclosure. Normally I resist ported enclosures tuned above 35Hz because they tend to drone, however with the 8 × 2 format we were going to need all the help we could get below 50Hz. A ported enclosure gives you added sensitivity at low frequencies. The drawbacks are a bit of hangover with certain alignments, and no driver loading at very low frequencies.

SPECS AND MORE SPECS. We measured the Carbonneau woofer's Thiele/Small characteristics. As expected, they were close but not exactly on spec. Typically, I find woofers to be 10–20% high on free air resonance, even with cruel overnight break-ins, and Q values are usually somewhat higher than specified. There will also be differences between the two drivers which may require different size enclosures. The relationships between Q and resonance for sealed boxes usually calls for the same box size. Ported enclosures may require adjustments. Don't be surprised if your speakers fail to live up to manufacturer specified characteristics.

The Carbonneau woofer's characteristics indicated the B4 alignment was possible with cabinet tuning of 40Hz. I believed the ported enclosure offered the best set of compromises. The sealed enclosure's size we envisioned would have resulted in a high 50–60Hz system resonance, and a relatively high system Q. Neither was acceptable. *Table 2* gives the vented/sealed box comparison.

Cabinet layout was also problematic. The space required a horizontal cabinet, but the tweeter couldn't be placed directly above the woofer. We decided to mount the woofer midway in the cabinet, the duct as close as possible to the wall. We mounted the tweeter as high as possible in the cabinet, and mirror imaged toward the inside. This design also afforded vertical speaker placement.

After selecting the basic components, we decided on an MDF enclosure, stained birch wood veneer, dual banana connectors on ¾″ centers, and a swimsuit fabric grille cover held with Velcro hook and loop fasteners. The grille cover frame was cut from ¼″ plywood. The fabric, selected to complement the room decor, was wrapped and stapled to the rear. Select fabric which allows light to pass. If you can see through it, you probably can hear through it.

The following outlines the procedure for designing and building a high-quality 8 × 2 using components selected for the Murphy system. Using this information, plus design tools published in *SB*, almost anyone can make a high-performance 8 × 2 using drivers specified here or with other drivers and crossover slopes. Nothing is sacred about these designs. They all have worked successfully, but none is perfect.

Step By Step:

1. Decide whether you *need* an 8 × 2 by answering the following questions:

- Is space is a problem?
- Is cost a limiting factor?
- I never listen to organs and cannons?
- Do I plan to upgrade (subwoofer)?

If you answered yes to all these questions, read on. If you answered no to any of these questions consider another design.

TABLE 2

DESIGN OPTIONS: TYPICAL 8″ TWO-WAY SYSTEM (fixed cabinet size)

Carbonneau	Woofer 1	Woofer 2
Q_{TS}	0.4	0.37
F_S	40.5	39.5
V_{AS}	1.32	1.37 ft³
Sealed and Stuffed:		
V_B (net)	1.4 ft³	1.4 ft³
F_B	40Hz	40Hz
F_3	56Hz	56Hz
Q_T	0.57	0.52
Ported: Approx. B4 alignment		
V_B (net)	1.05 ft³	1.05 ft³
F_B	40Hz	40Hz
F_3	40Hz	40Hz

F_3 (measured = approx. 45Hz close mic)

TABLE 3

PANEL CUTS REQUIRED

4	10½″ × 24″ top and bottom panels
4	10″ × 24″ front and back panels
4	9″ × 10″ end inserts

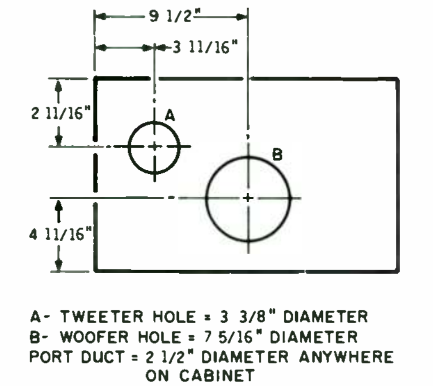

FIGURE 1: Murphy system's front panel.

2. Find a good, smooth woofer such as the Carbonneau 29-905. A low F_S (45Hz or lower) is good, Q values from 0.33 to 0.45 are optimal, and an equivalent air compliance of less than 1.5 ft^3 is also important if the cabinet must fit in a small place.

3. Search for a tweeter with a low resonance, a relatively large diameter, and good power handling. I like Polydax and Dynaudio tweeters, but most of them cannot be used successfully below 3kHz. I recommend the SEAS H297 1¼" dome.

4. Buy your drivers before proceeding. Measure their Thiele-Small parameters, and use a real time analyzer, if you can find one, to check frequency response in free air.

- Select a crossover point and slope that best matches the woofer's high-frequency performance as close to 2kHz as possible, but within the tweeter's power handling capability. For the Carbonneau and SEAS we selected a 3-pole (18dB/octave) 2kHz filter. *Table 4* supplies values for all system crossovers except the KEF 104 aB. These are good overall choices, but if you have good measuring equipment you may find slopes which are a better acoustic match for your drivers.
- Select a cabinet topology. Bob Bullock's easy-to-use design tables are an ideal choice.
- Design the cabinet. Remember, your ideal box figure is net for *internal volume*, therefore you must select dimensions accordingly. Add 10% for the woofer structure's volume, internal bracing, and crossover inside the box.

5. Build the enclosure. *Table 3* gives panel dimensions for the Murphy system. A lumberyard will cut particle board or ¾" plywood panels for you. I have had good luck with almost any particle board for these relatively small enclosures. Assemble the cabinets minus the front panel *(Fig. 1)*. Use dry wall screws, driven in with an electric screwdriver, to hold the panels while the yellow glue dries.

Use stringer, hardwood or pine works well, as a frame around the front opening, spacing it so the front panel will be flush to the sides when completed. Remember to allow clearance for your panel gasket. If you are "resonance wary," use stringer all around the interior joints. Be sure to rub a bead of glue into the joints from the inside to ensure an air-tight seal.

Glue one piece of 1" closet pole, laterally spanning the cabinet's interior, behind the woofer area. Fasten the pole on each side from the outside with a drywall screw. This will add to the structural integrity of the cabinet, and give you a convenient handle for moving the cabinet during finishing.

6. Cut the speaker and duct mounting holes, and attach the drivers to the front panel. Cut a 2" hole in any cabinet panel in which you wish banana connectors mounted. Mount the bananas on a piece of thin hardboard or plywood 3" × 3" square, and this inside the cabinet with glue and drywall screws. Temporarily mount the duct to the front panel with a Mortite seal, making the duct 1½" longer than your calculations indicate.

7. Tune the system using the constant current impedance measurement method. The impedance minimum between the twin bass reflex peaks is the system's resonant frequency. Because the duct was intentionally cut oversize, the box resonance will probably be too low. Trim it by removing about a ½" of duct. Remeasure, and keep trimming until you reach the right frequency.

PHOTO 2: Owner Murphy with installed system.

8. Assemble the system for test. Attach the banana jacks and drivers to the crossover with 16-gauge zip cord. Mount the front panel to the cabinet with 1¼" dry wall screws spaced about 6" apart, using foam weather strip or Mortite as a gasket.

9. Audition the system in its intended environ. If you have access to an RTA, measure system performance in free air at one meter and at the listening position with the speakers in the normal position. Because the Murphy system was intended for corner wall mounting, and for listening a minimum of 30° off-axis, the tweeter level was set about 6dB higher than the woofer's. Adjust the tweeter level resistor to match your taste and system positioning.

HEAR, HEAR. Listen carefully to the upper midrange/lower treble. If the system sounds shrill, hollow, or blatty try reversing the tweeter's polarity. If the system sounds poor with either polarity, reconcile yourself to a 2kHz notch filter *(Fig. 2)*. If needed, build the notcher in *Table 4*. Install the filter in series with the speaker outside the cabinet, and ad-

Continued on page 42

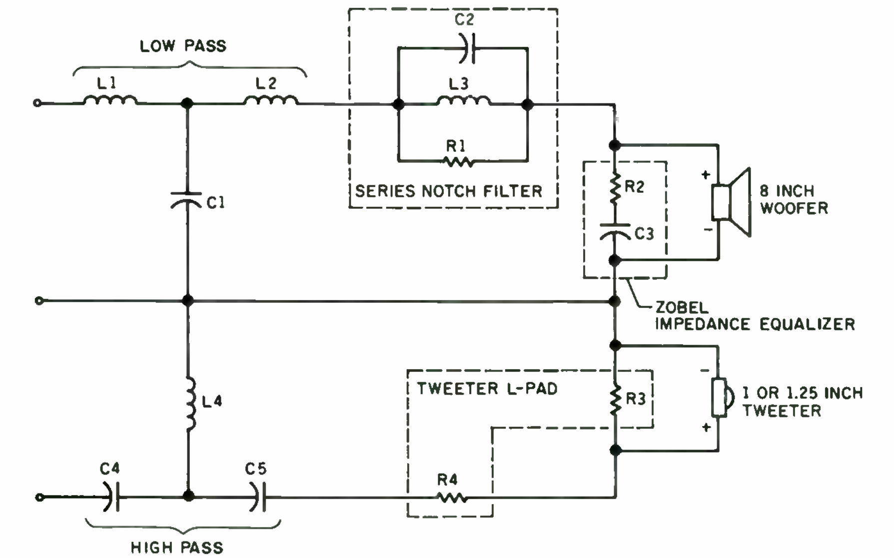

FIGURE 2: Crossover network including a notch filter, Zobel, and tweeter L-pad.

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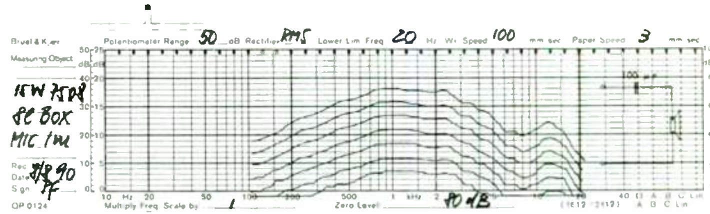
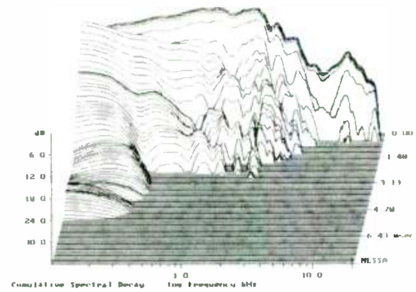
Vc	75	mm	Re	3.0	4.9	Ω
Fs	55	Hz	Bl	5.37	6.50	Tm
Sd	87	cm²	Qts	0.33	0.34	
X_{max} P - P	5.5	mm	Vas	7.1	7.8	l



Measured with gating: 10 m/S window

The curves show that input power peaks of even 1,000 watts are reproduced with full dynamics, and no compression is observed



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Fast Reply #KE118

PHOTO 3: Rear view of grille with author.

Continued from page 40

just the Q resistor for a flat response. A larger value sharpens the notch, and a lower value mellows it. Typical values range between 3–10Ω. Be sure to try the reversed polarity if a pleasing balance is elusive.

10. When you are satisfied the system is working correctly, remove the front panel from the enclosure and the drivers from the front panel. If your filter and crossover was mounted outside, place it inside the cabinet now, gluing the components with silicon sealer. Be sure to fix the wires so they won't later rattle. Now you can complete the front enclosure and front panel.

FINISHING TOUCHES. The cabinet should be finished on at least five sides. Purists will want to finish all six, but we finished all except the back. Craft-backed real wood veneer is available in many varieties, and costs less than Formica laminate. Most veneer can be applied with contact cement. The veneer we used is available in 24″ sheets, up to eight feet long.

We "folded" a 24″ sheet over the front and top sides, making the speakers appear to be cut from a single sheet of wood. Some Craft-glue-backed veneers can be applied with an iron. We'll describe the contact cement method.

11. Sand all box edges square, filling any small blemishes with spackling compound and then sanding smooth.

12. Apply veneer to the box, cutting it with a razor knife about 1/8–1/16″ oversize. Make sure your cuts follow the grain around the box. Spread cement on the veneer back and on the box surface. Carefully join the two surfaces. Bow the veneer slightly so first contact is made in the middle of the cabinet surface. Then roll out both ends so they affix themselves smoothly.

Once applied, use a paint roller to flatten the veneer from the center outward, making sure the edges are firmly glued. If you find bubbles in the middle, slit them with a razor, add some contact cement in through the hole and press the veneer firmly.

Trim both ends of the first piece flush with a router or a razor knife. Trim all other pieces. The joining piece will then be trimmed to a 45° angle. A router with pilot bearing works best. If you trim with a router you may have to use the 600# grit sandpaper to polish the small shiny "track" your router bearing will make on the veneer.

13. Apply finish material to the front panel. I recommend at least part of it be covered with Cushion-All velour contact paper for a soft flocked effect.

14. Finish the cabinet with multiple coats of tung oil finish. Wipe on all coats over a freshly sanded and tacked surface. The surface quality determines the quality of the final coat. Use a soft, lint-free rag to wipe on a *thin* first coat. Let dry, then carefully rub the surface lightly with 600# grit sandpaper using cooking oil as a lubricant. Clean the surface with mineral spirits and wipe dry. Add another coat, and repeat until the finish is satisfactory. We applied nine coats, but I have done up to 15. Even with low-gloss tung oil, the surface will be somewhat glossy after six coats.

Be sure to sand every coat. All drying finish coats will collect dust. If you don't remove the dust the finished surface will have a slightly "dirty" feel to it. We get rid of the dust by gently sanding the surface so the base coat is completely smooth and clean.

If you finish all six sides, you may have to put on a coat, let dry, spin the cabinet, coat the remaining sides, dry, sand and start again. Although this seems like a complicated process, time spent on applying the finish and sanding is really quite brief. The sanding is more like polishing in that little pressure is required and takes little time. Wiping on the finish goes quickly because it results in a very thin coat. The drips and sags which accompany brush applied finishes are absent with the wipe-on method.

On the Murphy system we put drywall screws into the front panel stringer

PARTS LIST

MURPHY'S SYSTEM

	Estimated Cost
(2) 8″ woofers	$25-50 each
(2) 1¼″ tweeters	$13-20 each
(1) 4′ × 8′ sheet MDF	$45
25 ft² veneer	$2.60 per ft.
drywall screws/staples	your junk box
yellow glue	
walnut stain	
16 oz. Tung Oil finish	$10
(2) banana jacks	$2.60 each
internal wire	junk box
(2) Bigfoot crossovers	$20 each
4′ Cushionall contact paper	$1.99 per foot
12 oz. cooking oil	kitchen cabinet
Mortite rope caulk	on hand
2′ 2″ PVC	$1.50 per ft.
(2) 13″ × 25″ ¼″ plywood	on hand
assorted 2W dropping resistors	60¢ each
4′ swim suit cloth	$1.99 per yard

Estimated total cost: $250–$320

Tweaking Your 8 × 2

Three tuning techniques are often needed in any speaker project. The passive notch filter is a commonly-needed, but often neglected one. The Zobel impedance matching network is very common and used to make sure the woofer has an impedance value at the crossover point, which is of a given value and electrically similar to a resistor.

Finally the L-pad is used to match the tweeter sensitivity to that of the woofer. The final values employed in our four 8″ × 2″ two-ways will be specified. Values for the RS-1 are not included because the KEF 104aB filter had these circuits built in and I didn't reverse engineer them. Of course, the Murphy system didn't require the notch filter nor did Madisound employ a Zobel.

TABLE 4

COMPARISON OF SYSTEMS

	RS-2	LG-1	Murphy 1.1
2kHz Notch			
R1 (Ω)	10	3	N/A
C2 (μF)	10	10	N/A
L3 (mH)	0.67	0.67	
Zobel			
C3 (μF)	10	20	N/A
R2 (Ω)	10	7	N/A
Tweeter Pad			
R3 (Ω)	5	8	omit
R4 (Ω)	5	4	6
Low-pass			
L1 (mH)	0.56	0.56	1.25
L2 (mH)	0.19	0.19	0.4
C1 (μF)	10.1	10	13.6
High-pass			
L4 (mH)	0.22	0.22	0.35
C4 (μF)	6.4	6.4	7.8
C5 (μF)	19.3	19.3	15

strips and left them sticking out far enough so the cabinet could be placed upside down, resting on the screw heads with no finished surface touching the work surface. Every morning I spent 20 minutes sanding and wiping a new coat on each surface, and repeated this each evening. Thus nine coats were applied in less than a week.

15. After you've achieved the right patina, you're ready to assemble the system. Remount the drivers in the front panel. If you use Cushion-All, you won't need gaskets for the drivers. Otherwise, use silicon glue or foam weather stripping for a sealer-gasket. Glue the duct with silicon glue, and then solder all connections. Attach the front panel with dry wall screws.

PERFORMANCE ANALYSIS. How do these three systems sound? I believe the Murphy is the best overall, followed

TOOLS DESIRED: (Measurement)

signal generator (Heath IG-18 or equivalant)
1 1k 2W resistor
VOM, DMM, or equivalent
RTA or Radio Shack SLM
Test CD with pink noise (or noise generator)
Router

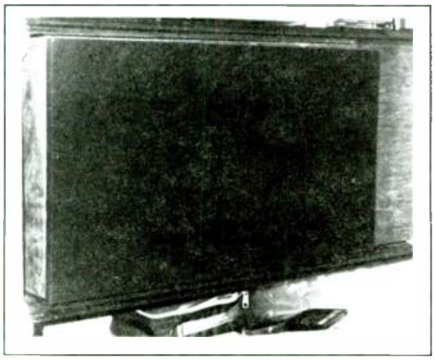

PHOTO 4: Finished system, installed with grille.

by the equalized sealed box. The ported system with the Morel tweeter finishes last but they are all audiophile quality.

The Morel/Peerless LG-1 ported system has a brash character the others lack, possible due to the Morel tweeter, which seems noticeably harsher than the

TOOLS REQUIRED: (Construction)

soldering pencil
table or radial arm saw (unless lumber yard will cut)
sabre, jig, or coping saw
screwdriver (electric preferred)
sandpaper (several sheets medium and #600 grit)
plane or sander

others. The equalized KEF RS-2 system sounds the most "audiophile." This speaker's dispersion narrowing is pronounced, and the dynamic range is the most limited. It begs to be mated to a subwoofer. Eventually we matched it to my "Passively Assisted Woofer System" (*SB*, 2/89). The RS-1 KEF system has a clean sound, and is relatively sensitive.

The Murphy system, engineered for a specific application, and designed to enhance performance in the crossover region is the best. Clean and open, its imaging is excellent at any reasonable listening position. Dispersion is rather narrow in spite of attempts to improve it, and bass sounds deeper than it really is. The response graphs were taken at 70dB SPL, and the 25Hz bass is not available at really loud levels. It is surprisingly good, and 50Hz can be rendered with authority. Go get 'em.

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POWER AMPLIFIERS

JOSEPH CURCIO

GK-B1: STEREO-70 MODIFICATION KIT [*GA* 1:89] Joe has regulated all voltages in his new 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 the power and output transformers as well as several other parts 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**

ERNO BORBELY

KP-3A: BORBELY 60W MOSFET AMPLIFIER. [2:82] All parts for one channel (except "L" choke) including board, driver and output heatsinks. **$90**

KS-1: BORBELY SERVO 100 MOSFET POWER AMP. [1:84] One channel includes all parts, board and output heatsinks. **$150**

KS-3: BORBELY DC 100 MOSFET POWER AMP. [2:84] One channel includes board, all parts, and output heatsinks. **$160**

KS-3PA: SERVO 100, DC 100 POWER SUPPLY. [2:84] Two channels, includes two 10kuF @ 75V caps, one bridge, fuses and one 500VA toroidal transformer. **$175**

KS-3PB: SERVO 100 or DC 100 MONO POWER SUPPLY. [2:84] One channel with all parts and 225VA toroidal transformer. **$125**

KS-3TA: SERVO 100, DC 100 TOROIDAL TRANSFORMER, 500VA ONLY. **$140**

KS-3TB: SERVO 100, DC 100 TOROIDAL TRANSFORMER, 225VA (mono). **$88**

KS-1M: COMPLETE BORBELY SERVO 100 MONO AMP with KS-3PB POWER SUPPLY. [1:84] Each **$275** Two or more, Each **$260**

KS-1S: BORBELY SERVO 100 STEREO AMP with KS-3PA POWER SUPPLY. **$450**

KS-3M: BORBELY DC 100 MONO AMP with KS-3PB POWER SUPPLY. [2:84] Each **$285** Two or more, Each **$270**

JAMES BOAK

KJ-8A: DYNACO MARK III POWER SUPPLY MOD. [1:78] All parts needed to add a solid state regulated power supply to the Dynaco Mark III, including heatsink. The kit also includes all parts necessary to add a balance and adjustable, independent bias control for the Mark III. **$38**

NELSON PASS

KJ-5-7: CLASS A 40W AMP A40. [4:78] This bipolar design from Nelson Pass of Threshold Corporation is as rugged as it is clean. 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**

PASS-CITATION MOD

KM-7: MOSFET CITATION 12 MOSFET MODIFICATION. [2:81] Complete kit, two channel, all parts to modify Harman-Kardon's Citation 12. **$170**

K. LANG

KV-2S: LANG CLASS A MOSFET POWER AMP. [2:86] A compact 20W per channel design from Germany which utilizes 4 push/pull power MOSFETs. Especially well-suited for multi-amp systems. Kit includes two circuit boards, all parts, two power supplies (± 24V @ 100mA; ± 15V @ 8A) with toroidal transformers and article reprint. Stereo pair. **$285**

KV-2DM: LANG CLASS A MOSFET POWER AMP. [2:86] Includes two amplifier channels and two each of the input and output power supplies for dual-mono operation (each channel independently powered). **$350**

WILLIAM Z. JOHNSON

KH-6B: AUDIO RESEARCH ST-70-C3. Modification kit construction booklet. **$5**

CD PLAYERS

KW-1: MAGNAVOX CD PLAYER MODIFICATION. Improves frequency response. Includes two Signetics NE5535, two Panasonic HF series 330μF capacitors and four 3.92k, 1% metal film resistors. **$12**

KW-2: MODIFICATION. As above, but with two AD-712 op amps in addition to the NE5535s. **$16**

KX-1A: DISC STABILIZER. Set of 3 Mod Squad Tiptoes, 3 Sorbothane feet and 25 AudioQuest CD Rings. **$70**

CDR/25: CD RINGS. Set of 25 AudioQuest CD Stabilization Rings with locator. Improves the tracking ability of any CD player. Set **$25**

KY-1: BEERS' BUDGET CD MOD. [1:89] Kit provides POOGE-4 improvements without additional wiring or circuit boards. Complete parts for assembling amplifier modules and replacing DAC components. Article reprint included. Soldering skills required, not recommended for beginners. **$95**

CDPV/2 PIERRE VERANY TEST DISCS. More than 100 demo tracks and equipment tests are contained on this 2 CD set. Detailed instruction booklet is included. In addition to list price, please add $2.25 shipping and handling. Set **$34**

PREAMPS

JOSEPH CURCIO

KS-6: CURCIO VACUUM TUBE PRE-PREAMP. [5:84] Contains board, all parts, jacks, tubes & sockets for amplifier/regulator. With master power supply, including board and transformers. No enclosures supplied. **$135**

KT-1: CURCIO TUBE PREAMP. [2:85] Contains board with all parts, bridge, relay & socket, tubes & sockets, heatsinks, and switches. Power supply with transformers included. **$385**

KV-3: AUTO MUTE. [1:86] Turn-on delay for power amp and speaker protection. **$18**

ORDER BY FAX OR PHONE 24 HOURS/DAY!

SULZER PREAMP POWER

KL-4A: OP AMP PREAMP VOLTAGE REGULATOR. [2:80] Sulzer ± 15V regulator, 30mA capacity. All parts and board. Requires ± 21V filtered DC input. No transformer, filter caps, or rectifier. **$40**

KL-4B: SULZER RAW DC SUPPLY. Triad F-91X transformer, diodes and two 5,000μF @ 35V capacitors. Will power two KL-4A supplies. Diagram supplied for construction. **$60**

KL-4C: SULZER RAW DC SUPPLY. Same as KL-4B but contains ILP ± 22V toroidal transformer. **$85**

KL-4D: ILP ± 22V toroidal transformer only. **$55**

FILTERS & SPEAKER SAVER

KF-6: 30Hz RUMBLE FILTER. [4:75] Two channel universal filter card supplied with WJ-3 (F-6) circuit board and all basic parts, 1% metal film resistors and 5% MKM capacitors for operation as an 18dB/octave 30Hz rumble filter. Kit may be adapted as two- or three-way single channel crossover with added capacitors and resistors. **$30**

KH-2: SPEAKER SAVER AND OUTPUT FAULT DETECTOR. [3:77] Two-channel kit provides turn-on and off protection. Fast optocoupler circuitry prevents damage from transients. Additional parts provided offer speaker protection in the event of amplifier failure. Kit includes circuit board, all board-mounted components, power supply parts and article reprint. **$65**

MIXING AND RECORDING

KF-3: GATELY POWER SUPPLY. Regulated ± 18V, 100mA per side. EG-2 circuit board, all parts, includes transformer and heatsink. **$52**

CROSSOVERS

*For KC-4A choose **ONE** frequency from those listed below. For KC-4B choose **TWO** frequencies from the list. NO OTHER FREQUENCIES ARE AVAILABLE FOR STOCK KITS.*
60, 120, 240, 480, 960, 1920, 5k or 10kHz.

KC-4A: ELECTRONIC CROSSOVER, KIT A. [2:72] Single channel, *two-way*. All parts and C-4 circuit board. Includes new LF351 ICs. Suitable supplies include KE-5 and KF-3. **$14**

KC-4B: ELECTRONIC CROSSOVER, KIT B. [2:72] Single channel, three-way. All parts and C-4 circuit board. Includes new LF351 ICs. **$18**

KK-6L: WALDRON TUBE CROSSOVER: Low pass. Single channel, 18dB/octave, Butterworth, [3:79] includes three-gang pot, level control, 12AX7 tubes, board and three frequency range determining capacitors. *Specify ONE frequency range per kit please.* (Hz.): 19-210; 43-465; 88-960; 190-2100; 430-4650; 880-9600; 1900-21,000. Single channel **$60**

KK-6H: WALDRON TUBE CROSSOVER: High pass. Single channel, 18dB/octave, Butterworth, [3:79] includes three-gang pot, level control, 12AX7 tubes and three frequency determining capacitors. Please specify **one** of the frequencies above. No other can be supplied. **$62**

KK-7: WALDRON TUBF CROSSOVER POWER SUPPLY. [3:79] All parts, including board, transformer, fuse, semiconductors, line cord, capacitors. Will power four tube crossover boards (8 tubes), one stereo bi-amped circuit. **$110**

SBK-A1: LINKWITZ CROSSOVER/FILTER. *Speaker Builder's* [4:80] first kit, including all parts and board for one channel of the three-way crossover/filter/delay. 24dB/octave at 100Hz and 1.5kHz and 12dB/octave below 30Hz, with delayed woofer turn-on. Board is 5½ × 8½". Requires ± 15V supply, not included. Use the Sulzer supply KL-4A with KL-4B or KW-3. Per channel **$75** Two channels **$140**

SBK-C1A: ELECTRONIC CROSSOVER. [*SB* 3:82] 30Hz filter adapted as a single channel, two way crossover. Can be 6, 12 or 18dB per octave. Includes WJ-3 (F-6) PC board, 4136 IC, quality parts. Choose frequency of 60, 90, 120, 250, 500, 1k, 2k, 5k or 10k. Power supply required. Can use the KL-4A/4B or KW-3. **$32**

SBK-C1B: THREE WAY, SINGLE CHANNEL CROSSOVER. [*SB* 3:82] Contains two each SBK-C1A. Choose high & low frequency. **$60**

SBK-C1C: TWO CHANNEL, COMMON BASS CROSSOVER. [*SB* 3:82] Contains two each SBK-C1A. Choose one frequency. **$64**

AIDS & TEST EQUIPMENT

KE-2: REGULATED POWER SUPPLY. [4:74] ± 15V @ 1.5A. Lab quality device but excellent for powering system components. Includes board, all board mounted parts plus two LM395K regulators. Transformer and filter caps not included. **$51**

KE-5: OLD COLONY POWER SUPPLY. ± 18V @ 55mA balanced, includes all parts, board and transformer. Not regulated. **$20**

KH-7: PRECISION 101dB ATTENUATOR. [4:77] All switches, 1% metal film resistors to build Gloeckler's prototype. Chassis, input/output jacks not included. **$65**

KJ-6: CAPACITOR CHECKER. [4:78] All switches, ICs, resistors, 4½" D'Arsonval meter, transformer and PC board to measure capacitance, leakage and insulation. **$90**

KK-3: THE WARBLER OSCILLATOR. [1:79] Switches, ICs, transformer, and PC board for checking room response and speaker performance without anechoic chamber. **$70**

KL-3: INVERSE STEREO RIAA NETWORK. [1:80] Two channels, 1% polystyrene caps and metal film resistors, gold jacks, cast aluminum box, solder lugs and alternate 600 or 900Ω R_2'/C_2' components. **$45**

KL-6: MASTEL TIMERLESS TONE BURST GENERATOR. [2:80] All parts with circuit board. No power supply. **$24**

KM-3: CARLSTROM/MULLER SORCERER'S APPRENTICE/PAUL BUNYAN. [2,3:81] Includes six boards and all parts including power supplies. No chassis or knobs. Two article reprints. **$290**

KP-2: TWO TONE INTERMODULATION FILTER. [1:82] All parts, circuit boards, 1% resistors included. **$26**

SBK-D2: WITTENBREDER AUDIO PULSE GENERATOR. [*SB* 2:83] All parts, board, and power supply included. **$80**

SBK-E4: MULLER PINK NOISE GENERATOR. [*SB* 4:84] All parts, board, 1% MF resistors, capacitors, ICs, and toggle switches included. No battery or enclosure. **$35**

SYSTEM ACCESSORIES

KC-5: GLOECKLER 23-POSITION LEVEL CONTROL. [2:72] All metal film resistors, shorting rotary switch & two boards for a two channel, 2dB per step attenuator. Choose 10k or 250kΩ. **$74**

KH-8: MORREY SUPER BUFFER. [4:77] All parts & board for two channel output buffer to isolate tape outputs in your preamp from distortion originating in a turned-off tape recorder. Many uses for this versatile matchmaker. Requires power supply. **$22**

KM-10A: SWITCHBOX. [2:81] (6⅝ × 4 × 2") Black with white letters with 5-position DP silver contact, steatite switch, five inputs, and one output with RCA jacks, nickel-plated, and five ground posts. **$45**

KM-10B: Same as 10A but with 12 gold-plated jacks. **$55**

KP-5: AUDIO SWEEP MARKER ADDER. [2:82] All parts and circuit board (no power supply) for adding two adjustable markers to a swept audio signal, 20Hz-100kHz. **$32**

SBK-D1: NEWCOMB PEAK POWER INDICATOR. [*SB* 1:83] All parts & board. No power supply required. **$7** Two for **$11**

SBK-E2: NEWCOMB NEW PEAK POWER INDICATOR. [*SB* 2:84] All parts & board, new multicolor bar graph display; red, green & yellow LEDs for one channel. No power supply needed. **$14** Two for **$22**

BOOKS from Old Colony Sound Lab

BUILDER'S GUIDES, general

BKAA-4 KILLER CAR STEREO ON A BUDGET *by Dan Ferguson*. Now you've got a simple choice when it comes to upgrading your car stereo. Instead of paying a few thousand to a high-end dealer, you can pay only a few hundred. With a good in-dash unit in place, you need only follow author Dan Ferguson's instructions for buying and replacing your front speaker, main speakers, and adding the killer—a subwoofer with enclosure, power amp and crossover. An easy cure for ho-hum auto sound. 1989, 118pp., spiralbound. **$19.95**

MH-2 HOW TO MAKE PRINTED CIRCUIT BOARDS *by Joel Goldberg*. All the basics on making your own circuit boards are covered both in theory and in practical advice: design and layout, artwork preparation, photo layout, silk screening, and etching. 1980, 117pp., softbound. **$8.90**

S-25 ELECTRONIC PROTOTYPE CONSTRUCTION *by Stephen D. Kasten*. Here's a great book for either the beginner looking to try electronic prototyping for the first time or the expert looking for a handy reference guide. Areas covered include wire wrap and related techniques such as solder pad and perfboard assembly. This book will help you through all the pitfalls of PC board design, and will help you put the project together in an attractive but functional package. 1983, 399pp., softbound. **$17.95**

S-27 DESIGN OF OP AMP CIRCUITS *by Howard Berlin, W3HB*. Op amps are a versatile and inexpensive integrated circuit. They can be used for linear amplifiers, differentiators, integrators, voltage and current converters, comparators, rectifiers, oscillators and more. The text includes 37 different uses and applications for op amps. Beginners will find this book helpful. 1977, 221pp., softbound. **$12.95**

S-32 HOW TO READ SCHEMATICS *by Donald E. Herrington*. This book teaches the recognition of schematic symbols, their use and function in diagrams, and the interpretation of diagrams for design, maintenance, and repair of electronic equipment. Especially helpful to the novice kit builder. 1989, 258pp., softbound. **$14.95**

T-8 ENHANCED SOUND: 22 Electronics Projects for the Audiophile *by Richard Kaufman*. Twenty-two cost efficient projects are offered which can increase the capabilities of your audio system, and improve its performance. Discussions on theory, design applications and construction techniques are also included. A sampling of the projects...surround sound decoder, passive image enhancer, auxiliary input switch, tone controls, amplifier bridging circuit, modern infrasonic filter, Linkwitz-Riley crossover, improved dipole, helical antennas, and more. Over 100 illustrations. 1988, 170pp., softbound. **$11.95**

T-10 ACOUSTIC TECHNIQUES FOR HOME AND STUDIO [2ND ED.] *by F. Alton Everest*. Learn how to improve your audio system by changing your listening room's characteristics. This cookbook of theory, method and construction ideas is fully illustrated and written in easy-to-understand language. 1984, 344pp., softbound. **$18.95**

BUILDER'S GUIDES, specific (cookbooks)

S-9 REGULATED POWER SUPPLIES [3RD ED.] *by Irving M. Gottlieb*. Static and dynamic characteristics, regulation techniques, IC regulation. 1981, 424pp., softbound. **$21.95**

S-10 IC OP AMP COOKBOOK [3RD ED] *by Walter G. Jung*. Jung's popular classic in a revised and expanded edition. One hundred pages are added to cover new devices, applications and manufacturer's data sheets. With over two hundred practical circuits with component values, this cookbook is one of Old Colony's best selling technical volumes. It belongs on every electronics bookshelf. 1986, 580pp., softbound. **$21.95**

S-13 AUDIO IC OP AMP APPLICATIONS [3RD ED] *by Walter G. Jung*. This new, updated version of a classic reference source is probably the best book available on the subject. Mr. Jung is not only a recognized authority on op amps, but has an enthusiast's interest in audio quality and actively pursues new techniques for better sound reproduction. Like his previous books in this series, this edition is in "cookbook" style, and includes actual circuits with component values which may be incorporated in working projects. The book also details the most common pin-outs, manufacturer listings and a wealth of other resource material. A must for any audiophile who constructs or modifies equipment. 1987, 250pp., softbound. **$19.95**

S-14 ACTIVE FILTER COOKBOOK *by Don Lancaster*. A practical, user-centered volume with everything you need to build your own active filters. Explains the various types and how to select the best for the circuit. 1975, 240pp., softbound. **$15.95**

S-17 IC TIMER COOKBOOK [2ND ED] *by Walter G. Jung*. A full introduction to the IC timer, the types, and general usage pointers. Many surprisingly useful audio related uses. An excellent practical and theoretical volume with lots of reference data. 1983, 430pp., softbound. **$17.95**

S-18 TTL COOKBOOK *by Don Lancaster*. Everything the beginner will need to know about transistor logic elements and usage. It has become a reference guide for engineers as well. 1974, 335pp., softbound. **$14.95**

S-26 CMOS COOKBOOK [2ND ED.] *by Don Lancaster*. CMOS is low cost and widely available, and it uses an absolute minimum of power. It's also fun to work with and very easy to use. This book offers practical circuits and does not dwell on math or heavy theory. Eight chapters cover just about every aspect of CMOS usage. Projects include high-performance op amps, TV typewriter, digital instruments, music synthesizers and video games. 1977, 414pp., softbound. **$18.95**

DICTIONARIES

P-2 DICTIONARY OF ELECTRONICS [2ND ED.] *by E. C. Young*. This remarkably compact reference covers electronics from A-battery to Z-parameters with succinct, concise definitions and illustrations. A quick reference completely revised and updated with lots of added charts and reference data. 671pp., softbound. **$8.95**

P-3 A NEW DICTIONARY OF MUSIC [3RD ED, first pub. 1958] *by Arthur Jacobs*. Alphabetically arranged entries covering composers, individual musical works, orchestras, performers, conductors, musical instruments, and technical terms. 1973, 458pp., softbound. **$8.95**

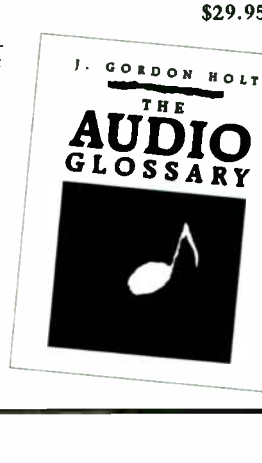
S-22 MODERN DICTIONARY OF ELECTRONICS [6TH ED.] *by Rudolph Graf*. This book should be in every library. It has more than 20,000 terms unique to electronics and other closely related fields. From angstrom to zoom lens, you'll find it in this updated dictionary. 1984, 1,152pp., hardbound. **$39.95**

T-9 THE ILLUSTRATED DICTIONARY OF ELECTRONICS [4TH ED.] *by Rufus P. Turner and Stan Gibilisco*. This outstanding offering from TAB Books contains over 27,000 terms and definitions. Clearly written and detailed with over 450 illustrations, it is an excellent reference for hobbyist and researcher alike. 1988, 648pp., softbound, 7½ x 9. **$24.95**

U-1 THE AUDIO DICTIONARY *by Glenn White*. This lively and entertaining mini-encyclopedia covers the terminology and basic concepts relative to sound recording, sound reinforcement, and musical acoustics. Also includes historical anecdotes and a discussion on digital audio. 1987, hardbound. **$29.95**

BKAA7 THE AUDIO GLOSSARY *by J. Gordon Holt*. Authored by the founder of *Stereophile* and one of audio's most famous gurus, this new best seller is a comprehensive overview of over 1,900 technical and subjective audio terms explained in precise yet at times humorous fashion. Foreword by Peter W. Mitchell, 27 illustrations. Hardbound includes dust jacket; limited edition is autographed, with gold-embossed binding. 1990.

BKAA7/S Softbound **$9.95**
BKAA7/H Hardbound **$17.95**
BKAA7/L Limited **$30.00**



LOUDSPEAKERS (see also Sound Engineering)

BKAA-1 AUDIO AMATEUR LOUDSPEAKER PROJECTS. A collection of 25 loudspeaker construction projects. These are the complete articles as they appeared in *Audio Amateur* (1970-79). Since 1980, *Speaker Builder* magazine has been the forum for these authors and designers. Although some of the projects are showing their age, many embody ideas that can be developed using our newer knowledge and insights. The electrostatic devices are still unsurpassed by anything done since. The collection is a rich source of both theory and practice as well as design. 1985, 135pp., softbound, 8½x11. **$20.00**

BKAA-2 THE LOUDSPEAKER DESIGN COOKBOOK (3RD ED.) *by Vance Dickason*. Everything you need to build the loudspeaker system you have always wanted but could not afford. Easy ways to pick the exact box size, the ideal drivers, the most pleasing finish and the correct way to feed your music to your new superb loudspeaker system. Proven designs, where to buy low cost parts and how to test the results for yourself. 1987, 82pp., softbound, 8½x11. **$19.95**

S-11 HOW TO BUILD SPEAKER ENCLOSURES *by Alexis Badmaieff and Don Davis*. The "whys" and "hows" of speaker enclosures. Drawings and instructions cover infinite baffle, bass reflex, and horn types plus combinations. 1966, 144pp., softbound. **$6.95**

T-12 DESIGNING, BUILDING AND TESTING YOUR OWN SPEAKER SYSTEM—WITH PROJECTS *by David B. Weems*. This 7⅜" by 9¼" hands-on softbound manual packs an incredible amount of useful info into its 208 pages, including easy directions for ten projects. **$16.95**

W-1 HIGH PERFORMANCE LOUDSPEAKERS [3RD ED.] *by Martin Colloms*. A thorough revision of the 2ND ED. (1980) updates and expands this authoritative volume. The author surveys new developments in the four-year interim and adds some highly original proposals for low frequency alignments, listening tests and much else. Colloms' book is indispensable for the serious speaker builder. 1985, 313pp., hardbound. **$38.95**

GUIDEBOOKS & DATABOOKS

D-4 A MANUAL OF VENEERING *by Paul Villiard*. This book is a clear, well-written manual on the craft of veneering which explains how to turn out your own hardwood veneers beautifully and economically. Mr. Villiard shows you all the techniques of veneering: how to match veneers; how to glue, clamp, tape, and edge veneered panels; how to veneer curved panels; and how to inlay, finish, and repair veneers. 65 illustrations and photos, index, 174pp., softbound. **$4.95**

N-6 LINEAR DATABOOK 1. First book in a comprehensive 3-vol. set of specifications and applications. Topics covered, with example circuits, include voltage regulators, op amps and buffers, voltage comparators and instrumentation amplifiers. 1988, 1,250pp., softbound. **$16.95**

N-7 LINEAR DATABOOK 2. This second volume includes information on active filters, analog switches and multiplexers, both analog-to-digital and digital-to-analog converters, temperature sensors and voltage references. 1988, 920pp., softbound. **$10.95**

N-8 LINEAR DATABOOK 3. The third book in this series focuses on audio, video and radio circuits. Also included is information on an array of special functions. 1988, 750pp., softbound. **$10.95**

N-678 LINEAR DATABOOKS. As above, complete 3-volume set. **$35.00**

N-9 LINEAR APPLICATIONS HANDBOOK. Heavily indexed and cross-referenced, this 1,220-page bible features hundreds of well-explained linear-IC circuits covering virtually every type of electronic device imaginable. 1986, softbound. **$16.95**

P-1A THE NEW PENGUIN GUIDE TO COMPACT DISCS AND CASSETTES *by Edward Greenfield, Robert Layton and Ivan March*. An invaluable companion to their best selling *Stereo Records and Cassettes Guide*, this most recent offering is extensive in its coverage of compact discs. Comparative reviews are included that assess the best versions of material available. 1988, 1,366pp., softbound. *Please add $1.00 per book for shipping, in addition to postage.* **$19.95**

S-30 TUBE SUBSTITUTION HANDBOOK [21ST ED.] *by Howard W. Sams Engineering Staff*. This guide contains more than 6,000 receiving tube and 4,000 picture tube substitutes. Includes American to foreign and foreign to American equivalents. Tube basing diagrams provide a reference for pinouts. 1980, 128pp., softbound. **$6.95**

SOUND ENGINEERING, REFERENCE WORKS

B-1 LOUDSPEAKER AND HEADPHONE HANDBOOK *edited by John Borwick*. This comprehensive technical volume fully covers the theoretical and practical aspects of loudspeaker and headphone design, operation and performance. Distinguished contributing authors include: Glyn Adams, Peter J. Baxandall, John Borwick, Martin Colloms, Laurie Fincham, R.D. Ford, Mark R. Gander, Stanley Kelly, Peter Mapp, C.A. Poldy, Desmond Thackeray, Floyd E. Toole and J.M. Woodgate. An invaluable reference textbook for the dedicated speaker builder. 573 pp., hardbound. **$110.00**

BKX-1 PERCEPTION OF REPRODUCED SOUND *edited by Soren Bech and O. Juhl Pedersen*. A collection of 18 papers from the symposium held at Gammel Avernaes, Denmark, in September 1987. This gathering of professionals reviewed the subjective evaluation of reproduced sound and assessed its importance for the electroacoustic industry. Participant authors include: T. Poulsen, R. Plomp, H. Staffeldt, J. Blauert, F.E. Toole, A. Gabrielsson, S. Bech, N. Kousgaard, M. Williams, V. Hansen and G. Thiele. All offer highly informative presentations. 165pp., hardbound. **$35.00**

MH-1 HANDBOOK FOR ELECTRONICS ENGINEERING TECHNICIANS [2ND ED.] *by M. Kaufman and A.H. Seidman*. A comprehensive compendium of electronic facts. Component selection, circuit analysis, power supplies, IC uses and characteristics, op amps, transistors, batteries and tubes. A one-volume encyclopedia on how components work and how to choose the best of them for your application. Includes seven new chapters on topics such as logic analysis, fiber optics, active filters, digital test gear and microprocessors. 1984, 752pp., hardbound. **$49.95**

MH-4 AUDIO ENGINEERING HANDBOOK *edited by K. Blair Benson*. A complete desktop resource for engineering professionals and students. Topics covered include Digital Audio, Broadcast Transmission Technology, Microphones and Amplifiers, Analog and Digital Disk/Tape, Film Recording and Reproduction, Studio Production and Noise Reduction. Also provides a listing of up-to-date standards and recommended international practices. Among the Handbook's 33 authors are audio industry experts such as: Dr. R. Cabot, R. Dolby, T. Holman, Dr. T. Doi, H.G. de Haan, Dr. J. Bloom and L. Tyler. More than 700 illustrations. 1988, 1,056pp., hardbound. **$86.95**

PH-1 HANDBOOK OF SIMPLIFIED SOLID-STATE CIRCUIT DESIGN [2ND ED.] *by John Lenk*. Design rules for basic circuitry including audio amps, integrated circuits, wave forming and shaping plus power supplies. Assumes basic theoretical base. Discusses purposes and types of testing. **$39.95**

S-19 SOUND SYSTEM ENGINEERING [2ND ED.] *by Don and Carolyn Davis*. A thorough introduction to sound systems for halls, studios, outdoor locations and much else; now expanded! 1986, 665pp., hardbound. **$49.95**

S-28 HANDBOOK FOR SOUND ENGINEERS: The New Audio Cyclopedia *edited by Glen Ballou*. Thirty-one sections covering just about every aspect of audio engineering from room acoustics, loudspeakers and amplifiers, to soundfield measurements and image projection. A complete audio reference library in itself, the most comprehensive and authoritative work on audio available. 1987, 1,250pp., hardbound. **$79.95**

TUTORIAL

BKAA-3/1 AUDIO ANTHOLOGY (Vol. 1). A fascinating look at sound reproduction as presented in the pages of *Audio Engineering* magazine. Features 38 articles from May 1947 to December 1949. Compiled by editor, designer and author, C.G. McProud, this series will be of interest to all audio enthusiasts. Reprint Ed. 1987, 124pp., softbound, 8½x11. **$16.95**

BKAA-3/2 AUDIO ANTHOLOGY (Vol. 2). More on amplifiers, loudspeakers and enclosures, and phonograph equipment. 45 articles from *Audio Engineering* magazine, January 1950 to July 1952. Reprint Ed. 1989, 124pp., softbound. **$16.95**

BKAA-3/3 AUDIO ANTHOLOGY (Vol. 3). Covers September 1952 through May 1955. Along with discussions on stereophonic developments, includes designs for 18 preamps and filters, 8 power amps, and 12 loudspeaker systems. 43 articles, 124pp., softbound. **$16.95**

BKAA-3/S AUDIO ANTHOLOGY SET (Vols. 1-3). As above, normally a $50.85 value. **$42.00**

BKAA5 LOUDSPEAKERS—THE WHY AND HOW OF GOOD REPRODUCTION *by G.A. Briggs*. Out of print for more than 40 years, this concise introduction to audio basics goes far beyond speakers, drivers, and boxes to include discussion of just about every audio phenomenon. Liberally illustrated, *Loudspeakers* is a pleasant tour through the early audio years and a provocative survey of the right questions about quality reproduction. 88pp., softbound. **$6.95**

BKAA6 THE WILLIAMSON AMPLIFIER *by D.T.N. Williamson*. In 1947, this power amplifier, using excellent-quality push/pull output tubes, a special output transformer, and a highly filtered power supply, became an overnight success. Published by exclusive arrangement, this booklet is not only a singular resource but also an important historical document which will give the reader unique insight into the tube designer's challenges. 40pp., softbound. **$4.95**

D-3 MUSIC, PHYSICS AND ENGINEERING [2ND ED.] *by Harry F. Olson*. A thorough introduction to the physical characteristics of sound and the relationship of sound to musical instruments by the former head of staff at RCA's lab for acoustical and electromechanical research at Princeton, NJ. A classic by one of the giants in the audio field. Easy to read chapters on acoustics, mikes and recording, recording and playback systems, as well as an electronic music chapter. 1967, 460pp., softbound. **$8.95**

P-8 INTRODUCING MUSIC *by Otto Karolyi*. Even if you've listened to music for years, you may be surprised at how little you know about its fundamentals. A beautifully basic and spare introduction to the grammar and vocabulary of music—enough to understand the language without speaking it. It will deepen almost any non-musician music lover's pleasure in listening. 1965, 174pp., softbound. **$5.95**

RR-1 THE ARRL HANDBOOK FOR THE RADIO AMATEUR *edited by Bruce S. Hale*. Although written for radio amateurs, this book is a valuable source of technical information for anyone interested in the theory and use of electronics. 1990, 1,170pp. **$23.00**

S-4 UNDERSTANDING IC OPERATIONAL AMPLIFIERS [3RD ED.] *by Roger Melen* and *Harry Garland*. Basic course in semiconductor electronics. Covering integrated op amp circuitry, design factors, bias current, offset voltage, frequency compensation and slew rate. 1987, 212pp., softbound. **$12.95**

S-29 PRINCIPLES OF DIGITAL AUDIO [2ND ED] *by Kenneth C. Pohlmann*. A state-of-the-art reference text on digital audio technology. Comprehensive material on fundamentals, recording and reproduction is presented in this completely up-to-date handbook written both for engineers and audiophiles. 1989, 350pp., softbound. **$29.95**

T-7 BASIC ELECTRONICS COURSE [2ND ED] *by Norman H. Crowhurst*. This highly recommended textbook defines literally every aspect of electrical behavior and state-of-the-art electronics. Included are fundamental building blocks of theory and practice such as Kirchhoff's Laws, properties of resistance, electron flow, magnetic fields and power calculations. 430pp., softbound. **$17.95**

T-11 UNDERSTANDING ELECTRONICS [3RD ED.] *by R.H. Warring*. The basics of electronics are presented here in a clear, concise, and thoroughly understandable fashion, with excellent explanations of solid-state theory, FETs, and fundamentals such as resistance, capacitance, and inductance. Also included is an introduction to the design of solid-state amplifiers and circuit boards. 1989, 205pp., softbound. **$11.95**

NEW KIT! ADCOM GFA-555 MOD

Based on Kit Ryan's article in *The Audio Amateur* (4/89), this power regulation circuit is intended to upgrade ADCOM's GFA-555, but will work with any 80V-in that requires 60V-out regulated @ 10A. A very versatile and popular mod, with article reprint included.
KY-2 Per channel **$99**

OLD COLONY ALSO OFFERS many high-quality metal film resistors and polypropylene caps. Please forward SASE for free listing of values and prices.

PARTS

Connectors & Cable

SCXT7: RCA-TYPE AUDIO PLUG. Gold-plated, top-of-the-line, solderless stack-up plug with safety collar.
Pair **$18*** Two or more pair Each **$17**

SCXT8: RCA-TYPE AUDIO JACK. Counterpart to SCXT7, gold-plated. Mounts from front of panel. Nylon insulators included.
Pair **$16** Two or more pair Each **$15**

PHONO JACK A. Mounts in ⅜" hole from rear of panel (up to 13/64" thick). External hex nut ensures tight installation. Gold-plated hardware included. Pair **$7.50**

NYLON INSULATING WASHERS. One flat/one shoulder, 10 pairs per set. ⅜" size—Fits Phono Jack A **$1.50**
¼" size—Suitable for ¼" phono jacks **$1.50**

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

AUDIO AMATEUR

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

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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**

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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] Ea. **$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**

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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**

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

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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**

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

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

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

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Signetics NE5534	$4.75
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Analog Devices AD-711 (8-pin DIL single FET op amp)	$2.40
Analog Devices AD-712 (8-pin DIL dual FET op amp)	$3.50
Analog Devices AD-712KN Military (8-pin DIL dual FET)	$11.25
Analog Devices AD-713 (quad op amp)	$10.00
Motorola MC34081P input op amp	$2.50

Et cetera

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2 FOLD BOTTOM UP

4 TAPE OR STAPLE SECURELY

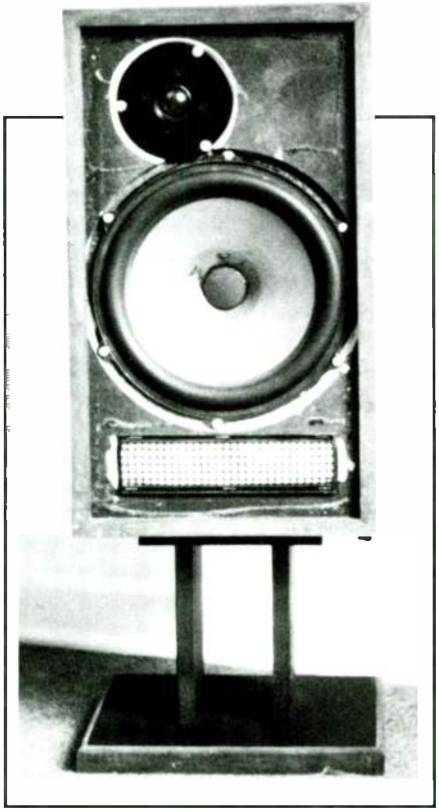
MODIFYING DYNACO'S A-25

BY LEN MOSKOWITZ

The Dynaco A-25 speaker system made its debut amid raves in 1969. A two-way system in slightly more than a cubic foot box, it was truly a bookshelf speaker. Considering its list price was only $79.95, (in 1969) and that it sounded better than speakers costing two or three times more, it's not surprising Dynaco sold lots of them. Almost 20 years later many are still around.

For its day, the A-25 had something near a flat frequency response, specified at ±5dB from 47Hz-20kHz. It achieved this using what might today be considered a strange configuration: a two-way system using a 10″ woofer. Two-way systems more commonly use 6½″ or 8″ woofers, because it's easier for a tweeter to cross over seamlessly to a small woofer than to a large one. Most tweeters having good high-frequency responses tend to lose their low-frequency response around 3kHz.

Most 10″ drivers' frequency response falls off rapidly above 1.5kHz. It's a rare tweeter which can go down that low, and still provide a balanced high end. Many manufacturers choose a smaller woofer with better high-frequency performance sacrificing bass performance in favor of simpler tweeter matching. Dynaco managed these trade-offs differently. It chose the SEAS 25 TV-EW 10″ woofer. The 25 TV-EW is a rare large driver because it maintains performance up to the relatively high frequency of approximately 2.2kHz (*Fig. 1*). It also gives better than average bass performance when installed in a small box.



The 25 TV-EW's high cut-off frequency made finding a compatible tweeter possible. The SEAS 87H 1½″ fabric dome tweeter provided a good compromise between matching the woofer's cut-off and smooth high-frequency performance. It was reasonably flat down to around 1.7kHz, without giving up too much of its high-frequency response (*Fig. 2*). On the high end, the 87H started rolling off above 12kHz, and was down ±3dB at 15kHz and 6-8dB at 20kHz.

This certainly wasn't audiophile performance, but was quite good for its price. Its dispersion wasn't specified, but listening proves it's not wonderful. One reviewer said he could hear a 12kHz tone at 30° off-axis and a 15kHz tone on-axis. The Dynaco A-10 and A-50 used the same SEAS tweeter.

YET ANOTHER TACK. Considering that acoustic suspension speakers such as the AR-3a and AR-5 were all the rage 20 years ago, it's surprising Dynaco took another approach. The A-25 is an aperiodic vent design, rather than a sealed or ported box. The reviews recounted how Dynaco tested each A-25, loading the vent until bass response was optimized. The SEAS 25 TV-EW woofer, with its paper cone and rubber surround, had a nice flat response.

When set in a properly loaded aperiodic system, it provided considerably lower bass than you'd expect from a box this small. In John Cockroft's article, "The Shortline: A Hybrid Transmission Line," (*SB* 1/88) he said that aperiodic vented systems are similar to very short transmission lines. The A-25's bass

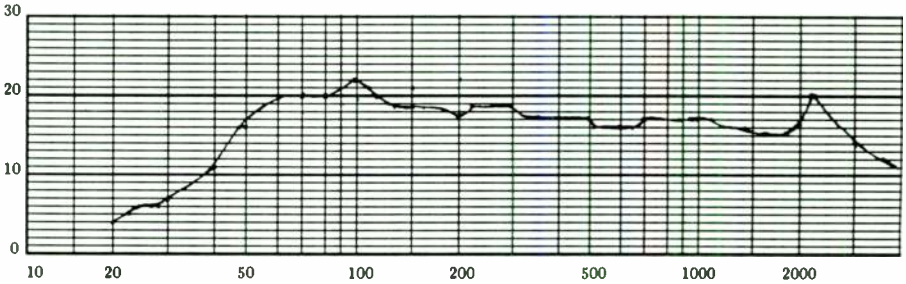


FIGURE 1: SEAS 25 TV-EW frequency versus amplitude response.

ABOUT THE AUTHOR

Len Moskowitz does artificial intelligence research for Bendix Test Systems Division in New Jersey. He is also an amateur musician and enjoys improving the sounds produced by his instruments and stereo.

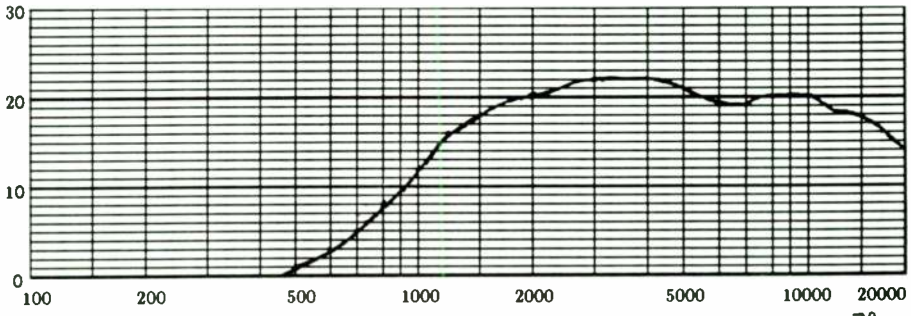


FIGURE 2: SEAS 87H frequency versus amplitude response.

sound shows this resemblance; its transient performance is notably tight and well-controlled. While a box this small can't reproduce the lowest music octave it does get pretty close.

The A-25's crossover is a deceptively simple affair. Since the woofer's response rolls off steeply above 2.2kHz, Dynaco didn't bother installing a low-pass filter, but provided the tweeter with a first order high-pass filter implemented in an interesting way (*Fig. 3*). Dynaudio currently uses a similar circuit in one of their systems (the Twynn). The amplifier feeds a 4.7 or 5µF capacitor, initially a non-polarized electrolytic, and later what appears to be a film capacitor.

The signal is fed to a resistive network, consisting of a series resistor (R1) preceded by a second resistor (R2) in parallel to the driver and R1. R2 has a minimum value of 10Ω, and R1 1.2Ω. Four 1.2Ω resistors can be added to R1 or R2 using a five position selector switch. When a resistor is switched from R1, it is added to R2, providing a variable level control which also varies the crossover's −3dB turnover point.

I analyzed the network with the SPICE network simulation program. Its performance with an 8Ω resistive load is summarized in *Table 1*. I was surprised that at its normal setting, Dynaco designed for a 2.5kHz crossover point. This is a bit beyond the woofer's capabilities, and the A-25's sound suffers.

WHAT TO UPGRADE? The A-25 has weathered the years reasonably well. While bass performance is excellent, compared with modern designs of similar size, the woofer's downward tilt in the midrange between 100Hz–2kHz sounds like a slight depression in clarity. The tweeter's high-frequency performance hasn't fared well. Compared to modern designs, its roll-off above 12kHz is clearly audible as a lack of air and detail. The tweeter imparts harshness to strings, cymbals, and synthesizers, and its restricted dispersion makes the preferred listening area smaller than we like.

THE FUN BEGINS. While I was in the mood to upgrade my old stereo system, I decided to see what could be done about my A-25s. The first step was to determine the A-25 drivers' characteristics. Ed Laurent, SEAS' US contact, kindly dug out a set of old specification sheets. Clearly replacing the 87H was my first priority. I searched old *Speaker Builder* articles and vendor catalog sheets for a suitable replacement, concentrating on response flatness between 2–20kHz, broad dispersioı. at higher frequencies, sensitivity similar to the 87H's (91dB), and compatible mounting characteristics. I found the perfect solution: Dynaudio's D28-AF.

Recommended and used in many *Speaker Builder* projects the tweeters are favorites of manufacturers and hobbyists. They have an amazingly flat frequency response (*Fig. 4*), wonderful dispersion characteristics, sensitivity equal to the 87Hs, and are similar in size. Frequency response extends to below 2kHz, with a resonant peak comfortably far below that at 700Hz.

Impressed after hearing them in Thiel's CS2.0 speakers, I ordered a pair from Madisound for less than $100. (Zalytron and Audio Concepts also stock them.) Analyzing the crossover and determining how the upgrade should proceed, a friend, Michael Hennedy,

Continued on page 59

TABLE 1

8Ω RESISTIVE LOAD

R1 (Ohms)	R2 (Ohms)	Insertion Loss (dB)	Crossover Freq. (kilohertz)
11.0	10.0	4.7	1.3
8.8	12.2	3.8	2.0
6.6	14.4	2.0	2.5
4.4	16.6	2.0	2.5
2.2	18.8	0.9	2.9

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Pure Titanium Formers

To assist in maximizing the transfer of energy from the voice coil to the diaphragm, while maintaining sensitivity and power handling, Audax engineered the complete Prestige Line to employ this refinement.

At Polydax, we view the design of a loudspeaker as a combination of elements embodied in a complex variety of compromises. When development on a new line of ultra high end loudspeaker components began, our commitment was to choose these compromises in such a manner as not to sacrifice sonic performance in any way. The extent of our success is most evident in the resulting family of drivers, appropriately named the Prestige Line.

Our emphasis on formulating breakthrough technologies has dated back to over half a century ago, when the company was first established. From the pioneering of our proprietary cone material, TPX, to the invention of the Supra magnetic technology, our passion to set new standards for supplying the highest quality loudspeaker components has never been stronger. We are confident that, from an engineering standpoint, every product in the Prestige Line offers you more advanced design than has ever been previously available.

The overall quality of any system is characterized by the concessions made in design, materials and workmanship. Polydax has taken the necessary steps to ensure that your system will not be compromised with our Prestige Line.

P R E S T I G E

MDA-100

4" MIDRANGE

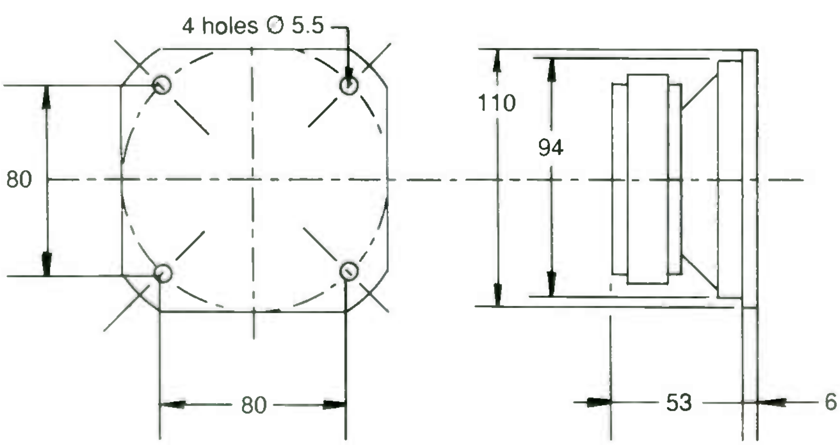
The research objective was to obtain a balanced tonality with perfect equilibrium across a wide pass band (+/- 1dB from 450 Hz to 6.5 kHz). The performance of this new driver is unmatched, and the smooth response allows applications to employ a minimum of crossover equalization.

The remarkable TPX material exhibits excellent properties of damping, rigidity and low mass, making it ideal for use as a diaphragm. Coupled to a surround made of NORSOREX, all undesirable distortion generated from cone ringing is eliminated.

Dramatic transient response results from the unobstructed venting of the magnetic structure.

The Pure Titanium former ensures that energy transfer from the voice coil to the cone is maximized. The Supra Magnet structure guarantees motional linearity over the full cone excursion.

An ultra rigid, die cast Zamac chassis and a pure NORSOREX phasing plug complete this design to make it the ideal choice for your next system.



All dimensions in millimeters

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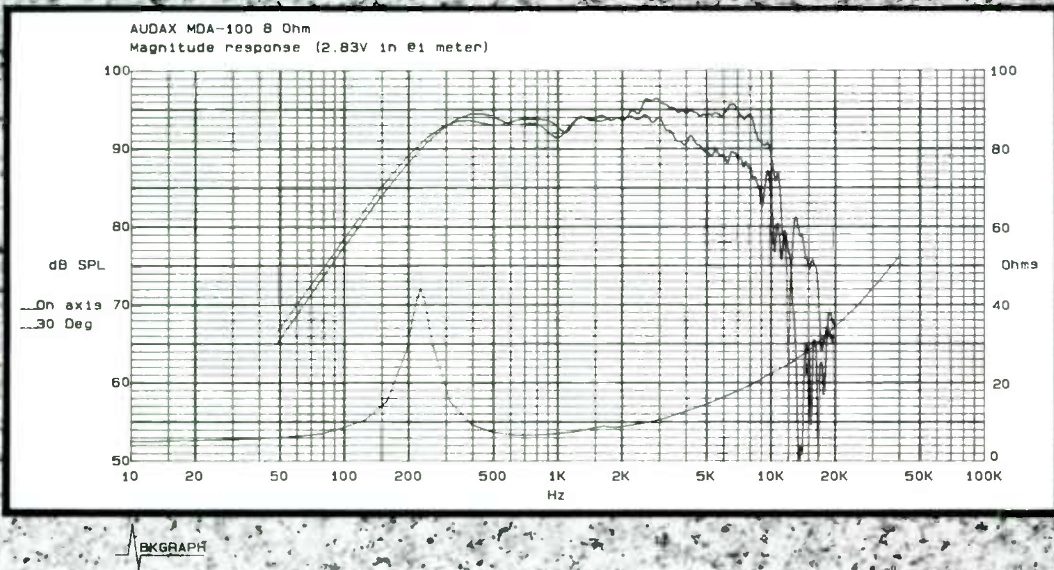
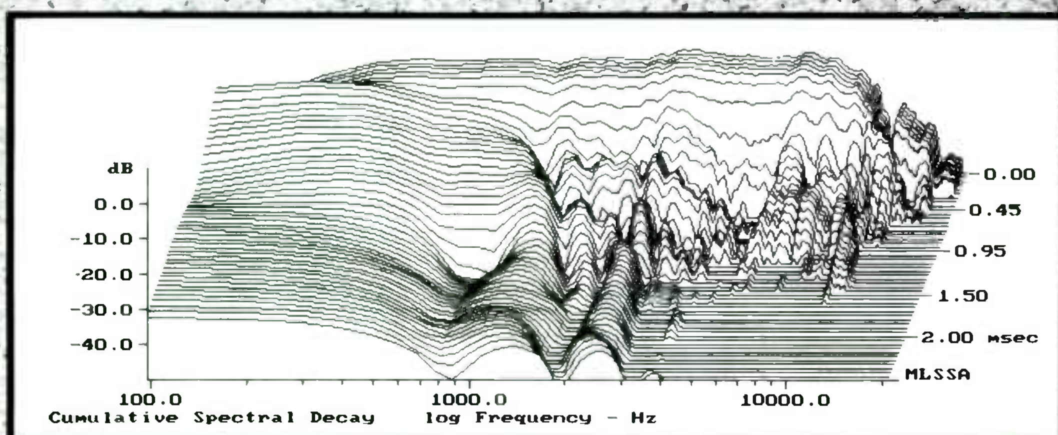
I N N O V A T I O N





Technical Characteristics	Symbol	Value	Units	Technical Characteristics	Symbol	Value	Units
Nominal Impedance	Z	8	Ohms	Voice Coil Length	h	3.2	mm
Minimum Impedance	Zmin	7	Ohms	Number of Voice Coil Layers	n	4	-
DC Resistance	Re	5.2	Ohms	Flux Density	B	1.28	T
Voice Coil Inductance	Lbm	280	uH	Flux in Gap	Ø	0.512	mWb
Resonant Frequency	Fs	230	Hz	Stray Flux	Fmag	-	A/m
Suspension Compliance	Cms	2.0E-02	mN-1	Force Factor	BL	5.72	NA-1
Mechanical Q Factor	Qms	4.06	-	Height of Magnetic Gap	He	5	mm
Electrical Q Factor	Qes	0.65	-	Linear Excursion	Xmax	1	mm
Total Q Factor	Qts	0.56	-	Diameter of Magnet	ØA	84	mm
Mechanical Resistance	Rms	0.80	kg/s	Height of Magnet	Hb	15	mm
Moving Mass	Mmd	2.5E-03	kg	Weight of Magnet	-	0.348	kg
Effective Piston Area	S	58.1E-04	m2	Characteristic Efficiency Level *	E	92.5	dB
Volume Equivalent of Air at Cas	Vas	9.4E-02	m3	Nominal Power Handling	P	60	W
Voice Coil Diameter	d	25.3	mm	Mass of Speaker	-	0.98	kg
Voice Coil Former Material	-	Titanium	-	* adjusted for 1 Watt reading at 1 meter			

PRESTIGE MDA-100

4" MIDRANGE

polydax SPEAKER CORPORATION

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Wilmington, MA 01887

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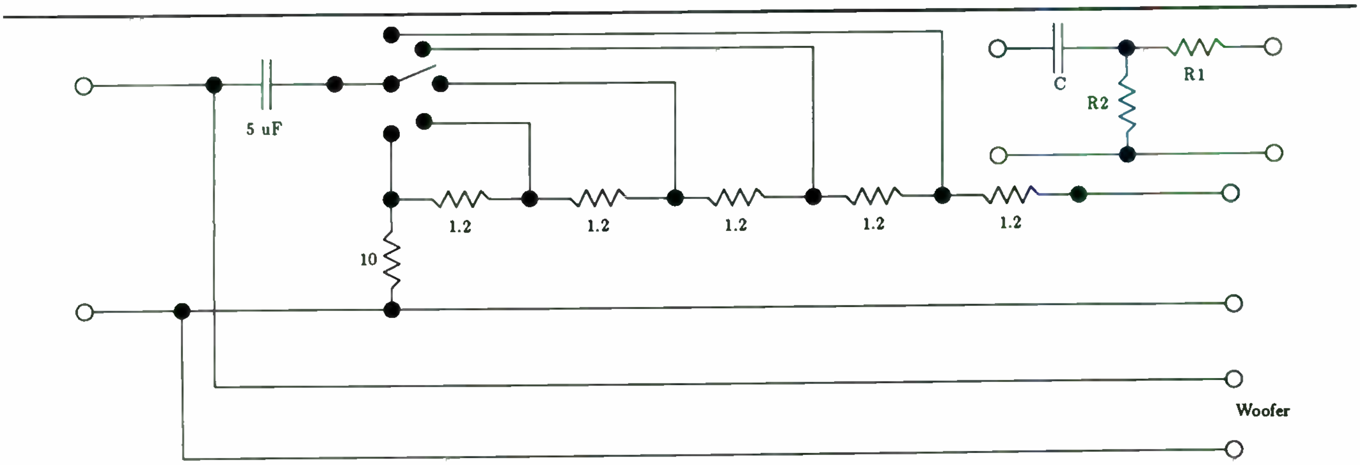

FIGURE 3: Stock Dynaco A-25 crossover schematic (simplified network at top right).

TABLE 2

CROSSOVER POINTS

R1 (Ohms)	R2 (Ohms)	Insertion Loss (dB)	Crossover Freq. (kilohertz)
11.0	10.0	4.7	1.5
8.8	12.2	3.8	1.7
6.6	14.4	2.9	1.9
4.4	16.6	2.0	2.1
2.2	18.8	0.9	2.5

Continued from page 54

came up with an impedance model for the D28-AF (*Fig. 5*). We used this model and the SPICE network modeling program to determine crossover performance.

MAKING THE MODIFICATIONS. Removing the 87Hs, which were sealed to the baffle with a viscous sealant, I noted the two A-25s weren't quite identical. One speaker's tweeter was mounted ¼″ further forward than the woofer. The hole for this tweeter wasn't bevelled to finesse the tweeter into the baffle, but instead had straight walls. This system also used a non-polarized electrolytic capacitor in its crossover. The other A-25's tweeter was mounted at the woofer's depth and the mounting hole was bevelled out to the baffle. The crossover used what looked like a film capacitor. Before mounting the new tweeters, I bevelled the first unit's tweeter hole, brought it to the same depth as the second, and replaced both capacitors.

The D28-AFs *almost* drop into the 87H's mounting positions. I opened the hole ¼″ with a medium grit sanding drum mounted on a power drill. Once the tweeter fit comfortably, I drilled holes for the mounting screws, caulked the rear of the tweeter mounting plates with silicon rubber, soldered the signal leads, and screwed the tweeters in place.

To complement the new tweeters, I upgraded the crossovers with Solen Chateauroux polypropylene capacitors, also available from Madisound. Since the Dynaudios could accommodate a lower crossover, I decided to use a slightly larger 6μF capacitor, lowering the crossover point to 2.1kHz for the −2dB selector switch position. Insertion losses and crossover points for the modified crossover are in *Table 2*. The capacitors were positioned inside the box near the selector switch, and were fixed in place with silicon caulk.

HOW THEY SOUND. I played with the crossover selector switch, settling on the position that's one notch above the normal—where the modified A-25 is head and shoulders above the stock model. The new tweeters provide transparency and air common in speakers costing 10 or 20 times more. Horizontal imaging is solid, but it lacks depth, perhaps due to cabinet diffraction effects. While bass response is still missing that bottom octave, it is as tight and clean as it has ever been.

At first I put the speakers on the floor about two feet from the side wall, and a foot from the rear wall. There, the midbass was a bit too full. Then I placed the speakers on 9″ stands, putting the tweeter about 26″ off the floor and angled slightly back. This, coupled with moving the speakers further out into the room, made the fullness disappear. The result: a nicely balanced spectrum, and a very pleased music fan.

FUTURE PLANS. When I continue the upgrade, I'll remove the A-25's grille moldings and add some felt or Soundcoat acoustic foam around the tweeters, with an eye toward reducing cabinet diffraction—and hopefully improving imaging. The next step will be replacing the 25's TV-EW woofer with its more modern counterpart, the 25 F-EW, which has an

Continued on page 87

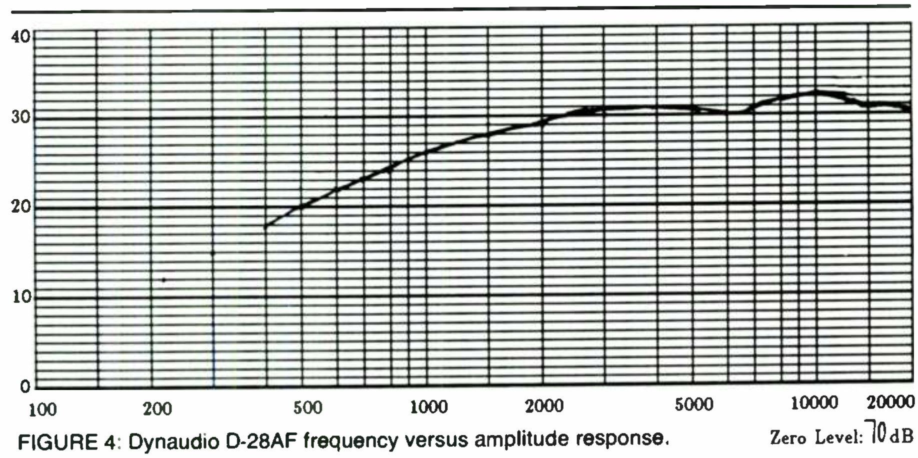

FIGURE 4: Dynaudio D-28AF frequency versus amplitude response.

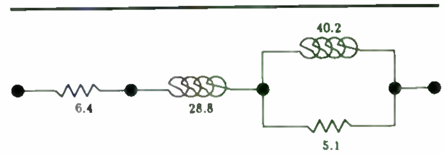

FIGURE 5: Simplified SPICE impedance model for Dynaudio D-28AF.

Kit Report

Audio Concepts' Sapphire II

By Gary Galo, Contributing Editor

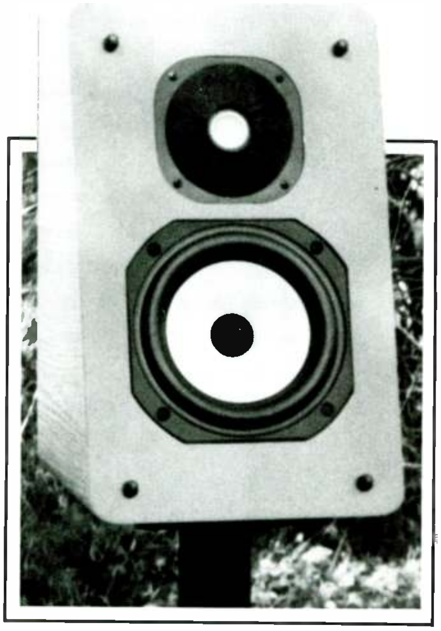

PHOTO 1: Front view of the Sapphire IIs mounted on the AC Stands. The grille cloths are attractive, but should be removed for the best stereo imaging.

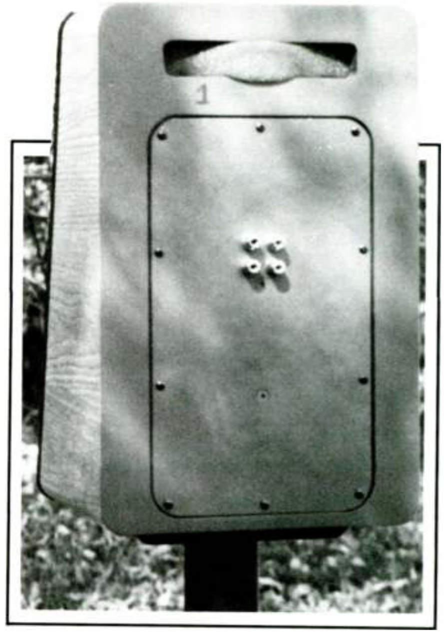

PHOTO 2: Rear view of the Sapphire II showing the four gold-plated binding posts, which allow bi-wiring. The rear panel, fastened with 12 screws, doubles as the crossover mounting board.

Manufacturer's Specifications: Tweeter: Modified Focal T120KT; Woofer: Focal 7K011DBL; Frequency response: 65Hz-20kHz ± 3dB; Crossover: Minimum phase design; Tweeter: Quasi first-order; Woofer: First-order on voice coil 1; Upper midrange response shaping network on voice coil 2. Crossover frequency: 3kHz; Sensitivity: 89dB, 1M/1W; Impedance: 7Ω nominal, 4Ω minimum; Dimensions: 16″ × 10″ × 10″; Height on stands is 40″.

Price: Full kit—$699/pr. plus $30 shipping; Parts kit—$479/pr. plus $15 shipping; Assembled—$759/pr. plus $30 shipping; Optional stands—$99 (black), $119 (white) plus $15 shipping. Manufacturer: Audio Concepts, Inc., 901 South Fourth St., La Crosse, WI 54601, (800) 346-9183 (orders only), FAX (608) 784-6367, technical help, (608) 784-4570.

Audio Concepts has been offering high-quality loudspeaker components and kits to speaker builders since 1977. Under the guidance of its president, Mike Dzurko, Audio Concepts has offered loudspeaker builders many kits known for their attention to detail and technical refinement. Supplying drivers and other components, the firm has been selective in choosing product offerings, unlike many other distributors, who offer nearly every driver made by nearly every manufacturer.

The Audio Concepts catalog contains what they believe are the best products in each component and price category. They carry several products not found in other distributors' catalogs, including AC Spikes for coupling speakers to the floor, gold-plated spade lugs which will fit around the largest amplifier binding posts, AC Foam for enclosure lining and room treatment, as well as the excellent AudioQuest loudspeaker cables.

The Sapphire II is based on Audio Concepts' older Sapphire loudspeaker, but is housed in a smaller enclosure. The Sapphire II falls into the "mini-monitor" class, and can be used as a stand-alone system. They can also be used as satellites, along with a pair of subwoofers, if you wish truly deep bass. My review samples arrived in four well-packed cartons, one containing the two enclosures, one containing the drivers, crossovers, and hardware, and two containing the optional black stands. When purchased as a full kit, The Sapphire II is just that. Every item needed to complete the loudspeakers is included, down to the last screw.

Drivers and Loading

The Sapphire II enclosure design was a joint effort between Audio Concepts and Jack Caldwell, a familiar name to builders of high-quality loudspeaker kits. Caldwell has designed several loudspeakers for Audio Concepts, and is well-known for the SOTA Panorama. Like the earlier model, the Sapphire II enclosure is an aperiodic design containing a vent stuffed with damping material which relieves internal pressure in the region near system resonance. Aperiodic loading provides much better control over the woofer's cone motion than acoustic suspension designs.

In an acoustic suspension enclosure, the trapped air inside the enclosure is quite reactive at low frequencies. Its "springiness" causes the woofer to make large excursions in the area around system resonance. The excessive cone motion, in turn, substantially raises the system's impedance at the resonance frequency.

The Sapphire II enclosures contain a slot in the rear which is stuffed with a foam plug, and they are also heavily damped internally. Each is filled with a synthetic damping material which Audio Concepts calls AC Stuff.

The aperiodic loading effectiveness is illustrated in *Fig. 1*, which is the Sapphire II's impedance curve. The system resonance frequency was impossible to pinpoint. The impedance rises to 5.1Ω between 70Hz-80Hz, with no further rise at any specific frequency in this region. This shows exceptionally well-controlled cone motion at low frequencies. The system is also very low Q. Caldwell claims the Q is slightly higher than 0.5.

The impedance falls to 3.5Ω at 20Hz. Although this is well below the system's low-frequency cutoff, your amplifier will

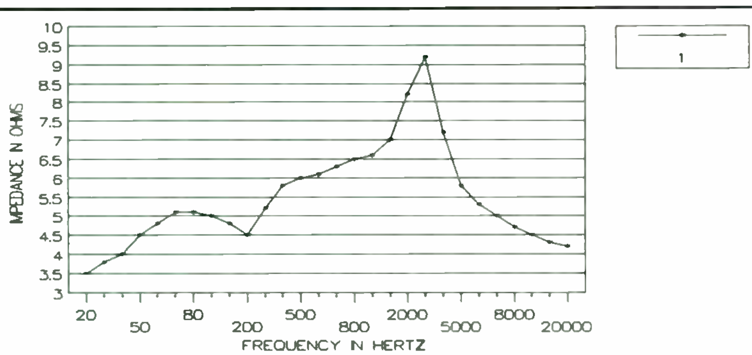

FIGURE 1: Impedance curve for the Sapphire II. Both samples were identical.

still be driving the loudspeaker at this frequency. I recommend a power amplifier with sufficient current capability to drive low impedance loads with low distortion levels. Audio Concepts says as little as 40W per channel is adequate for the II, but recommend 50–150W per channel for optimum performance.

Remember, power output alone is not the issue. An amplifier which delivers 100W per channel into an 8Ω resistor, but falls apart trying to drive a 3.5Ω load, isn't a good choice. A lower power amplifier maintaining low distortion and stability into low impedance loads, will deliver much better performance than a high-power amplifier which can only maintain low distortion into 8Ω resistors. The Sapphire II is not particularly efficient, so a 100W per channel amplifier is *not* overkill.

Each Sapphire II contains one Focal 7K011DBL woofer, and one Focal T120KT tweeter. The woofer cone uses Focal's patented K2 Kevlar 1mm sandwich, consisting of a compound of synthetic resin (serving as a bonding agent) and microballs of foam between two layers of Kevlar cloth. The sandwich combines low mass with excellent rigidity, and the cone is suspended with a rubber surround. The cast frame further improves the driver assembly's rigidity.

The 7K011DBL is a dual-voice coil driver, each having a nominal impedance of 8Ω. Focal recommends designing the crossover so one voice coil operates in both the bass and midrange frequencies, while the other covers low frequencies only. By designing a response-tailoring network for the second voice coil, the low-frequency response of the driver can be extended. The second voice coil has a different purpose in the Sapphire II, which I'll explain shortly.

The tweeter's concave dome, made of Kevlar cloth, is actually larger than the voice coil, allowing the driver to operate as a nearly point source at high frequencies. Focal manufactures several T120 tweeter variations, but the KT version in the Sapphire II has a rear-vented pole piece. Audio Concepts modified the tweeter, adding aperiodic damping and sealing off the rear vent. The result is a tweeter with well-controlled internal resonances. Audio Concepts uses an AC felt tweeter ring on each tweeter to control diffraction.

Crossover Design

Jack Caldwell designed the minimum phase crossover. Audio Concepts does not supply a schematic with the kit, although a pictorial illustration is included in the manual. I sketched out the crossover circuit, but Caldwell wants it to remain proprietary and asked us not to publish it with the review. I believe this runs contrary to the spirit of kit building and the philosophy of *Speaker Builder*, but we have respected his wishes. I don't believe that publishing this schematic does any harm to the designer.

Anyone wishing to steal the design for commercial purposes would surely want to hear the loudspeaker first. You would normally have to purchase the kit in order to do this. After buying the loudspeaker, you will be free to sketch out the schematic yourself. No one would borrow a design strictly on the strength of a review.

The crossover frequency is around 3kHz, and the high-pass filter looks like a second-order, 12dB/octave filter. The tweeter's actual acoustical rolloff, however, is quasi first-order. A first-order, 6dB/octave filter feeds the primary woofer voice coil. As mentioned, the second voice coil is not used to extend the woofer's bass response, instead, a series LCR network forms a small notch filter centered at 3.7kHz. This corrects for a small time domain aberration in this region. The design goal was to reproduce a holographic, three-dimensional soundstage with very precise imaging.

Cabinet Construction

The enclosures, (*Photos 1* and *2*) are superbly constructed. No effort was spared in making the enclosure as acoustically inert as possible. Extensive internal bracing helps eliminate enclosure panel flexing. They are are braced top to bottom, side to side, and front to back. The design uses a sloping front panel, which improves the drivers' alignment by time, and breaks up resonances which can develop in conventional rectangular enclosures.

The enclosure is made of ¾″ medium density fiberboard (MDF). Mike Dzurko said he experimented with several MDF densities before finding the one he believed would best control cabinet resonances.

The sloping front panel is routed to ¼″ to allow mounting the drivers flush. The enclosure's interior is coated with Acoustical Magic, a latex-based paint containing titanium, and other ingredients which resistively absorb cabinet resonances. The brand name may sound like high-end audio mysticism, but it appears to be highly effective.

The cabinets are as attractive as any commercial loudspeaker I've seen. The four front-to-rear corners, top and bottom, are rounded and a one-piece walnut veneer surrounds the top and sides, joined on the bottom where the joint won't be visible.

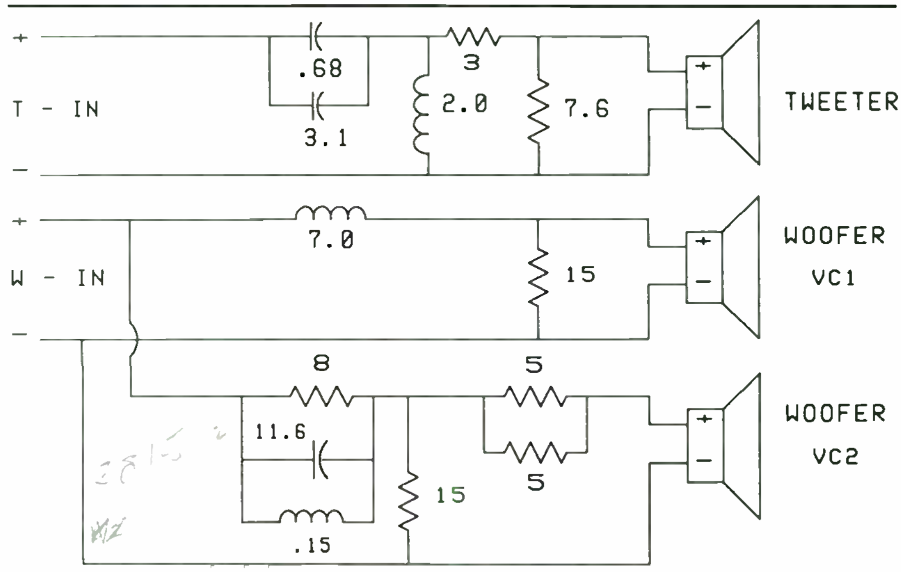

FIGURE 2: The Sapphire II minimum phase crossover. The LCR notch filter on the second woofer voice coil corrects a time domain abberation at 3.7kHz.

The veneer work is *outstanding*. (The joints are so perfect I had difficulty finding them.) The front and back are painted gray, and the attractive black grille cloths can easily be removed. The enclosure is a first-class piece of cabinetwork.

The rear panel has a large routed opening where the crossover board is mounted. The crossover is not mounted onto a printed circuit board, instead crossover components are glued to a two-layer Masonite laminate, which when fastened to the enclosure forms the main portion of the rear panel. Two ½″ PVC spacers are placed between the laminate and the internal bracing. A pair of long screws go through the rear panel and spacers, and are threaded into the internal brace, tightly coupling the rear panel laminate to the internal bracing, reducing the possibility of rear panel resonances. *Photo 2* shows a rear view of the loudspeaker.

The inside of the laminate is coated with Acoustical Magic, and the back is painted gray to match the rest of the enclosure's rear panel. Silicon sealant and epoxy fasten crossover components. The coils are first glued with the silicon seal, then after the silicon has cured four beads of epoxy are added to increase the mounting's strength—yet another step to ensure the absence of enclosure vibration. The crossover components, properly glued, further deaden the enclosure's rear panel. The manual claims this arrangement is sonically superior to mounting crossover components on a printed circuit board, and I agree.

The crossover uses premium grade components, including IAR Wonder Caps and Chatteauroux polypropylene capacitors. AudioQuest F-14 cable is used for all internal wiring, and contains four solid core, high-purity copper conductors. It is a high-quality, cost-effective cable, flexible enough to make it practical for internal wiring.

Audio Concepts made provisions for bi-wiring the Sapphire IIs. Two pairs of gold-plated binding posts are mounted on the rear panel, one feeding the woofer crossover section, and another for the tweeter. The posts are the ones Audio Concepts supplies with their AC Cup, but the plastic cup is not used on the IIs. They are mounted directly on the Masonite. I'm sure Jack and Mike believe, as I do, a plastic cup would compromise the rear panel's structural integrity. The posts (among the finest quality I've seen) stick out beyond the back panel, making easier connections. The heavy-duty posts can accept 10-gauge wire, or be used with banana plugs, or the large gold spade connectors.

Assembly

The kit includes a 15-page illustrated manual covering assembly, setup, and operating instructions. For builders adventurous enough to purchase the parts kit, helpful suggestions for constructing the cabinets are included. Unless you own quality power tools and possess woodworking skills to match, you're probably better off purchasing the full kit with factory-assembled enclosures. Illustrations are included for all cabinet dimensions, including the complex internal bracing.

The manual warns: "These drawings may be used as a guide for building your own cabinets... and should not be taken as certified diagrams..." The complex angles of the sloping front panel and internal bracing will require a fair amount of custom fitting. To duplicate performance the full kit offers, you'll must use the *exact* materials supplied with the full kit, including the same MDF grade. I don't mean to discourage the hard-core builder, but I wish to present a realistic assessment of the task.

Assembling the full kit is an enjoyable project. Although the assembly instructions are generally good, a few points need clarification. What follows are assembly instructions, (in *italics*) along with my

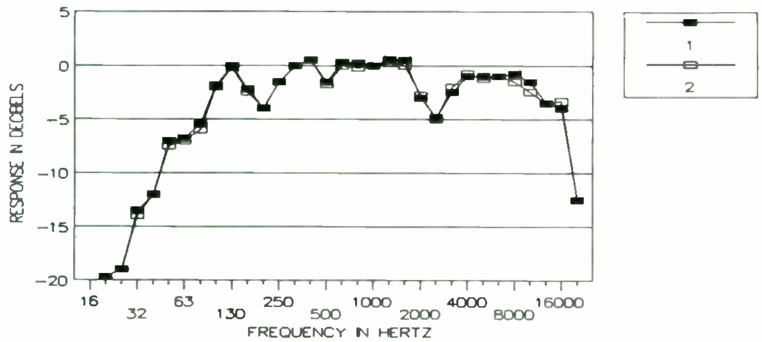

FIGURE 3: One-third octave warble tone response with the microphone on-axis and positioned midway between the woofer and tweeter.

additional comments. I have quoted the manual as written.

1. Carefully unpack your parts kit. Check to see that you have all the parts listed on the parts list. NOTE: Hardware for installation of the speakers is in a small bag stapled to the inside of the cabinets when ordering a full kit. Both of my bags had broken loose during shipment, and I found them elsewhere in the carton. Locate the staples used to fasten the bags to the enclosure and remove them.

2. Vacuum the inside of the cabinets to make sure that they are totally free of any dust or chips.

3. Use silicon sealant to attach the plastic spacers around the two inside screw holes on the crossover board. Note that the longer spacer is for use on the hole closest to the binding posts. Allow to dry. The two screw holes will probably be filled with Acoustical Magic. Ream them out with an awl, or the supplied screws. You may have to bend crossover leads slightly in order to make room for the spacers. To ensure the spacers are tightly coupled to the rear panel, I recommend using long 6/32 bolts, washers, and nuts to hold the spacers in place while the glue is curing. Put washers on the bolts, and insert the bolts through the holes in the rear panel. Place a bead of silicon sealant around one end of each spacer. Put the spacers over the bolts and fasten in place with another flat washer and nut. Tighten the bolts just enough to pull the spacers snug against the rear panel. After the silicon seal has cured overnight, remove the no longer needed bolts.

4. Install the AC Stuff™ into the enclosure. There are four 13" × 18" pieces of AC Stuff™ per speaker. The internal bracing divides the enclosure into four vertical partitions. Install one piece of AC Stuff in each partition.

5. You will notice that there is an aperiodic port on the upper cabinet rear. This is to be stuffed with one 2" × 7" piece of convoluted foam. Refer to Sheet 2 in the back of the manual. The contoured side of the foam faces the inside of the enclosure. Be sure the foam is tight against the enclosure's inside edges.

6. Mount the crossover into the back of the cabinet using foam tape to seal. Do not overtighten. It is important to get a secure air-tight seal. Use caution with the three long center screws. They are inserted in straight to avoid splitting the cabinet brace. Cut a length of foam tape two inches longer than necessary to cover the outer perimeter of the crossover board cutout. Peel off the backing and carefully press the sticky side against the cabinet. Press firmly to make sure the tape doesn't peel off. After covering the opening's entire perimeter, trim the foam to an exact fit. You can even cut it 1/16" longer than necessary. The foam will compress to form a tight fit with the other end.

Carefully push the crossover leads between the AC Stuff and the front/rear brace. Route the wires so the tweeter leads come through the small driver hole and the woofer leads come through the larger one. Place one pair of woofer leads on each side of the brace. Carefully press the crossover board into position, making sure none of the wires are caught between the plastic spacers and the brace. Make sure the foam tape remains in position. Install the 10 black screws around the board's perimeter. Note there are only two long center screws per enclosure.

7. Install the foam tape around the driver mounting holes. The tape should be installed with the sticky side toward the cabinet. It should be such that it is on the outside edge of where the driver will be. See notes on installing tape, which I added to Step 6.

8. Hook up the leads from the crossover to the tweeter. The tweeter has a polarity marking, (usually a red dot), near the positive terminal. Take your time pushing the connectors on, they are delicate. This is probably the hardest part of the whole kit assembly, but Tweak™ or Cramolin™ will help slide the connectors on. Be patient. You may find a small needle nose pliers helps. Install the tweeter using the small screws, and do not overtighten.

The contacts the push-on connectors add will compromise loudspeaker performance, albeit to a small degree.

Audio Concepts, understandably, doesn't wish to bear responsibility for warranty replacement of drivers damaged due to improper soldering technique. If you're competent at soldering, I recommend removing the connectors and soldering the wiring to the terminals to avoid damaging the drivers. First, test each driver's continuity from the terminals to the voice coil using a Volt-Ohm-Milliameter (VOM) on the RX1 scale. There should be very low resistance, and a clicking sound each

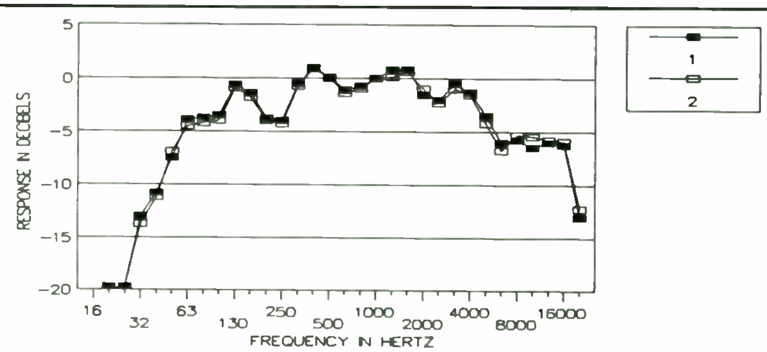

FIGURE 4: One-third octave warble tone response with the microphone 15° off-axis and at a height of 28".

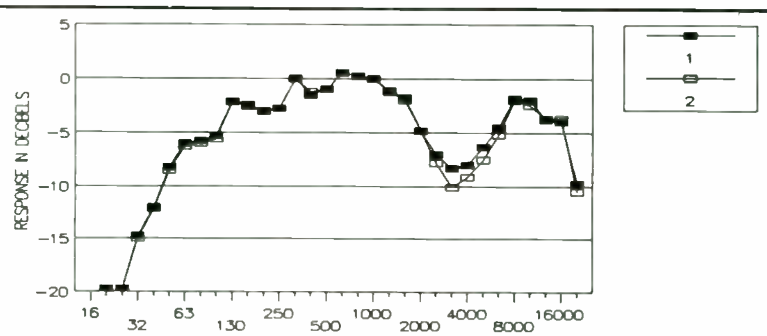

FIGURE 5: One-third octave warble tone response with the microphone 15° off-axis and at a height of 41".

time you make the connection. Most digital meters don't click due to high internal resistance, which is why I recommend the primitive analog VOM.

If the driver is "open" after soldering, you'll know your error, not the manufacturer's, caused the failure. Caveat: soldering the terminals will void the drivers' warranty, so give this recommendation careful consideration. The Focal drivers are well-constructed, so they should stand up to any careful soldering procedure. Pressing the tweeters into the cutout, be sure the wires are not pinched between the driver magnets and the bracing.

9. Attach the wires to the woofer observing the polarity markings near the terminals. Note that there are two sets of wires and that the woofer has two sets of terminals. The connections are interchangeable. All the comments I made in Step 8 apply here, as well.

10. Install the woofers using even pressure on all attachments. Caution: it is easy to press too hard or unevenly and push your tool through the cone. Be careful! Again, don't pinch the wires between the magnets and the bracing.

11. Hook up the Sapphire IIs to your system and try at low volume level to ensure correct hookup.

12. Allow 20–30 hours of break-in time before the speakers sound their best.

When you finish assembly, gently push each woofer cone inward a short way. If the foam stuffing in the aperiodic vent has been installed properly, the woofer will appear sluggish when it returns to its resting position. If it bounces back quickly, you have a leak around the stuffing. You can pull the foam back to ensure the foam is tight against the enclosure's inside edges. Give each enclosure a few knuckle-raps—you'll be impressed by the enclosure's deadness.

The AC Stands are screwed into the bottoms of the Sapphire IIs ensuring tight coupling, but be sure to *center* the stand on the enclosure's bottom. The AC Spikes contain ¼-20 threads and are screwed into the MDF at the base of the stands, allowing easy leveling. Be sure all four spikes make contact with the floor beneath your carpet.

Measurements

I ran frequency response curves on the Sapphire IIs using an Old Colony ⅓ octave Warble Tone Generator (which I built) and a Josephson Engineering Measurement Microphone. All measurements were made at 1W, with the microphone at one meter. The grille cloths were removed. My initial measurement was directly on axis, the mike vertical and midway between the woofer and tweeter (*Fig. 3*). Sample 1 is the loudspeaker I used as the left channel, and Sample 2 the right.

Both loudspeakers were moved to the same position for the measurements. You'll notice the two samples are within 0.5dB of each other throughout their operating range—very good, indeed. It's easy to misinterpret this graph. There are two noticeable dips in response, one at −4dB and another at −5dB. Notice there is little activity above the 0dB reference (set at 1kHz). Over most of their range, the Sapphire IIs are actually flat ±2.5dB.

Since first-order crossovers are more sensitive, vertically, to microphone (and ear) position than even order crossovers, or D'Appolito arrangements, I thought it would be worth investigating other microphone position responses. Caldwell told me the loudspeaker's high-frequency balance was best with the ear 15° off the tweeter axis. He recommended "toeing them in" slightly, but having the two speakers' intersection behind the listening position so the listener is 15° off-axis, and the *ideal* vertical position is near the bottom of the woofer.

I normally sit in a director's chair when I'm critically listening. My ears are 41 inches from the floor, one inch above the II's top. I decided to measure them at two vertical positions, both with the mike 15° off-axis. *Figure 4* shows the response at woofer bottom 28″ off the floor. Here, the high frequencies roll off sooner, and the low-frequency roll-off is more gradual, relative to *Fig. 3*.

I also measured response at my normal listening position. This mike position produced the most erratic upper midrange response (*Fig. 5*). *Figure 6* shows the

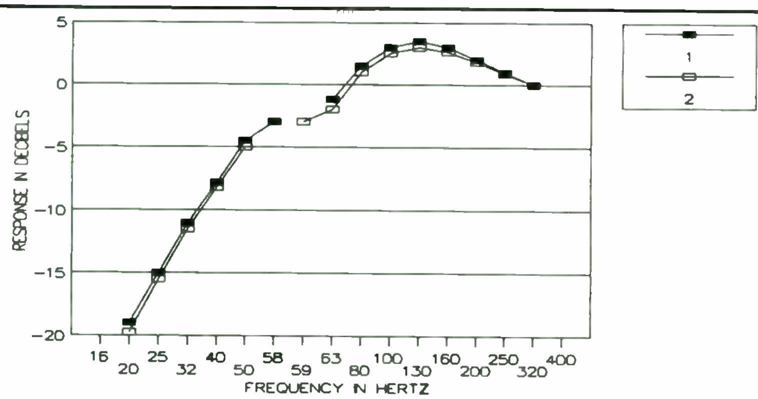

FIGURE 6: The Sapphire II near field response using ⅓-octave warble tones. The curve is expanded to show the −3dB point for each sample.

woofers' near field response from 20Hz–320Hz. Note the horizontal axis expansion at the low-frequency cutoff point. The −3dB point was 58Hz for Sample 1 and 59Hz for Sample 2.

Listening Evaluations

My evaluations were conducted using pre-production prototypes of two Adcom power amplifiers which Victor Campos, Adcom's director of product development, lent to me. The first was the GFA-585, a stereo version of the GFA-565 monaural amplifier, now on the market for several months. The 585 contains circuitry identical to the 565, but has fewer output devices and operates at a lower power output level. It is rated at 250W/channel into 8Ω, but 8Ω doesn't indicate its real capabilities. The 585 will drive low impedance, reactive loads with ease, due to its high current design.

The 585 offers more than brute power. It's a refined amplifier, featuring exceptional inner detail, a large soundstage, natural highs, with dynamics and low-end to burn. Most impressive, it reveals subtle dynamic shadings and articulations other amplifiers mask. The 585 production units should be on the market soon at a price of about $1,200. (A comparably-powered Krell costs nearly $6,000.)

I also used a prototype of the GFA-545 II amplifier, an updated version of Adcom's 100W/channel GFA-545. The old 545 was a good amp, except for a somewhat edgy high-end. The 545 II's high- and low-end, and the imaging have been improved. Both Adcom amps contain circuitry flat to DC, due to the absence of capacitors in the feedback loop. A servo circuit keeps the output DC offset at a low level. A premium quality film coupling capacitor at the input prevents introduction of any DC to the circuitry which the servo might not correct. The 545 II performed very well with the Sapphire IIs.

Other equipment consisted of my "way beyond POOGE-4" Magnavox CDB-650 CD player and an Adcom GFP-565 preamplifier. I also recruited a second pair of ears for evaluative listening. Those belong to Lorelei Murdie, concert halls manager at the Crane School of Music, and an avid audiophile and music lover. Her work exposes her, like myself, daily to live classical music, and she is perceptive and critical about music reproduction.

Her system consists of an Adcom GFP-565 pre-amp, a POOGE-4 Plus CDB-650 and an Adcom GFA-545 power amp. Her loudspeakers are Vandersteen 2CIs. I have spent many hours listening to her system, and know its characteristics well. We evaluated the new Adcom power amps on her system before I connected them to the speakers.

The Real Test Begins

Before listening to the Sapphire IIs, I broke them in for about 45 hours on FM interstation noise. Even after break-in, the sound continued to improve for about a week. Mike said he noticed continuous improvement for up 80 hours, which reinforces my findings. A somewhat hollow quality in the lower-midrange/upper bass region disappeared after complete break-in. All listening was done with the grille cloths removed, (Dzurko agrees this provides the best sound) since the grille frame introduces diffraction which degrades the imaging.

So, how do the Sapphire IIs sound? In a word, marvelous. It is one of the finest loudspeaker systems I have ever auditioned. No loudspeaker in the "mini monitor" class is expected to deliver any real low bass. The Sapphire IIs don't, but their second order rolloff (*Fig. 6*) is gradual enough to provide a semblance of the bass, even if the bottom octave and a half is missing. Their low-end is clean and well-defined.

What strikes you first about the Sapphire IIs is their imaging. They reproduce a three-dimensional soundstage as realistically as any I've heard from a dynamic loudspeaker. Depth perspective is so convincing you'll often think you're listening to a dipole. The depth is so great Lorelei thought it was almost too deep compared to the width. I recently purchased one of the new Mercury Living Presence CDs, the Schoenberg/Berg/Weber disc with Antal Dorati and the London Symphony (Mercury 432 006-2). The spatial cues they reproduced are uncanny. Within the first five seconds of the Schoenberg *Five Pieces for Orchestra*, you'll hear the orchestral sections jump around the soundstage, ending with the trombones way back, and slightly right of center. Try finding a loudspeaker with more accurate imaging than the Sapphire IIs.

I found the depth/width relationship becomes much more realistic with careful speaker positioning. I followed Caldwell's advice, angling them so my listening chair was 15° off-axis. Angled this way, the soundstage is wider, even though there is a very slight reduction in depth. The Sapphire IIs reproduce a more realistic rectangular soundstage with the 15° off-axis positioning. I also found bi-wiring the loudspeakers (double runs of AudioQuest indigo blue cable) opens up the soundstage even more.

The Sapphire IIs have excellent inner detail in the midrange and treble. At moderate listening levels, they have an almost electrostatic-like transparency. They never sound like typical "box" loudspeakers. Audio Concepts has successfully eliminated the sound of the enclosure. Lorelei and I did notice the midrange loses some resolution at higher volumes, particularly if the recording contains a lot of bass. Forcing the driver to attempt to reproduce the low-end taxes the cone, causing some resolution loss in the midrange. They lose far less midrange detail, when driven hard, than most small dynamic loudspeakers. Aperiodic loading used to control woofer cone motion has really paid off.

I'm amazed how powerful these little loudspeakers can sound, within their frequency range limits. Aside from the lack of low bass, the Sapphire IIs fill a fairly large room with clean, natural sound. Their tonal balance is neutral. Various vertical listening positions I tried revealed *no* changes in tonal balance as significant as the frequency response curves might suggest. Ear level is less critical at a normal listening distance than it is when you're only one meter away from the loudspeaker.

No portion of the frequency spectrum is more prominent than any other. The extreme top doesn't have quite the ease or extension of the Dynaudio D-28/D-21 combination I use in my own reference system. The Sapphire II, however, is superior to my loudspeaker (*SB* 1, 2/82) in midrange detail and soundstage presentation. The woofer and tweeter integration is seamless.

They reproduce instrumental timbres with amazing accuracy, again resembling a fine electrostatic in this regard. In fact, I've heard more than one electrostatic with far more sonic coloration than they

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Software Report

It Tells You And Your Speakers Where To Go

The Listening Room, V3.01s by **Sitting Duck Software**, PO Box 130, Veneta, OR 97487. Includes one 5¼" disk and manual. Suggested list price, $29.95.

Reviewed by G.R. Koonce
Contributing Editor

This interesting software package is designed for positioning speakers, and the listener, in such a way as to minimize standing wave effects and other room generated influences. At low cost, you'll be using software which is fun, and produces sound benefits.

This program resulted from Ralph Gonzalez' (math and spatial geometry) and Bill Fitzpatrick's (programming and interface) combined efforts. One part of the program allows you to investigate standing wave effects on the sound you hear. If you own a computer with graphic capability, another allows investigation of early reflection effects, via a Boundary or ER plot.

As explained in the documentation, standing waves can affect your system's apparent frequency response, as well as the transient decay time of your listening environment. The manual discusses these effects, and describes how to use the program to position the speakers and listener for best results. The program can also be used to position turntables and other equipment, minimizing acoustic feedback problems.

The Boundary plot shows the effects of early reflections from the floor, ceiling (optional), side and rear walls. Again, the manual explains what you are trying to accomplish. Sitting Duck Software will include a printed manual, but at this writing it's only on the disk as README.DOC. Note this file is "paged" for simplified printing by entering: TYPE README. DOC < PRN.

Computer Requirements

The program is designed for any IBM-compatible computer running DOS 2.11 or later, and having 256K or more RAM. To take advantage of the Boundary plot software you must have graphic capability. The software supports Hercules, CGA color, EGA color or VGA color graphics, and has printing capability for the text *and* graphics. I have never seen a program in this price range which would print screen graphics.

All review information pertains to running the program on an AT-compatible with EGA color graphics, and containing a co-processor. I have run several versions of the software, but all comments and figures pertain to the latest version which I received, the 3.01s.

Program Description

The program needs no installation, and can be run right from the floppy disk (a copy of course) if desired. Initially, when you run the program the floppy disk should *not* be write protected, as the printer setup is saved to disk. Start the program by typing: TLR, or by calling up the batch file ROOM.BAT (per the instructions, but labeled RUNME.BAT on my disk).

After the screen "greeting," you enter the room dimensions. The program accepts room lengths and widths from 72–420" and notes that the width represents the wall along which your speakers are placed. Room heights from 72–180" are supported with the option to delete height effects for special conditions. The program allows movement of speakers and listener over only one-half of the room dimensions, a limitation which prevented investigation of my usual speaker construction and testing area.

After entering room dimensions, you move on to the standing wave portion. *Figure 1* shows the best my computer could do reproducing the screen. There are two basic modes to choose. The default is the symmetric mode: the two speakers are placed the same distance in from the side walls and equidistant from the rear wall. The listener is symmetrically *placed* along the room width.

This is a good mode to learn, even if it does not fit your listening conditions. On the screen's left is a graph showing H, L, and W symbols for the effects of standing waves on the frequency response over 20–220Hz. You can observe the effects of moving the listener relative to the back wall and the floor, and of moving the speakers relative to the front wall, side walls, and floor.

On my computer, response to moving *anything* was nearly instantaneous, that is, seeing the H, L, and W symbols in their new locations. This makes experimenting with various locations fun and effortless. Note that positions are dimensioned in inches and that you want to use a speaker height which represents the system's low-frequency output locations —generally the woofer or possibly a port.

Pressing "A" puts you in the asymmetric mode: the two speakers can be positioned independently, and the listener moves relative to the side walls. In this case, due to the asymmetry, you'll notice more H, L, and W symbols on the

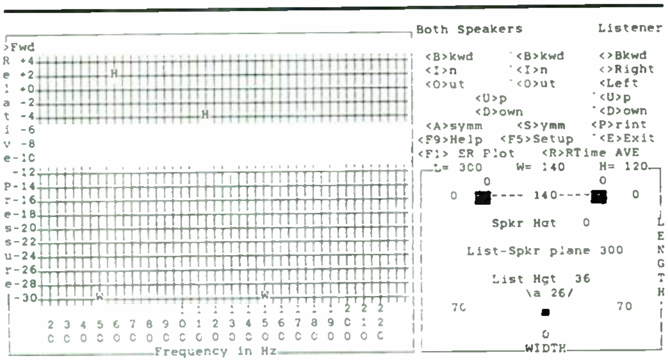

FIGURE 1: Screen for standing waves.

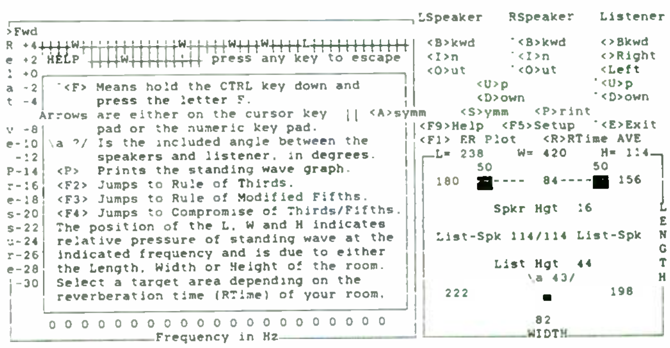

FIGURE 2: Help screen.

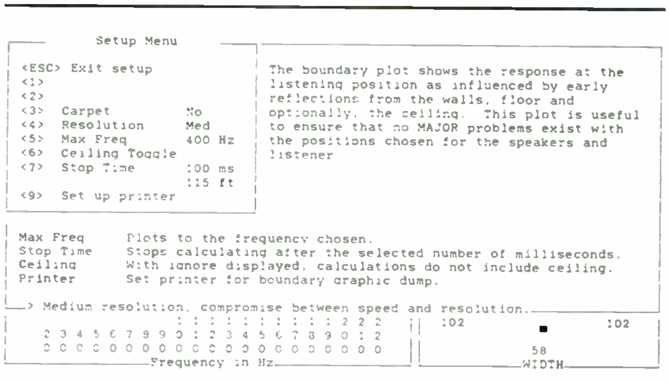

FIGURE 3: Screen for setup menu.

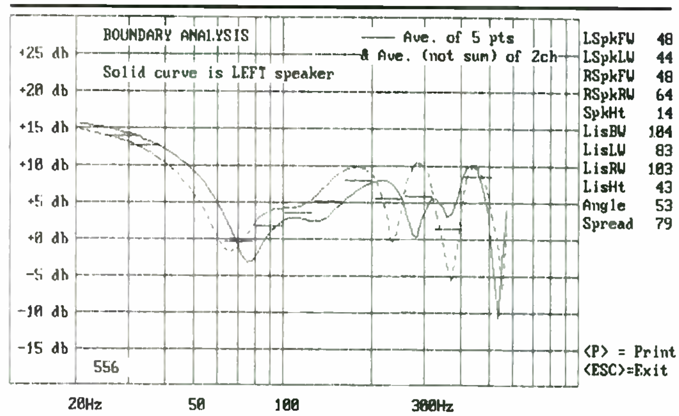

FIGURE 4: A complex boundary plot.

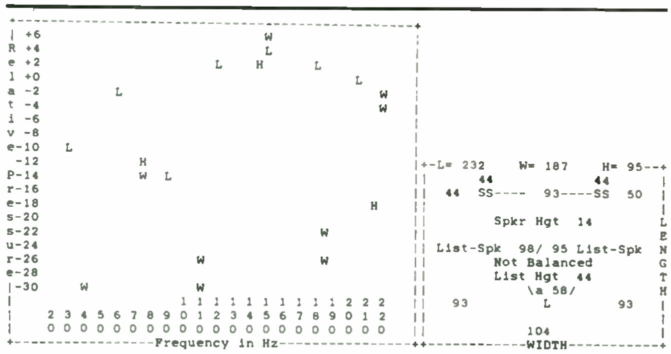

FIGURE 5: Standing wave plot of new room, original speaker positions.

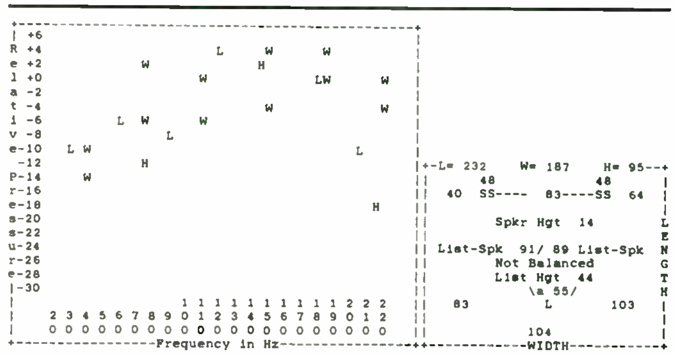

FIGURE 6: Standing wave plot of new room, revised speaker positions.

screen. Symbols resulting from the right speaker are shown in reduced intensity, but will print with the *same* intensity. If you wish to use the Boundary plot, you must move the listener into a "balanced" position, as indicated on the screen's lower right in the layout portion.

The manual covers the fundamentals of what you are trying to accomplish here. Basically, you are trying to move the H, L, and W symbols into a *target area* to eliminate major peaks or valleys. The program's standing wave section gives you the option of selecting three reverberation times, Live, Average, or Dead (by pressing "R"). These set the target area where you're trying to position the H, L, and W symbols at different levels. *Figure 1* shows the target area for average is −6 to −10dB. Reverberation time selection moves the target area only it does not affect the symbols' position.

The screen's lower right (*Fig. 1*) continuously shows the speakers' and listener's configuration in the room. Print the standing wave screen by pressing "P." The first time you run the program you must go into Setup (press F5) to configure the printer. The manual indicates this is not necessary, but the code wouldn't print the standing wave screen until I set up the printer. When you exit the program, a file (BOUNDPR.INI) will be added to your disk which sets up the printer for the next time.

A Help screen (press F9) is provided. *Figure 2* is my computer's best printing effort. It gives instructions on how to interpret what key combination moves what, and also what information on the standing wave screen means. The F2, F3 and F4 keys allow you to experiment with special preset speaker/listener positions, all explained in the manual. They only work, however, in the symmetric mode. You can escape from these special modes by pressing "A," then returning to symmetrical mode by pressing "S."

The program's second major portion is the Boundary plot, accessed by pressing F1. This section requires computer graphics capability. As briefly described earlier, the Boundary plot shows the effects of the early reflections from the floor, side, and rear wall, and optionally the ceiling on the frequency response. What you want to eliminate are broad peaks and dips in the lower frequency range.

The Boundary plot takes some time to display, and it's not easy to try all sorts of variations. Options are provided for the Boundary plot, (*Fig. 3*) accessed by selecting setup (press F5) with the following limits:

1. Whether there is carpeting. (Toggle)

Continued on page 66

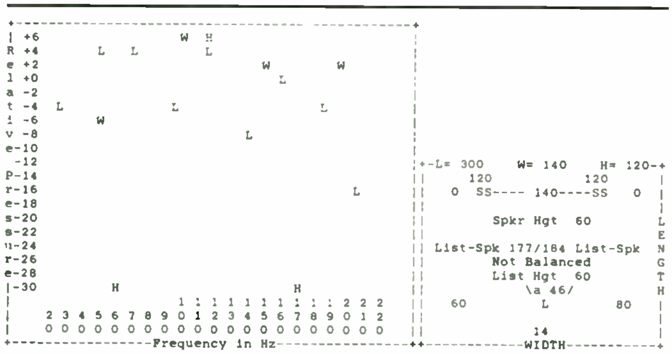

FIGURE 7: Standing wave plot of scaled enclosure, port up 1.4".

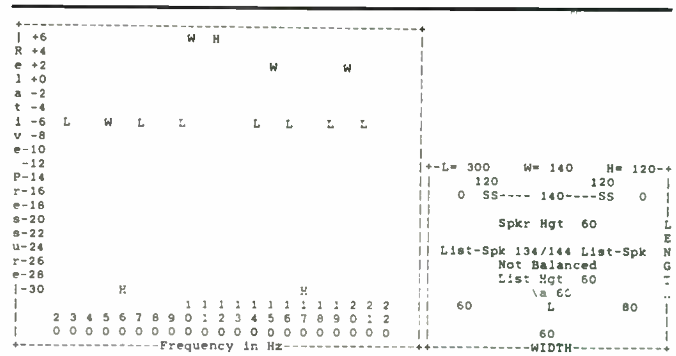

FIGURE 8: Standing wave plot of scaled enclosure, port up 6".

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2. Resolution (low, medium, high, and average).
3. Maximum frequency of the plot (200Hz-1kHz).
4. Whether there is a ceiling. (Toggle)
5. Stop time (2-100mS).
6. Printer setup.

The option meanings are fully explained in the manual, and won't be covered here. Keep in mind options selected can significantly affect the Boundary plotting time. *Figure 4* illustrates a sample Boundary plot using the asymmetric mode. It took 80 seconds to put the two curves on the screen, but this is a complex plot and most should be much quicker. The number in the plot's lower left corner (556 in *Fig. 4*) is the frequency of the minimum dip on the last curve plotted.

Application

Does using The Listening Room really make a difference? It sure does. I had a perfect chance to investigate this. I normally build and test speaker systems in my garage, making it a seasonal activity. This past winter I added a heated room behind the garage so I could work during the winter months. I moved my homebuilt "standard" speakers into the new room for background music and possibly some serious listening.

The sound quality was terrible. Male voice was so bad it approached unintelligibility. Serious listening was impossible, and for background listening I resorted to small desk speakers. The room has a rug on the concrete floor and storage shelves across one end which form a diffuser behind the speakers. The low ceiling and remaining walls are "hard" with little sound asorbing furnishings. I was sure only major room modification could make a significant improvement.

When The Listening Room arrived, I believed it was an ideal chance to see if it could offer any improvement. *Figure 5* is a typical output from the program's standing wave section, obtained by pressing "P." It shows the results for my original speaker and listener placement. There are more symbols shown here because I was using asymmetric mode. Which speaker produces which symbols cannot be distinguished in the printout, but can on the screen.

After some fun playing with The Listening Room, I arrived at the results in *Fig. 6*. I wasn't able to move all the symbols into the Target Area, as the manual warns you. I could not believe, however, *Fig. 6* represented a major improvement over *Fig. 5*. Playing music proved this wrong—the sound was greatly improved. The room needs more work to be "right," but The Listening Room is definitely a valuable tool for setting up your listening environment.

The Boundary plot in *Fig. 3* shows the results for the modified speaker placement. Note how the placement information is presented. Certain program limitations prevented modeling the garage's listening environment which I use in the summer.

What goes on in your listening room also goes on inside your enclosure in standing wave effects. Would it be possible to use The Listening Room to investigate these effects? This is not the program's intended application, and has certain limitations. I gave it a try, though, by scaling all dimemsions 10:1 (frequency will be scaled by the same number).

Figure 7 shows the standing wave plot for a 30" high (length) × 14" deep (width) × 12" wide (height) enclosure. The driver (speaker) was positioned 12" from the top and centered on the front panel. The 6" port (listener) was centered on the front panel, but right against the bottom with its center 1.4" up the front panel. As *Fig. 7* illustrates, this is a terrible port location. All sorts of standing wave patterns are causing high levels at the inside end of the port. This agrees with my experience: locating the inside end of the port close to any wall is a poor choice.

Figure 8 indicates improvement after raising the port's center line 6" up the front panel. Investigating standing wave effects with The Listening Room can be a useful side application of the program—within limits.

Conclusion

The Listening Room includes two demonstration programs, ROOMDEMO.EXE and ROOMDEMO.DOC, which you are free to pass on to friends. If you do not have access to an IBM-compatible computer, Sitting Duck Software will analyze your room. The usual cost is $20, but the company will analyze two rooms for the price of one for *Speaker Builder* readers.

Send a SASE to Sitting Duck Software (address above) for the special work sheet to describe your listening room. Identify yourself as a *Speaker Builder* reader when ordering worksheets or using this service.

It is a good, reasonably priced program, which has the benefit of investigating speaker and listener positioning—no need to push around a lot of furniture. It provides fast screen and print output of standing wave effects. With computer graphic capabilities, it offers a somewhat slower pace on screen and printing Boundary plots. Although there are some placement limitations, The Listening Room makes modeling your listening room fun and worthwhile.

Bill Fitzpatrick, of Sitting Duck Software, added the following comments on the program's capabilities. The program does not require nor recognize a co-processor. The latest version allows listener movement throughout

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Product Review

For Perfection, Grille Your Own

By James T. Frane

When you've completed those new speakers, you may want to add the finishing touch by making grilles. Perhaps the fastest and easiest material to use is acoustically transparent open-cell plastic foam. AR, JBL and other loudspeaker manufacturers have used them in the past. Unfortunately, the sole source for this type of material seems to be Radio Shack. I say unfortunately because it would be nice to have a variety of choices.

I decided to investigate Radio Shack's grille foam—which I'll refer to as RS—to see how well-suited it was for use as speaker grilles. I was particularly interested in its effect on frequency response and imaging performance. I already have grille frames for my speakers that consist of a particle board frame covered with polyester cloth. I conducted listening evaluations and made on- and off-axis frequency response measurements to compare RS with the particle board/cloth grilles and with the speakers with no grille installed.

Available in either brown or black, RS has a strip of adhesive-backed Velcro to hold the foam to the front baffle. The back surface is flat and smooth, while the front is a pattern of raised squares created by deep grooves cut vertically and horizontally. The foam is transparent through the grooves, but nearly opaque through the squares.

Using a sharp knife, I cut the foam to size. Next, since my tweeters are of the dome type and protrude slightly from the face of the front baffle, I skived off just enough of the material on the backs of the foam grilles to ensure clearance for the tweeter domes. I then applied the Velcro strips to the front baffle at a few places, installed the RS, and sat back to listen.

A slight but definite shift in the frequency balance occurred. With the speakers aimed at the listening position, the upper mids to the treble range were a little less prominent with grilles installed. With the speakers toed in so that they crossed in front of the listening position, the upper bass region seemed to be boosted, with little or no differences at the mid to upper ranges of the spectrum, compared to having no grilles installed. In both cases, I found no appreciable differences in frequency response between the RS and stock grilles.

Imaging, however, was a different story. Both the soundstage width and depth were diminished with the RS as compared to either the stock grilles or no grilles. I was a bit surprised at this, because the RS was advertised as being acoustically transparent, and also because it did away with the particle board frames which might otherwise cause diffraction and deteriorated imaging.

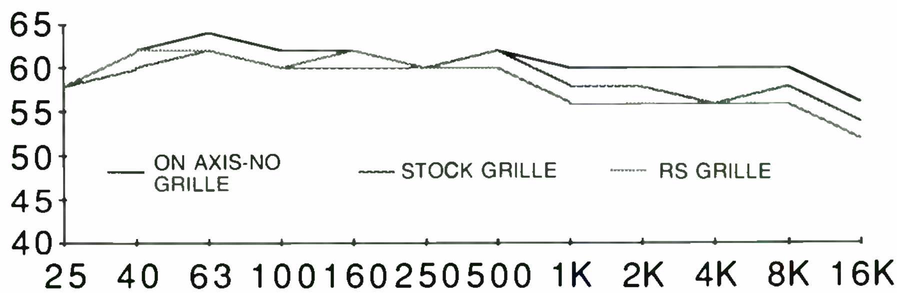

FIGURE 1: Comparative on-axis frequency response curves.

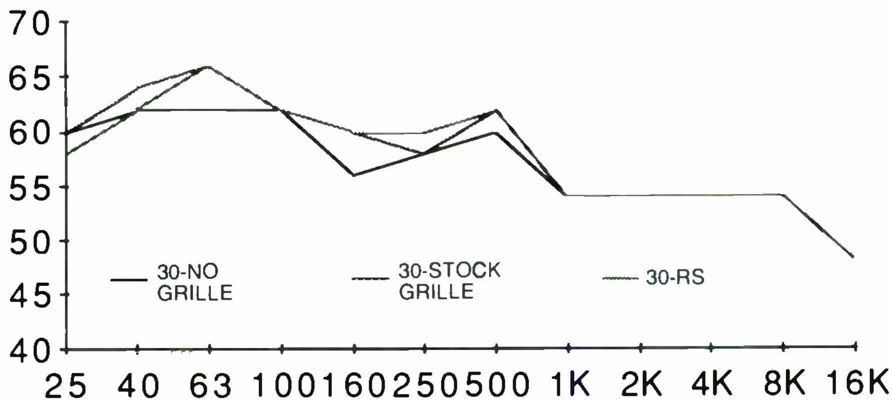

FIGURE 2: Frequency response of each configuration.

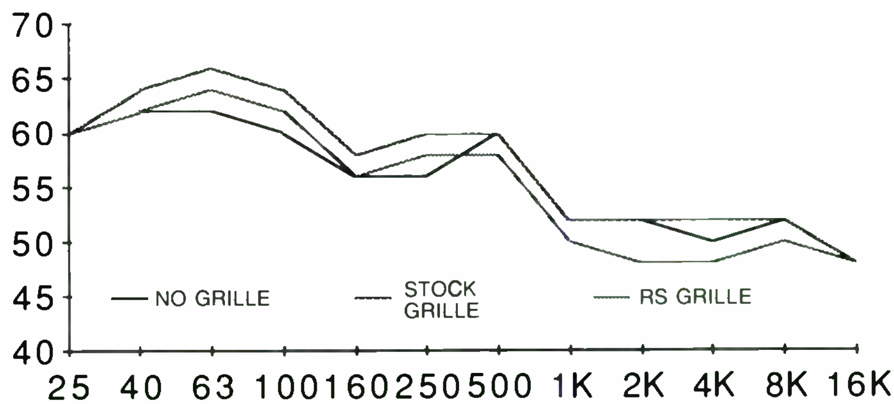

FIGURE 3: Plot of frequency response at 45° off-axis.

Measurement Set-Up

Since each configuration sounded slightly different, I made frequency response measurements to determine why. I took measurements on axis, at 30°, and at 45° off the speaker axis. All readings were taken with the other speaker silent to avoid delayed-input errors.

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For all measurements, I positioned the microphone 24″ from the front baffle at a height midway between the tweeter and the midrange/woofer. The sound source was the built-in pink noise generator of an ADC SS-525X equalizer/analyzer. The measurement readouts were taken from the fluorescent bar graph frequency response display of the same unit—which is graduated in 2dB increments—using the calibrated microphone to match this equalizer.

Measurements

Figure 1 shows the comparitive on-axis frequency response curves with the stock grille, no grille, and the RS. The bare speakers provided the response nearest to flat. Some attenuation of frequencies above 1kHz resulted with both the stock grille and with the RS, the RS having the more detrimental effect.

Figure 2 shows the frequency response of each of the configurations, with the microphone 30° off-axis. Here, both the stock grille and the RS peak at 63- and 500Hz.

Figure 3 plots the frequency response curves at 45° off-axis. As you can see, everything evens out a bit, with the stock grille having the marginally smoothest curve above 1kHz. The RS also introduces attenuation of some frequencies, particularly above 1kHz. It is not as acoustically transparent as it could be, probably because of the block pattern cut in the front surface of the foam.

On the plus side, however, RS is inexpensive, readily available and convenient to use. And, if its effect on frequency response is complementary to your speakers, this material might actually improve their performance.

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Kit Report

Focal Egg Update

By David W. Davenport

Normally, when I complete a review for *Speaker Builder* I move on to my next project. In the case of the Focal Egg II, however, which I reviewed in *SB* 6/89, a few loose ends needed tying up.

The first was a request (*SB* Letters 1/90) by reader Mark Skiles that I evaluate the cellulose 7C014-DBE driver in the Egg II. Due to the success Dave Wilson, among others, had using cellulose-coned drivers in their designs, I agreed an evaluation of the 7C014-DBE was in order.

I requested a pair of drivers from Focal, and Kimon Bellas was kind enough to import them from France. They are not now generally available in the USA. The 7C014-DBE's ribbed, doped paper cone is thinner and more flexible than the Neoflex cone of the 7N412-DBE. The dust cap is sealed, similar to the dust cap on the older 7N402-DB.

The 7C014-DBE's sound is pleasant, with a lot of space and ambience. It exhibits a "laid back," softer presentation, compared to the Neoflex unit. The 7N412-DBE, however, provides better dynamics and more "authority" along with better detail definition. The Neoflex driver also has better overall tonal balance, as well as deeper and cleaner bass. The cellulose 7C014-DBE is a fine driver which I could live with, and may even prefer in some systems, however, my nod still goes to the Neoflex for the Egg II.

In my *SB* 6/89 review, I reported the 7K011-DBE Kevlar driver exhibited a slightly dark cast in the Egg II. I have since briefly listened to this driver together with the T120K tweeter in a different system configuration, a modified 333 kit. I can't go into detail because I didn't perform a full evaluation, but this configuration didn't exhibit the dark cast which I heard in the Egg II.

I am surprised at the qualitative differences observed, rather than the quantitative effects I expected. I believed that since the three types of drivers were so similar, any differences in the sound of the drivers used in the Egg II could be attributed to the different cone material. It would follow, therefore, observed characteristics would hold true from one system to the next.

This was not the case, and I now realize

PHOTO 1: The cellulose 7C014-DBE in the Egg 2 provides ample space and ambience.

the dark cast I reported was not solely a characteristic of the 7K011-DBE.

A Further Refinement

In *SB* 1/88, I discussed the special considerations of providing impedance compensation for a dual-coil driver. A first-order approximation is possible by connecting the two voice coils in parallel for measuring inductance, and then splitting the compensation equally between the two coils. As reported in the 6/89 review, the result was an 8Ω resistor in series with a 22μF capacitor across each coil.

A further refinement (effecting a small difference) provides the following: a 10Ω resistor in series with a 30μF capacitor across the coil driven through the 2mH inductor; and a 4Ω resistor in series with a 52μF capacitor across the coil driven through the 4mH inductor.

I'm sure you are familiar with the Focal Aria Seven, a D'Appolito design using a pair of 7K011-DBLs and a T120K tweeter—the same tweeter the Egg 2 uses. In the Aria Seven's design, Joe D'Appolito chose to provide compensation for the T120K's resonance peak. This compensation takes the form of a series resonant circuit consisting of a 5Ω resistor, 1.2mH inductor (including 1.7Ω inherent resistance), and a 46μF capacitor. Curious about this compensation's effect, I ordered a pair from Madisound and installed them in the Egg IIs.

I was surprised at the effect. The sound was generally smoother, but that wasn't what impressed me. Rather, it was the effect on the ambience, which was cleaner and better focused. The depth and width presentation was strikingly improved. I could sense the location and dimensions of empty space—instruments existed within this space. I sum up the result with a comment from my listening notes: "more musically involving." I strongly recommend this modification to anyone with a T120K in their system.

CONSUMER ALERT: A fellow speaker builder, in whom I have complete confidence, has reported a potential component interaction problem. The problem is a break-up of the sound, along with high distortion. As far as he can determine this only happens when a dual-coil driver is connected to a vacuum tube amplifier through a long (approximately 15-ft.) high-capacitance cable.

He recreated the problem with two amplifiers, as well as two models of dual-coil drivers. I haven't experienced the problem in my system, which uses seven tube amplifiers and four dual-coil drivers. The difference is I use a 5-ft. length of Monster Powerline II between my amplifiers and speakers.

SHY AUTHORS
SEND YOUR LETTER TO THEM VIA US—with your STAMPED ENVELOPE

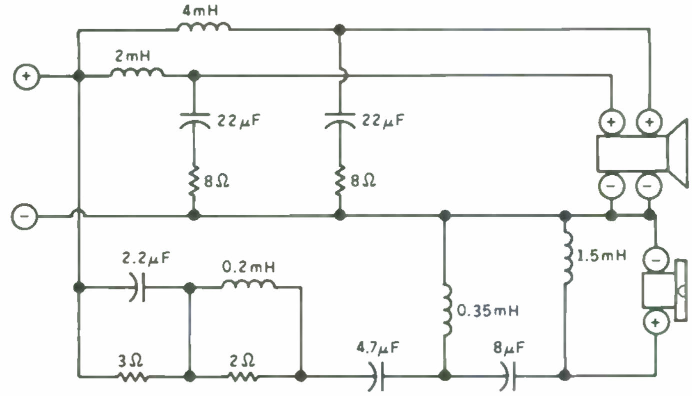

FIGURE 1: The original schematic.

SB Mailbox

Continued from page 3

5. I have tested two samples of the short coil version of the TX1125JSN midrange. In free air, the resonance is about 155Hz with a Q_T of 1.0. Enclosed in SEAS' subenclosure, the resonance is about 185Hz with a Q_T of about 1.2. This would require the following circuit adjustments:

C64, 65	0.001µF
C63	0.056µF
C66	0.33µF
R63, 64	113kΩ
R65, 66	453kΩ
R67, 68	19.1kΩ

The long coil version is still listed in the A&S Speakers catalog. I believe that unit is preferable since it allows experimenting with lower crossover frequencies.

6. An op amp, widely available, and which can also be used is the LF353. Its performance is similar to that of the TL072.

Fernando Ricart
Voorhees, NJ 08043.

tsk, tsk

I've been a *Speaker Builder* subscriber for several years, and have always enjoyed receiving the latest issue. But the issue I just received (*SB* 4/90) was very disappointing.

On the cover is what looks like a penitentiary surrounded by a barbed wire tank trap. I'm not interested in grape cultivation. Shouldn't there be a photograph on the cover more representative of the magazine—namely a "loudspeaker?"

The editorial on page 8 also strays from *SB* precepts. I really don't want the magazine to tell me which amplifiers, cables, and cartridges, I should be using. Numerous other audiophile publications thoroughly cover system integration and use, most of which I already ascribe to.

In Mailbox, pages 87-91, Mr. Cockroft and Mr. Nousaine seem to have nothing better to do than insult each other's alignments. Why don't they quit mincing words and shoot it out? Not with bullets but with speakers. How about an independent panel reviewing each one's speaker project, and announce a winner? In the future I'd like to see less hostility between *SB* contributers.

Alan Ersen
Sacramento, CA 95823

Speaker Builder *4/90's cover is a view of Skywalker Ranch, the Lucasfilm headquarters building where sound reproduced by loudspeakers is of vital interest. I trust California's department of tourism will not hear about reader Ersen's disdain for two of California's principal exports. —Ed.*

THE MUSICAL DONUT

Two years ago, I built two Klipschorns. They have everything a music lover could want: dynamic range, bass response, and low harmonic and intermodulation distortion. My wife, a string teacher, who plays in several local symphonies, uses the system during practice. She says it is the closest thing to a real orchestra she has ever heard.

Being a perfectionist, I believe there is room for improvement. There is a definite "hole in the middle," (the corner speakers are 26 feet apart) and I need a center speaker to develop a better wall of sound.

The question is this: Do you recommend your Show Horn (*SB* 2/90) for filling the void between two Klipschorns? Data in the article makes it appear to be ideal. Would you recommend your midrange horn for use with the bass horn, and which one? Which tweeter?

L. Paul Monohan
Reston, VA 22091

Contributing Editor Edgar replies:

Twenty-six feet is obviously too much separation for good stereo. Two solutions come to mind. First, build two artificial corners, such as recommended in the Paul Klipsch interview (*SB* 4/89), place your corner horns in them, and reduce the separation until "the hole in the center" is filled in to your satisfaction. Depending on your room decor, this solution may or may not be a good one.

The second solution is the route you mentioned. The "show horn" would be a good candidate for a center-fill bass horn with its rectangular shape. Yes, my mid-horns are a valid choice. For the tweeter, I am afraid your choices rapidly narrow down to the venerable T-35.

I recommend that you closely examine artificial corners. Not only is it less effort and money, but I've always liked two-channel stereo for the best imaging. You could follow Klipsch's recommendation in the interview for electronically generating a center channel, but imaging quality suffers.

DRIVERS' RANGE

I built your compact transmission line subwoofers (*SB* 1/85) using 8" drivers. Now I would like to use 10" drivers. Is it possible to use dual 10" drivers, and which 10" drivers would be the best?

I have just completed the SWAN satellites and plan to use your subs, since I was so pleased with the results of my first pair, which were smooth and seamless.

Joseph Jennings
Tacoma, WA 98467

Craig Cushing replies:

Enlargement of my TL subwoofer design is practical and relatively easy. I've already modified the box to accommodate a pair of 8" drivers, (the 64²" cross-sectional area is tailor-made for such a modification) and further upsizing to utilize a pair of 10" drivers would be worthwhile. Naturally, the box would also need some lengthening to take advantage of the driver complement's likely lower F_S.

For proper flow, increase the line cross-section to 10½-11" square, (which would substantially enlarge the cabinet's footprint) and make sure the chamber behind the woofers is taller to accommodate both drivers. Stacking the drivers vertically is probably the easiest way. A cabinet height increase of 6-8" would probably be sufficient to optimally extend low-frequency response. You must, however, calculate actual line length based on the F of your drivers' F_3.

My first choice for drivers would be the Eclipse 1038s (available from Madisound or Meniscus). They're rugged, accurate, and relatively inexpensive. Gary Galo has tested them and likes them in the TL format. Although I haven't heard them yet, specifications for the Peerless CC Line 260 SWR look excellent—particularly the long linear excursion. I don't think you'd go wrong using either driver.

Let me know how your project comes out.

WHAT PRICE SYMMETRY?

I have been experimenting with many speaker systems for the past 15 years. In 1988, I embarked on a project to build a no-holds-barred two-way satellite system. The result was a system incorporating the Dynaudio T-330 Esotar tweeter and the Eton 7-380/32 7" Kevlar woofer. The cabinet construction is two concentric Sonotube walls with sand and lead sheet in the internal space, and the inner walls coated with Acoustic Magic.

The system is ported with 2" PVC pipe ducting. The crossovers are outboard and are first-order networks at 2.7kHz with impedance compensation. The extraordinary power-handling capability of both drivers makes the 6dB/octave crossover a reasonable choice.

I have been pleased with the results. The sound is smooth, and detailed. These high-quality drivers are as fast and effortless as anything I have heard. I run the satellites down to 80Hz at which point an active crossover rolls them off (24dB/octave) in favor of a pair of subwoofers.

My question is as follows. For the past

couple of years, I followed discussions in *SB* about the symmetric D'Appolito driver configuration. I wonder if this system design would pay dividends in my own system. It would be relatively straightforward to add another Eton woofer to each speaker to produce the symmetric configuration.

My current system, however, requires roughly a 4dB tweeter attenuation to properly match the two drivers. Adding another woofer in series will result in the same acoustic output; adding the second woofer in parallel will result in a 6dB boost to the low end. In either case, I am not certain whether the simple crossover I now use would give satisfactory results.

Does Mr. D'Appolito (or anyone else) have any insights on using these particular drivers. Is there any preferred way to passively cross these drivers, or must I bite the bullet and bi-amp? I believe one could build a really superb system with these drivers—though it certainly is pricey.

Randy Simon
Belmont, CA 94002

Joe D'Appolito replies:

Yes, you could use your drivers in my driver configuration. The system should be designed along the lines of the ARIA SEVEN of the Signature 717 systems which use similar drivers. Running the woofers in parallel would give you an extra 2dB sensitivity, which could be used to partially compensate for low-frequency diffraction loss.

The crossover frequency you are using is a little high for the driver separation you'll be forced to accept. I say forced because the T-330 is very large for a 1″ tweeter. You need not bi-amp, but the passive design will be non-standard. I'm afraid you'll have to judge for yourself whether the results are worth the cost.

SIXTH-ORDER SENSE

I have several bass reflex woofers, and would appreciate information about how to construct sixth-order bandpass woofer boxes. I think I've read everything which talks "around" the subject. For ordinary people in the real world, how sensitive are the boxes to tuning?

Thank you for your assistance.

Edward Endicott
San Francisco, CA 94122

Joe D'Appolito replies:

You make a sixth-order symmetric response bandpass subwoofer by cascading a fourth-order acoustic bandpass subwoofer with a series LC circuit. That simple description of the sixth-order bandpass, however, belies the design process difficulty. The series LC circuit isn't simply an external bandpass crossover network, but an integral element of the electroacoustical design. In addition to the parameters which influence bass reflex system design, F_{SA}, V_{AS}, Q_{TS}, V_B, F_B, and Q_B, sixth-order bandpass response is also greatly influenced by the resonant frequency and Q of the series LC network.

The sixth-order design has many advantages over the fourth-order design. For the same passband, the sixth-order system can be up to 6dB more efficient. The LC circuit also controls low-frequency cone motion and greatly reduces out-of-band spurious responses due to standing wave resonances in the front volume and organ pipe resonances in the port. Because the series LC circuit Q is easily controlled, it is usually possible to obtain flat response in the passband over a wide range of drive parameters. This should be contrasted with the fourth-order design, where passband ripple is almost inevitable.

A full description of the sixth-order design process is too complex for a reply here, but I am preparing an article on this subject for future publication.

ISOBARIK OPTIONS

I am writing because I like Isobarik speaker design. I read your article, "An Isobarik System," (*SB* 3/85) and have some questions I'm bold enough to trouble you with.

I built a three-way system using Madisound drivers/crossovers. I used their recommendations for the HD2 4B45 10". The results were disappointing. There wasn't much bass, and what was there was muddy (using as a test the 32Hz organ note from Zarathustra on a London CD).

I wrote to Madisound, and at their suggestion returned the drivers for testing. They had quite a different real vs. advertised T/S profile. F_S is 40 instead of 23, Q_{TS} is 0.495 instead of 0.31, and V_{AS} is 56L instead of 268L. So, I rebuilt the boxes with the new figures. The results are better—worth the extra work—but to me they still sound a little muddy in ported enclosures. Is it common for speakers to be so far off advertised specifications? How can one design speaker systems if data is so unreliable, and if one does not have equipment and skills to test them?

Now about the Isobarik. In the interest of deep, clean bass, I have been eyeing the VMPS 15" woofers in the A & S catalog. They are inexpensive enough that I could use a couple, each in subwoofer boxes of modest dimensions. Using Dickason's tables, for a Q_{TC} of 1, I'd make a box of 6.1^3 (minus $1\frac{1}{4}^3$ for the tube, which would be the same as 9.7^3 for a single driver).

The boxes I have in mind would look like *Fig. 1*.

The speakers would fire downward. The rear baffle (the top in this case) will be made of 1" slate. It's polished and quite attractive, and very dense. I'd put 3" ball casters under the speakers.

1. How far above the floor must the

Continued on page 78

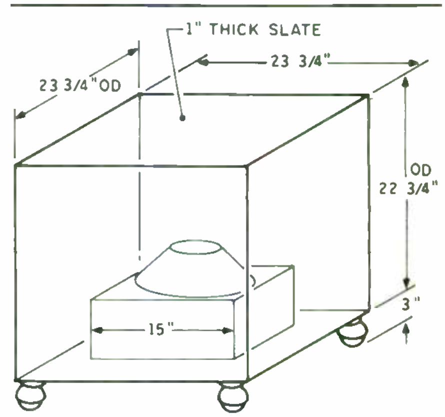

FIGURE 1: Box dimensions and design.

THE INTERNATIONAL RECREATIONAL ELECTRONICS JOURNAL

April 1990

Elektor Electronics USA

Video line selector

Q meter

Automatic mains switch

RS232 splitter

Bridge rectifiers revisited

Coded locking circuit

9 770268 451012 04

Continued from page 75

boxes be to avoid problems? The floor is carpeted (and no neighbors below).

2. Dickason shows a compound setup with the rear woofer back-to-back with the front, out of phase. Is there any advantage to this? I believe one would gain a little internal box volume with a shorter tube front-to-back.

3. Matching the woofer to the satellites, I can see two options, as I shall bi-amp. The first is using an AC Richter Scale as crossover and Equalizer. Looking at Dickason's chart on page 4, there is a bit of a hump with a Q_{TC} of 1. Will the Richter Scale let me flatten that out? If my calculations are correct, I get an F_C of 28.3 and F_3 of 22.25. Have I made a mistake with these predictions?

The second option would be using the Bassis kit described in a recent *Audio* magazine (April, 1990, p. 36) and a crossover kit from Old Colony. I am less inclined to do this because it looks more expensive, and because I'm not sure I have the necessary skill and knowledge to fit a power supply to a couple of crossovers and get the entire speaker system matched up. If I could find a way to overcome these drawbacks, would the second option have advantages over the first?

4. Whichever option I take, will I need to add impedance compensation for the subwoofers? Does the use of electronic crossovers make that unnecessary?

I have one more set of questions. In the interests of cost and size, suppose I scaled down the above and used 12" woofers? I calculate the F_3 in the mid-30s. Would either option above allow me to lower and flatten F_3, and still get clean bass?

If you can offer any advice about the matters I've touched on, or suggest further reading, I will be grateful.

PS) I listen exclusively to classical music, lately mostly chamber music.

Niels Winther Braroe
Charlestown, MA 02192

John Cockroft replies:

Unfortunately, your experience with the Madisound speaker isn't an isolated occurence, though in most cases I believe you could expect better results. I had a similar experience with the Madisound 8152 8" woofer. I purchased one which had: F_{SA}, 41Hz, Q_T, 0.527. I didn't measure V_{AS}, as I was going to use it in a transmission line, where it doesn't matter. Published specs for this woofer are: F_{SA}, 32Hz ± 2Hz, Q_{TS}, 0.35.

I could never get this speaker to sound good in anything. It sounded shallow and muddy. I eventually gave it to a high school friend to play with. Don't misunderstand me, I'm not down on Madisound. I think it's a great company. It's just that speakers aren't boxes of corn flakes.

There are many things which can go wrong when they try to make consistent speakers. Many times one error will cancel another error, and the speaker will become much like its brothers and sisters. Once in awhile everything seems to go wrong (as you and I know). This is life.

There are pitfalls in designing without measurement. These are often minimized by working with simpler systems, such as sealed boxes and my hybrid transmission lines and the aperiodic boxes (such as Dynaudio's Variovent). You may not come up with exactly what you wanted, but it will probably be something you can use. Vented and passive radiator systems and horns don't fare as well with casual treatment, as there are many things to balance. You can't balance very well if you don't know what it is you are balancing.

Apparently, your Zarathustra CD was in better shape than the one which drove Robert Spear (*SB* 3/90 p. 102) to the brink.

The VMPS 15" woofer looks like it would work fine for your Isobarik purposes. I came out with the same figures you mentioned. One word of caution: You said 6.1^3 (minus $1¼^3$ for the tube). That should be *plus* $1¼^3$ The 6.1^3 is net volume.

The box you describe would probably work well. I'd guess the 3" caster spacing would be a pretty good speaker spacing for a floor firing woofer. Other designs have used similar spacing with apparent success. I think the 1.24dB hump around 30Hz will not even be noticed. It will, no doubt, be swamped by standing waves in the room. The ear isn't very sensitive to low magnitude SPL changes at lower frequencies. (I'm not sure which ear I'm referring to when I say "the" ear, but I'm too old to worry about it.)

Since that's what it's designed for, I'd assumed the Richter Scale would probably work well as a subwoofer crossover/equalizer. I am not familiar with the Bassis kit you refer to. There are other, much less expensive ways to go. Marchand sells assembled XM-1 electronic boards for $23.95 each, as advertised in *SB*).

All that is required for a crossover is two boards and two frequency modules (at $1.45 each you could get a pair of 100, 125, and 200Hz modules and use the pair which sounds best). You will also need a ±15V power supply. Marchand sells one, Old Colony Sound has them, and Jameco makes a nice regulated kit for less than $20. I use the Marchand boards and a home brew power supply.

I believe the Isobarik configuration with the two speakers facing the same way allows a shorter tube, since the front speaker's magnet may extend a bit into the rear speaker's cone space. Make sure you leave enough room so the rear cone won't hit the front magnet in the long excursions subwoofers are apt to make.

There is a theoretical advantage to the back-to-back, out-of-phase version. There's supposed to be a cancellation of second-harmonic distortion because of the voice coils moving in opposite directions. In a true push-pull system (where both speakers are radiating) this is probably true. I'm not sure this really happens in the case where one speaker is still in the womb (so to speak).

Using an electronic crossover allows you to ignore impedance compensating circuits (Zobels) as most modern amplifiers can handle quite a range of impedances above the minimum.

If you wanted to use the 12″ VMPS woofer, a box to give $Q = 0.707$ (based on published specs) with $F_C = F_3 = 37.3$Hz would be about 2.4^3 ft. net. This box is small enough to be stuffed with fiberfill pillow stuffing (or Acousta-Stuf) at about ¾lbs/ft³. You could probably get by with a 4″ layer of insulation grade fiberglass on all the walls of the larger box (if economy is a factor).

Remove any paper or plastic vapor barriers from the fiberglass. Be sure to wear vinyl gloves when handling fiberglass. Glue it in place with dabs of white glue, or use something like box nails. Also put some fiberglass on the outside of the tunnel. Line the inside with ½″ felt, or ½″ cotton batting, or 1″ fiberglass. Don't let it interfere with the cones or surrounds. Glue this well so it won't move around when the cones move.

Since you already have a power supply for the crossover, you could easily add a bass boost filter. If you're going to use a summed channel subwoofer you would only need one filter downstream of the resistors which are used to combine the channels. For a box close to $Q_{TC} = 0.707$ a 12dB peak should occur at 0.51 F_C, for a response which will extend to about $0.49F_C$. In your case, the filter serves as an infrasonic filter below 18Hz.

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.)

AREN'T YOU A FAMOUS AUTHOR?

Maybe you've never thought of yourself as an author, but that shouldn't stop you from telling your story. If you can write a letter, you can relate your account of how you solved a problem, improved a lackluster machine or speeded up a process. Maybe you needed a special tool or gadget that nobody makes and you made it yourself. Your ingenuity shouldn't go unrewarded. Write up your project, large or small, and send it along. On really large projects, write a short proposal first to make sure that we aren't about to publish a similar one. We pay $50 per page minimum for articles! So warm up your word processor and share your adventures.

Your amplifier will seldom (if ever) be required to put out the extra 12dB, as there isn't much music around 18Hz. I would first try the system without the filter. It may be satisfactory. (See *SB* 3/90, p. 36 regarding Millard Johnson's Isobarik experience.)

I'm not familiar with the Dynaudio Twynn satellites (other than seeing ads for them), but I don't think speakers with a Q_{TS} of 0.74 are a good choice for serious music. I haven't heard them, but I believe one of the new speakers Joe D'Appolito designed might be just what you need. The 12″ VMPS version of the subwoofer (with or without the filter) would be adequate for chamber music.

DOUBTING T/S

Speaker Builder published my article "Tweeter Q Problems" (5/89), and I have a doubt I hope you can help me resolve. I usually do my designs through simulations, using a SPICE-related program (ECA 2, Tatum Labs). Correct models are a must. The T/S models are specified using the DC resistance of the voice coil as R_E.

However, this is lower than the speakers' minimum resistance, since when the model was developed I used a crude VC model.

I've used a slightly modified value for R_E, in which its value is taken from the speaker's minimum impedance, when I don't have the full values for the VC supplied by the manufacturer. At this writing, only KEF has supplied it to me.

The other components—L_{MS}, C_{MS}, and R_{MS} are then calculated as usual from Q_M and Q_E, at F_S. Is that a valid approach?

Now, the critical question: How would you compare the ARIA 5 to the SWAN satellite, especially the dome X horn tweeters?

Jorge Omar Olivera
Campinas, Brazil

Joe D'Appolito replies:

The T/S model ignores voice coil inductance. When this inductance is included in the equivalent circuit, the minimum impedance above the basic resonant frequency is always larger than R_E, the voice coil DC resistance.

The proper way to model this effect is to include the voice coil inductance in your analysis. If you are interested only in low-frequency performance and voice coil inductance is not excessive, I would use R_E and *not* correct it for the measured minimum impedance.

KLIPSCHORNS REVISITED

I've been a subscriber to *Speaker Builder* almost from the beginning and decided I would tell you how much I enjoy the magazine, and how great it is to be able to exchange information, experience, and opinions. I'd also like to tell you that recently I've run a few classified ads in your magazine and the respondents have been very helpful.

I would like to share my experiences and opinions in this hobby which I've been involved in for the past 10 years.

I've been reading about the late Richard Heyser's work. We have lost one of the great minds in audio, but we were lucky he shared his interest in audio with us. His statement, "You out there, Golden Ear, you know you're right," is so true. It really does come down to the listening experience. Specs and theory are important when used properly, but so often they aren't. Heyser was one of the few who could relate measurements to the listening experience. As he said, "What we are trying to do right now is produce an illusion of a musical event in our minds."

I'd also like to comment about Gary Galo's statements in *SB* 5/89 on Klipsch products and the shortcomings of commercial horn systems. I don't know all the circumstances under which he has heard Klipsch systems, but I believe his statements do a disservice to Klipsch speakers and audiophiles. I own a pair of Belle Klipsch, which I bought in 1985 after listening to a pair. They gave the most realistic reproduction of a musical event I have ever heard. The next closest was a pair of JBL 250ti and Audio Research equipment. I've also heard Acoustat 2+2, Quad ESL USA, and Magnepan MGIII. All provided satisfying music, but I preferred the Klipschorns.

Why do I disagree with Mr. Galo? My experience tells me there are so many variables in musical reproduction anything could cause differing opinions, especially the listening room, speaker location and listener location—all adding up to the "system." I call it a system because these elements are so dependent on each other. Different types of speakers interact with the room differently, dipoles, wide/narrow dispersion (large, flat panel speakers) and controlled dispersion speakers (horns).

Such varied dispersion characteristics require different loudspeaker placements and wall absorption and diffusion treatments. I believe room treatment and proportions are almost as important as loudspeaker selection. It is probably one of the main reasons people disagree about the qualities of loudspeaker types. Small rooms, such as my 7 × 13 × 17-ft. listening area, make it difficult to get the best imaging and tonal balance out of loudspeakers.

I listened to the Klipschorn and also Klipsch Forte in a much larger room (approximately 10 × 16 × 25). The Klipschorns had great clarity, as if the wall behind the speakers had disappeared, replaced by the room in which the recording was made. The instrumental images, especially drums, were properly sized and had clarity and body. Vocals were also well-focused, and tonal balance was excellent. They showed excellent linearity and low harmonic and intermodulation distortion.

When I put the Klipsch speakers in my small listening room, clarity and imaging wasn't as good as what I heard at the dealer's. I tried fiberglass panels on the walls beside the speakers to kill early reflections. After nearly a year of experimenting, however, I realized it was the wrong approach. It was causing a dullness

SHOOT THOSE BEAUTIES

A clear, colorful slide of your favorite *Speaker Builder* project could be worth $50—as well as the pleasure of sharing your workmanship with your fellow readers. We prefer "vertical" (the bottom of the photo on the short side of the slide) format on 35mm but 2x2s are equally acceptable. So fire up your cameras, site your device on a neutral or un-busy background, inside or outside, and send us the results. Mark your submission: "Editorial—SB Covers."

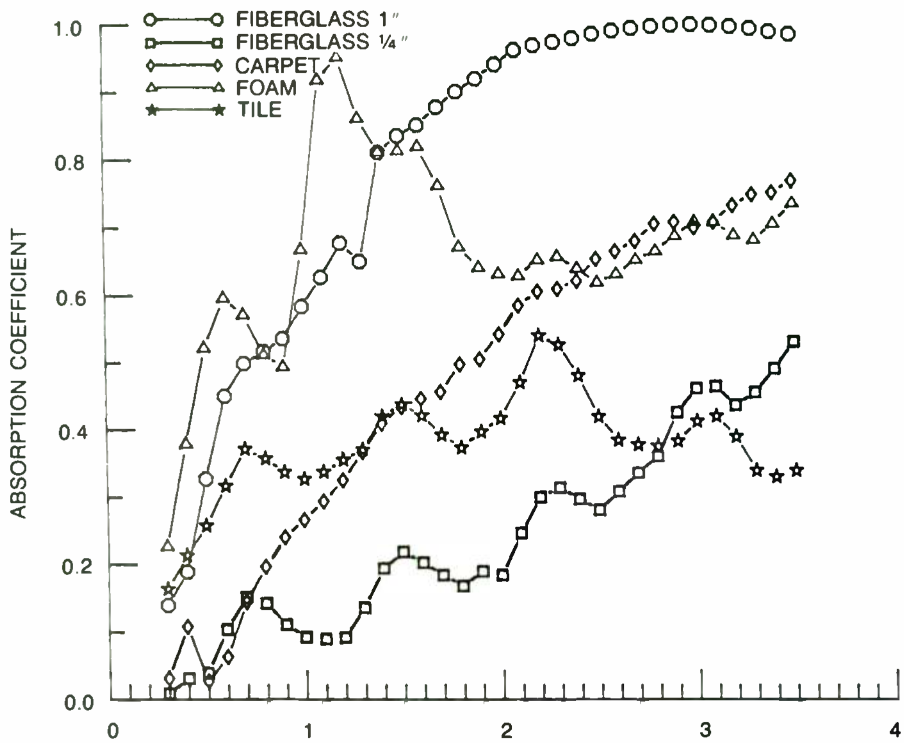

FIGURE 1: Materials' sound absorption capacity against frequency.

to the sound and imaging wasn't much improved.

I removed panels which were close to the speakers, and put them together to form a 6 × 9 area behind the speakers to help kill the slap echo and early reflections. Corner placement seems to help focus the bass by controlling the radiation angle and giving the most extended bass. I regained the tonal balance and imaging improved greatly. I'm now close to getting the sound I heard at the dealer's.

I plan on using some kind of diffusion on the walls, which I believe will get me closest to the sound of a large room. I could easily have blamed earlier performance problems on the speakers. We must, however, look at the speakers and room as a total system, as I was to learn.

Michael D. Beasley
Alcoa, TN 37701

A FEW LOOSE ENDS

I have read *Speaker Builder* now for more than 10 years, and your "Speaker System for CDs" (*SB* 4/90) is the first project I am going to build. I'm retired now, and must watch my spending, so I may wind the crossover coils. I have some questions about the article:

1. Are these coils of size 12, 14, or what? Do you have their resistances?

2. I assume resistors 2 and 20 shown for the MID are not used as the note says. Is this correct?

3. Are either the MID or tweeter "boxed-in" on the back side (within the primary enclosure)?

Thanks for the nice article.

E. Gene Bortmes
Tulsa, OK 74135

Philip Erhorn replies:

Thanks for your kind letter regarding my article.

To answer your questions, I did not wind my crossover coils, but purchased them and the capacitors from my supplier, Zalytron Industries, listed at the end of the article.

The resistors shown in the crossover's midrange output were not needed with the Philips driver. With others they might be appropriate to keep relative efficiencies correct. The woofer contributes a lot of midrange response due to the rather high crossover point.

The midrange driver and the tweeter are "closed back" units, and require no further protection in the cabinet from the woofer.

The woofer I used is identical with the Zalytron TA305F. It has exceptional low bass response.

When you complete this system, please give me your reactions.

DATA, DATA, EVERYWHERE

I recently came across data taken more than 10 years ago measuring the absorption coefficient of materials tested in an acoustic impedance tube. Although the data was taken a decade ago, it may still interest *SB* readers who are choosing box lining material. *Figure 1* plots the ability of a material to absorb sound against frequency. The larger the absorption coefficient the better.

The 1″ fiberglass is similar to that used in suspended ceiling panels. The ¼″ fiberglass is relatively dense and is surfaced with a commercial foam backed carpet designed to be glued to a subfloor. The foam is a 2″ thick waffle pattern acoustic material used as wall treatment in many recording studios. The tile is typical ⅝″ thick cellulose ceiling tile.

From the data, you can see to absorb low frequencies, you need a thick absorber. None of these materials does well at 300Hz, but at 1.2kHz, the 2″ foam absorbs almost all sound but falls off at higher frequencies. The 1″ fiberglass has a smoother response equalling the foam's performance at 1.4kHz, and becoming even better as the frequency rises.

Although the ½″ carpet doesn't do much for the lower frequencies, it is better than the 2″ foam above 2.3kHz. Tightly glued to the inside walls of a speaker cabinet, it does wonders deadening unwanted panel resonances without ap-

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preciably decreasing internal box volume. It is also considerably less messy than smearing roofing tar and sand inside your speaker box. Maybe a combination of ½″ carpet with a 1-2″ thickness of fiberglass is just the ticket for your tuned enclosure.

Robert A. Baals
Yorktown, VA 23692

24K INFORMATION

In your reply to a letter from reader RF Stonerock, Jr., in the 1/90 issue of *Speaker Builder*, you asked for the whereabouts of Gold Ribbon Concepts. As a friend of the principals of the company, I can provide you with that information.

Gold Ribbon Concepts still makes 30″ vapor deposited planar dynamic drivers on a limited scale. The company now concentrates on custom installation of home entertainment and public address systems which do not utilize ribbons. The company's current name is Gold Ribbon Sound Cinema, rather than Gold Ribbon Concepts.

When Gold Ribbon Concepts pursued the esoteric speaker market, the company

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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.

was beset by many of the problems which typify small perfectionist audio companies. Chief among those problems was dependence on unreliable suppliers. Gold Ribbon Concepts could not meet demand, so the company wisely chose to curb demand by curtailing advertising for the ribbon, and concentrated on other products.

Gold Ribbons are still available—in fact, I have a new pair. The company also sells a complete assembled system including enclosure, two amps, electronic crossover, and active equalization. I understand Demian Martin, designer for Spectral Audio Associates, also markets a system using the Gold Ribbon, but it's not for sale in the US.

The Gold Ribbon is a remarkable transducer, but for the hobbyist it poses formidable demands. Suitable cabinets are very expensive and difficult to build, and the system really should be bi-amplified and actively equalized using the very best electronics. When everything's done right, a Gold Ribbon system will give anything in the world a run for the money, but it's not for everyone. Time, money, and a lot of technical expertise are required.

Daniel Sweeney
Burbank, CA 91054

MATERIALS ARE MATERIAL

I recently discovered the merits of using 10″ diameter ⅝″ thick cardboard tubes for enclosures which have been relatively free of resonances. The latest effort uses two B110Bs and a Morel MDT33 in a D'Appolito configuration, and the Linkwitz 100Hz-1.470kHz active crossover. The sub-woofers are two B200As in each 60-litre closed box with electronic equalization. The speakers are driven by home-built 100W MOSFET amplifiers.

The results are very good, but I would like to compare them with a similar system using a passive network before I decide on my ultimate system. I decided on the SWAN IV as this design embodies diffraction correction and I will more nearly be comparing like with like. However, there will be deviations due to the unavailability of certain materials and you did warn that seemingly trivial changes can be detrimental. So I'd appreciate your comments on the effect of the likely changes.

I will not be able to duplicate sandwiching of the MDF/plywood veneer. I can use ¾″ mahogany veneered MDG made in New Zealand. I planned to line the tops, bottoms, and sides with bitumen pads ¼″ thick. The resulting internal volume will be the same, with the same external dimensions. There is a school of thought that the pads are more effective on thinner panels, and should not be cemented onto them. Instead, they should be tacked at the corners and center to allow movement with respect to the MDF.

An alternative would be ⅝" MDF, with the pads replacing the sand/bitumen mixture of your earlier design. I would appreciate your views about which would offer lower and perhaps similar coloration to your SWAN IV. I do not like the 1" recess in the rear (for aesthetic reasons) but I note that this gives a similar depth to the original design, so it may be critical.

The SWAN IV photos seem to show all edges rounded, but the text only refers to the sides' tops and bottoms. In fact, the photo (*SB* 5/88 p. 40) shows a lip around the front panel. This cannot be right, and I assume this is a protective device during manufacture.

I plan to use the subwoofer during tests, but understand this must be changed to a system with comparable power handling capacity to derive the full benefits of the overall system. Unfortunately, the replacement 305 is not suitable as foam surrounds do not survive well in the tropics. A rubber surround is preferable. Similar cabinet material considerations will apply.

I do not plan any other changes. The speakers will be those recommended, although my Focals are not matched pairs. (When I purchased them the retailer said manufacturing tolerances were close enough so this was not essential. I must replace the Dacron filling with long-hair wool, as I do not have the former.

I wonder how effective the bass cabinets' acoustic foam linings are. I would have thought the material would be relatively transparent at the frequencies I'm concerned about. Except for the internal bracing to shift resonances upwards, there was little one could do with respect to damping— short of concrete.

C.L.P. Carrington
Barbados

Joe D'Appolito replies:

Regarding your questions about cabinet construction and damping in the SWAN IV, the MDF/plywood sandwich construction was chosen so the home builder could produce sufficiently damped cabinets with readily available material. Production systems are made with 1" MDF, not commonly available at lumber yards.

The photos for the SWAN IV article were taken at different stages in the system's development and do not always agree with the published plans. At a minimum, all front edges of the cabinets should be rounded. Production systems are rounded on all edges. The front panel lip shown in one of the photos represents a very early design which was quickly abandoned.

Schools of thought on cabinet damping rarely define what they are trying to damp, and their effectiveness is uncertain. Two types of excess energy often need to be dissipated in loudspeaker systems, acoustic and mechanical. Not surprisingly, these forms of energy are dissipated by acoustical resistance and mechanical resistance.

Let's get rid of some common misunderstandings about cabinet vibration. Driver cone acceleration forces produce an equal and opposite force on the drive frame. Because the frame is usually tightly fastened to the cabinet, this reaction force is efficiently transmitted to the cabinet walls. When the forcing frequency corresponds to a cabinet resonance, a significant vibration results. Transmission of acoustic energy within the trapped air volume to the cabinet walls is inefficient, and rarely causes significant panel vibration in well-constructed enclosures. Standing waves within the enclosure can, however, influence the loudspeaker's acoustic response.

To rid mechanically induced panel vibration we first brace the panels to raise their resonant frequency. We then add panel damping, generally more effective at the higher frequency, to dissipate the remaining energy. To be effective, the damping material must be in contact with the vibrating panel. Bitumen pads are used extensively in the auto industry to damp sheet metal panels. In this application they are cemented to the sheet metal panels.

In our application they should also be cemented to the enclosure walls. Allowing them to sway in the breeze will absorb some acoustic energy before it reaches the cabinet walls and is converted to mechanical energy, but it will not damp the mechanical panel vibration. Firmly cementing bitumen to the walls will damp all vibration, regardless of its source.

We must be careful about acoustic energy damping within the enclosure volume. The SWAN IV Bass Module is a bass reflex design. Its low-frequency efficiency depends on a high box Q. Thus only the higher frequencies, which may bounce around inside and pass back out through the cone or ports, should be damped. This is done by lining the cabinet walls with foam or fiberglass.

Of your available materials for cabinet construc-

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.

tion, I would use the ¾" MDF. It should be adequate for the satellites. You may require more interior bracing for the Bass Modules. You'll have to experiment on that. The 10" Eclipse drivers, among those recommended for the Bass Modules, use a rubber surround. Dacron is commonly available in department and fabric stores as pillow stuffing, and you may be able to find it in Barbados.

BOXMODEL

continued from page 37

of about 12% of C. By changing to one 3" and one 4" tube in system A the air speed drops to about 8% of C. I usually settle for less than 10% as acceptable.

IV. CONCLUSION. With BOXMODEL it is easy to play the "what if" game because data can be entered and/or changed quickly and easily. Thus, you can almost effortlessly compare a wide range of driver and system possibilities before you decide on a particular design.

The program is also good for checking your system out against what the model predicts. For example, with a set of measured data, you could see the consequences of various loss distributions, or how measurement error would change response. You can also get a good idea of the cone excursion requirements of the system.

DYNACO A-25

continued from page 55

even flatter frequency response both on- and off-axis, and excellent high-frequency extension equal to the 25 TV-EW. Its high-frequency response is even more compatible with the D28-AF and the A-25's simple crossover. Using a ferrite magnet instead of an AlNiCo, the 25 F-EW is 1dB more sensitive than the older units, so the crossover's resistors might need to be modified. Alternately, I may eliminate the passive crossover

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and bi-amp, adding impedance compensation to the woofers. Neglecting the woofer's low-frequency resonance, its impedance peaks at 15Ω near the crossover point.

I've also considered a D'Appolito tower configuration (two 25 F-EWs flanking a D28-AF in a four cubic foot aperiodic box). That's a project I hope I'll soon get to. The increased woofer volume should improve bass response, and the multiple drivers will bring up acoustic efficiency. Just to whet my appetite, I ran the 25 F-EW's Thiele/Small parameters through Warren Merkel's Perfect Box CAD program (available from the Madisound bulletin board). In a 2 ft^3-per-driver ported box, it predicts a −3dB point of 43Hz, and a −10dB point of 27Hz. With a little luck, an aperiodic box will shave off a few more hertz. With better imaging and the D28-AF's fine performance, I should have a system which will satisfy me for a long time to come.

Kit Report

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have. I rarely hear a loudspeaker which "disappears," allowing you to concentrate on the music.

Many reviewers, myself included, have probably overused the phrase "musical as well as accurate," but it best describes these speakers. This loudspeaker remains musically satisfying hour after hour, without any listening fatique. The Sapphire IIs demand clean electronics, and are accurate enough to reveal any changes you might make in your system. I would have no problem using them to evaluate other components' sonic characteristics, particularly if a subwoofer were added to fill in the missing bass.

Comparisons

I connected them to Lorelei's system for a few days. We spent two evenings listening and comparing them to her Vandersteen 2CIs. Her Vandersteens are also bi-wired, so connecting her cables to the Sapphire IIs was easy. The Vandersteens are among the best dynamic loudspeakers for soundstage reproduction, re-creating a three-dimensional soundstage which reminds you of a dipole. They also have fairly good low-frequency extension. Their one objectionable characteristic is harshness, or grit, in the upper midrange/lower treble region. This problem is most noticeable on massed strings and choral passages.

They gave the Vandersteen soundstage a run for its money. They equalled the Vandersteen's imaging and depth capabilities in every respect, and were free of the Vandersteen harshness. I believe the Sapphire IIs are more musically accurate than the Vandersteens—if you're willing to part with the 2CIs' low bass. Lorelei isn't, and says, "I really want to hear them with the Saturn subwoofers." If that combination delivers the goods in the low-end, I think Lorelei will be in the market for a new loudspeaker system.

Lorelei's listening chair is somewhat lower than my director's chair, and I believe they produced a better image in her room than mine, despite the fact her electronics and CD player are not as refined as mine. I also noticed an improvement in imaging sitting on a lower chair in my listening room, confirming Caldwell's views about optimum vertical position.

Conclusion

The Sapphire II is a refined audiophile loudspeaker which, within its frequency range, will give the best dynamic loudspeakers stiff competition. Any reader who doubts that a loudspeaker kit can compete with the finest factory-assembled products should think again. The Sapphire II is an outstanding kit, and an excellent way to learn about loudspeaker construction and design. Beginners and advanced builders should find this an educational, as well as a musically satisfying project. You may find, however, starting with this kit is a problem. This design is so refined and well-executed that building a better loudspeaker "from the ground up" will be difficult. I admit to being intimidated by Caldwell's expertise level which produced the crossover network. I have a lot of homework to do.

I love deep, clean, accurate low bass. The bass is the foundation of most music, and I wouldn't permanently install a system in my listening room without the bottom octaves intact. I have talked to Dzurko about reviewing the Saturn subwoofers. I have even conducted some preliminary experiments using my own transmission line woofers as subwoofers for the Sapphire II. The results have been impressive.

If the Sapphire II/Saturn combination delivers the low bass, with proper integration of the two loudspeakers, Audio Concepts has a full-range system to be reckoned with.

Software Report

continued from page 66

the entire length of the room, and allows you to ignore the front and/or side walls for the Boundary plot. If a wall is missing, as in an open door garage setup, for example, just ignore the relevant marker in the standing wave graph.

THE KLIPSCHORN THROAT REVISITED:

OR, *OOOOPS*

BY BRUCE EDGAR
Contributing Editor

FINAGLE'S FOURTH LAW: No matter what occurs, there is always someone who believes it happened according to his pet theory. (See "Pox Humana," p. 110.)

EDGAR'S COROLLARY: It is easy to be seduced by a simple mathematical result.

When I published the article on the Klipschorn constricted throat (*SB* 4/90) with an explanatory model, I believed I had achieved a significant breakthrough in horn design. As it turns out, however, the bandwidth extension associated with the Klipschorn constricted throat is a special case, not a general one.

After performing several controlled experiments, I have concluded that in general the constricted throat does not work as "advertised," and the measured responses are the same whether or not the throat constriction is in place.

THE EXPERIMENT. After the Klipschorn throat article appeared, my colleague Dave Rowe read it and analyzed the constricted throat on the basis of an acoustical model instead of the electromechanical model I used. He called me later and said, "Bruce, it won't work."

My immediate reaction was, "What do you mean? I have a measurement (that is, the Klipschorn result) which shows it works."

At that point, I had unwittingly fallen into the trap of Finagle's Fourth Law. Neither of us were willing to budge from our positions, but as scientists, we agreed to devise a controlled experiment to determine the truth.

The experimental apparatus consisted of a 100Hz quartersize straight exponential horn with easily removeable partitions which formed the constricted throat similar to that of a Klipschorn

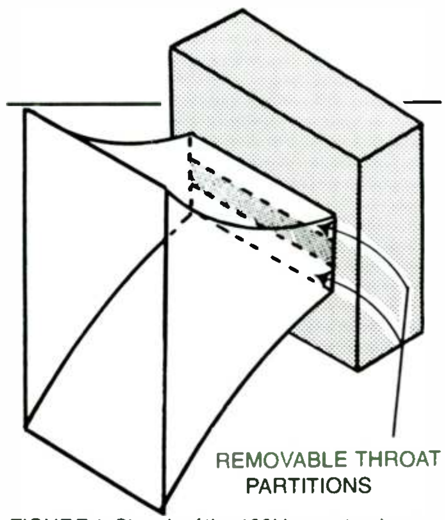


FIGURE 1: Sketch of the 100Hz quartersize exponential horn (S_M = 346²″ S_t = 78²″ L = 16″) used in the controlled experiment.

(S_t' = 3 × 13″, S_t = 6 × 13″), as I've illustrated in *Fig. 1*. I also tried a 100Hz quartersize straight hyperbolic-exponential (M = 0.6) horn with a removable constricted throat (S_t' = 5 × 10″, S_t = 10 × 10″).

I measured the near field spectrum response with a Spectrum Dynamics FFT analyzer, operating in an averaging mode. I used white noise as input to the amplifier. Keeping the drive levels and all other conditions the same, I performed a number of trials, with and without the throat partitions. I tried several 15″ drivers from my collection of speakers, including the Klipschorn K-33E, on both horns. For each driver, (*Fig. 2*) the responses with and without the throat partitions were indistinguishable.

DISCUSSION. If my constricted throat theory were valid, then we would have the two responses (with and without throat partitions) exhibit the classic constant gain-bandwidth characteristic. The response with the throat partitions would have a wider bandwidth but a lower amplitude level, compared to the case without the throat constriction. Instead, we see no differences.

There is some consolation for a horn builder who has built a bass horn with a constricted throat—he probably didn't harm the horn's response. So why isn't there there any difference between a regular throat's responses and a constricted throat's?

The simplest answer is: a wave travelling down a waveguide (horn) isn't affected by an obstruction if its transverse protrusion is less than one-tenth of a wavelength. The partitions in my experiments were just on that condition's fringe. Therefore, the driver couldn't see any effects from the typical constricted throat.

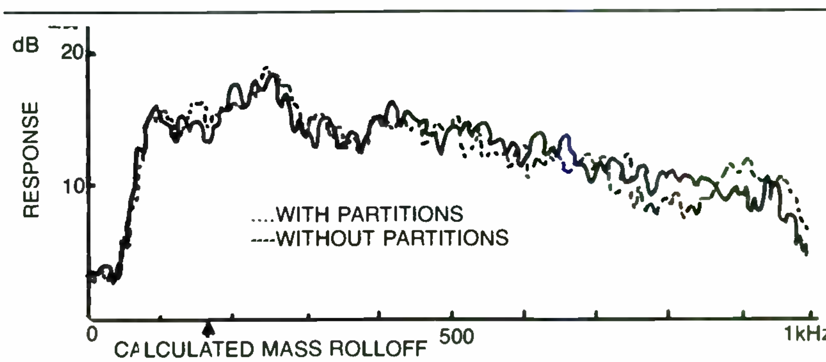


FIGURE 2: Response of the K-33E driver on the 100Hz horn with and without the throat partitions.

In *Figure 2*, the curves begin to diverge by several dB at 800–900Hz, where the 1½" partition height is approximately 10% of a wavelength. However, if a small obstruction (such as a bend) is repeated at intervals along the horn, there will then be reflections, which may have a harmful effect on the response. The reason the Klipschorn has a different response with and without the constricted throat, is due entirely to internal reflections from the bends along the path.

The throat partitions change the reflected wave pattern just enough to differ measured responses by several dB. Our Klipschorn result is a special case, and cannot be generalized to other applications.

Returning to my article, every formula up to Equations 7 and 8 is correct, because you can derive them from a complete electro-mechanical-acoustical model of the driver and horn. Equations 7 and 8, however, are based upon a wrong asssumption of how the throat transformer works in an acoustical model—and, therefore, are invalid.

So how do you extend a horn's bandwidth? The answer is still the same: use a driver with a big magnet, a low Q_{ES}, and a high F_S on a horn with a small throat. There is an unusual bandwidth extension with the K-33E driver above the calculated mass rolloff of 167–300Hz, as in *Fig. 2*. This phenomenon may be due to stiffness control of the driver (Read "The Edgar Midrange Horn," *SB* 1/86), but it's difficult to predict extra bandwidth benefits for any given driver on a horn.

My experiments also brought home how bends seriously affect bandwidth. As you see in *Fig. 2*, the mass rolloff is fairly slow (only 6dB/octave). In my experience, however, the bends in a typical folded horn will introduce a 10–20dB/octave, or higher, rolloff. Following a good folding strategy, such as in my "Show Horn" article, (*SB* 2/90) is as important as choosing a good driver in extending the bandwidth.

CONCLUSIONS. I apologize to *SB* readers misled by my article (*SB* 4/90). Mistakes and later corrections lead to better understanding—a process in the evolution of science. Retracting an erroneous conclusion, however, has been a sobering experience.

So move over Sam Tellig, I now can sympathize with your Armor-All trials (*Stereophile* 5/90). Thanks to Dave Rowe for pointing out my mistake, and helping formulate an explanation.

Tools, Tips & Techniques

BETTER LATE THAN NEVER

I recently constructed a pair of Audio Concepts Monitors. I bought the parts eight years ago, but have managed to procrastinate until a few months ago. I used the same basic construction techniques as described in *Speaker Builder* for the Swan IVs, except as noted below.

The corner construction details for the Swan IVs are similar to a table I built many years back. I was disappointed with the results. I'm not good with a rasp I guess. For the Compact Monitors, I used a sliding cut-odd table on my table saw to cut a ½″ by ½″ rabbet in place of the 45° bevel cuts. I resawed an oak board to ½″, cut ½″-wide strips from the board and then glued the strips into the rabbets (*Fig. 1*).

These could then be rounded-over with a router, but I elected to leave them square for cosmetic reasons. I found it best to cut the oak pieces slightly bigger than the rabbet and sand them down. I think this method is easier, but you cannot achieve as large a radius when rounding over as with the Swan IV technique. A deeper rabbet would weaken the corner glue joint, although gluing in the strips should strengthen them.

I used yellow glue instead of epoxy for the strips. The yellow glue can be easily wiped up when it oozes out of the joint. I used plenty of strategically-placed bar clamps to hold all the strips in place while the glue dried.

For a grille cover, I used black waffle-pattern open-cell foam from Radio Shack. To avoid diffraction from metal or wooden standoffs, I cut narrow strips from the foam and used Goop to glue the strips to the back of the main piece of foam (*Fig. 2*). The Velcro strips which Radio Shack includes wiht the foam them hold the result to the cabinet. Goop works well in this application. Other adhesives I tried either wouldn't adhere or required an excessive amount of adhesive. For the finish I used Danish oil.

I commend Audio Concepts for their fine customer service. One of the push-on connectors on the crossover wires was soldered closed, and in trying to push it onto the tweeter terminal I snapped off the terminal. Audio Concepts replaced the tweeter, even though technically the warranty had expired. I'm sure other companies which advertise in *Speaker Builder* also provide good service to their customers, but AC has earned my loyalty and future business.

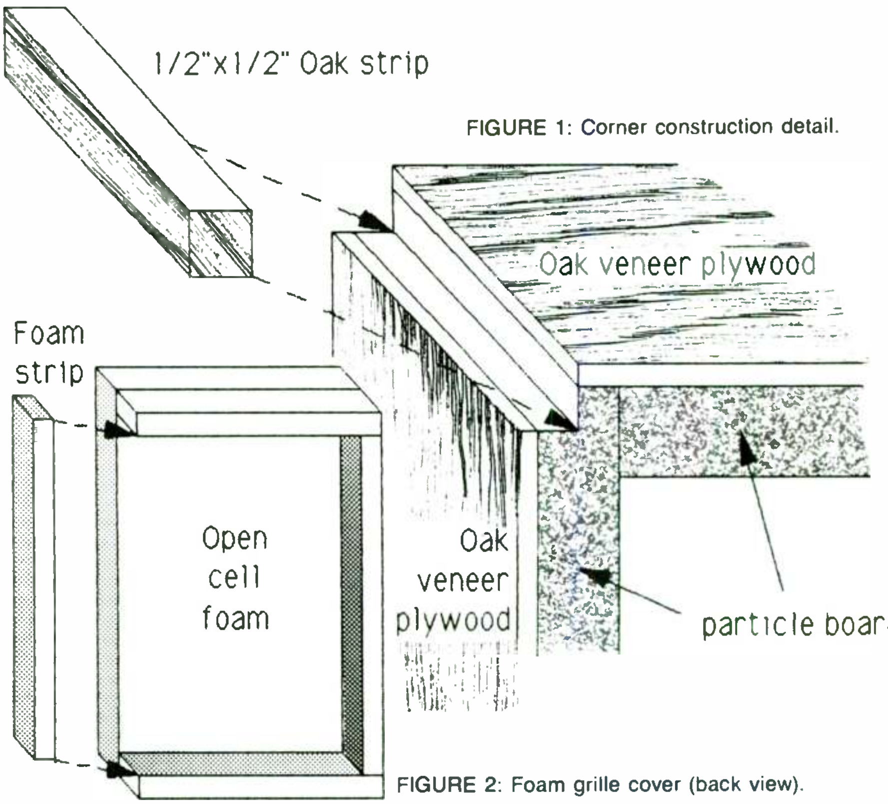


FIGURE 1: Corner construction detail.

FIGURE 2: Foam grille cover (back view).

Thomas S. Downey
Brighton, MA 02135-1857

EASY TURNS COUNTER

I don't normally wind my own coils, but recently I needed some rather large inductances and decided the savings outweighed the time spent winding. What I really needed, though, was a turns counter. I once used a calculator to make an odometer for my bicycle and, remembering this, I realized it would work well in this application, as well.

To use my technique you'll need a calculator which will allow you to punch "1 +" and then, by hitting the "=" key repetitively, automatically update the display each time. In this case, one (1) will be added to the total count displayed.

Carefully disassemble the calculator and connect a pair of wires across the "=" key switch, preferably somewhere on the circuit where it will not interfere with the "=" switch or otherwise damage the circuitry. To the other end of this pair of wires connect a reed (magnetic) switch. I recommend using a variable speed drill for winding; just tape a bar magnet to the chuck. Mount the reed switch close to the magnet, turn on the calculator and press "1 +." Now each time the magnet passes the reed switch the display will be updated by one.

Simple, and it's probably cheaper and less time-consuming to construct than the alternatives.

Karl Rabe
Jackson, MS 39216

GO VAN GOGH

I have an audiophile tip that might be helpful to many people.

As you know, all drivers fatigue. The paper cones of drivers lose some of their rigidity with continuing usage. I have a simple process to somewhat revive cone rigidity.

Use a can of high gloss or enamel paint and spray two or three coats onto the cone, letting each dry before applying the next. More coats may be applied for even more rigidity.

The most common application is reviving old or weather-beaten car speakers. I've used this method on many car speakers and the new sound is remarkably better. This technique is far cheaper than using special types of poly coatings. One can of paint does 40 or more 6″ × 9″ speakers—very cost effective. Use any color paint to give your cone a fancy look.

Andrew Steffek
Centereuch, NY 11720

RECYCLING MAGNETS

Anyone interested in experimenting with reverse-polarized magnets for Q_T modifications (Richard Pierce, *SB* 4/90) may have problems in obtaining additional magnets. Blown speakers are an excellent source, but you must disassemble them from their pole plates.

I've found that most drivers use a heat-sensitive adhesive, usually a "super-glue," to hold them together, and can be readily taken apart with no damage to the magnet.

As the Curie point for ferrite magnets is at least 600°F, you can heat the whole speaker (or just break off the magnet structure) in an oven at 350°F without weakening the magnet's strength. After 20–25 minutes the adhesives break down. Wearing gloves (please) and exerting some pressure, the plates break free from the magnets fairly easily.

Some old Blaupunkt auto speakers fell apart using only a screwdriver. A Polydax needed the help of an arbor press, but a vise or hand-clamp would suffice. A Sparkomatic driver broke clean with a side force on the magnet relative to the plates. You must support the structure in a manner which applies force either away from or across the magnet to break the glue joint.

A recent experiment with some Polydax TX1125 RSN drivers was encouraging. A modest magnet which still attracted the present Polydax structure lowered the Q_T from 1.15 to 0.93. An oversize magnet which repels the structure further lowered the Q_T to 0.91, and was hardly worth the effort. Super-Glue works well to bond the extra magnet to the structure, but first clean both surfaces with solvent.

Matthew Honnert
Carol Stream, IL 60188

A GRAPHIC PROGRAM

Recently, I came across some useful information concerning graphics programming which I applied to a program I read in *SB* 4/86. Brian D. Smith's program calculates a tractrix horn's dimensions. The program is straightforward, and easy to implement. It tends, however, to run slowly when confronted with a horn which has a low cutoff frequency. Of course, compared to doing the calculations by hand it is an immense improvement.

My changes optimize the numerical calculations, allowing faster processing of information. Multiplication is much faster than division in BASIC, and multiplying a number by itself is more efficient than using exponentiation to square it.

I made only a few changes in the original program to allow easier conversion to your specific application and programs you have developed around it. They are as follows:

```
130  THROAT = SQR(AREA1 * 0.31831)
REM 0.31831 = 1 / PI
150  B = SQR(PI * (A * A))
290  (A * A) * PI
310  ((A * A) * PI) / 8
440  YONE = SQR((R * R) * PI * 0.5
470  YTWO = SQR((R * R) * PI) * 0.5
490  PRODUCT = SQR((A * A) - (R * R))
530  DIST = SQR(((XONE - XTWO) *
     (XONE - XTWO))
     + ((YONE - YTWO) * (YONE -
     YTWO/)))
590  AREA = (R * R) * PI
(PI references = 3.14159)
```

You may wonder why I did not change some of the division calculations to multiplication. Integer operations process data much faster than single- or double-precision decimal numbers, so I believed it was unnecessary to change them at this time. The REM line is just a reminder of what this number corresponds to.

The difference these few changes makes seems to make a case for optimizing code to increase performance. The other possible changes would be to convert single- and double-precision values to integers (possibly using an assembly language subroutine) for processing, and then convert them back for output to the printer or screen.

TABLE 1

PERFORMANCE COMPARISON

F_C	100Hz	20Hz	5Hz
Original	1′ 20″	7′ 35″	31′ 17″
Optimized	0′ 20″	1′ 54″	7′ 54″

I have included some performance times of horn calculations with and without the changes (*Table 1*). I hope this will be of use to people using Brian Smith's program to increase productivity.

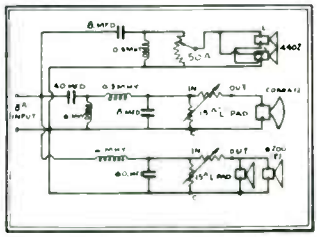
Gregg S. Irwin
5837 Comstock #5
Whittier, CA 90601

If you already have a copy of Brian Smith's program, then you may wish to add the above modifications. Copies of the modification as well as the original program are available from Mr. Irwin whom you may contact at the above address.

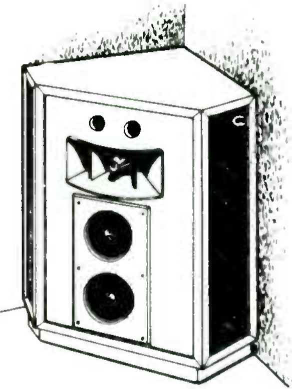
Vintage Designs

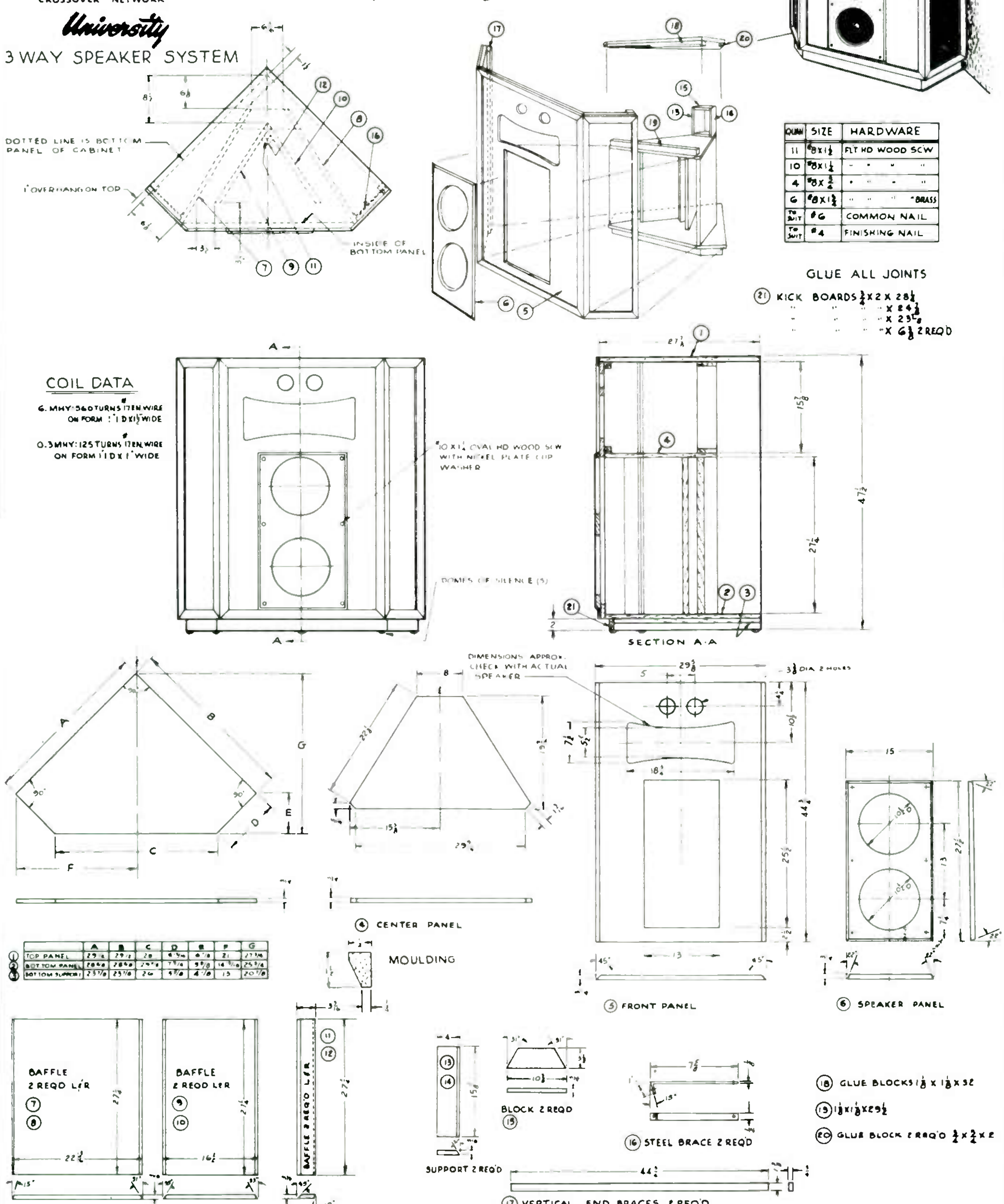
University 3-Way Speaker System

Courtesy of Bruce Edgar, Torrance, CA 90503



SCHEMATIC WIRING DIAGRAM
CROSSOVER NETWORK





QUAN	SIZE	HARDWARE
11	#8 X 1 1/2	FLT HD WOOD SCW
10	#8 X 1 1/4	" " " "
4	#8 X 3/4	" " " "
6	#8 X 1 3/4	" " " " BRASS
TO SUIT	#6	COMMON NAIL
TO SUIT	#4	FINISHING NAIL

		A	B	C	D	E	F	G
1	TOP PANEL	29 1/8	29 1/8	28	6 13/16	6 7/8	21	27 7/16
2	BOTTOM PANEL	28 5/8	28 5/8	29 7/8	7 5/16	5 5/8	14 11/16	25 3/4
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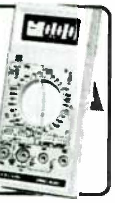

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Focal 7N313 7″ mids, $115/pair or trade for Focal 515 series or better 8″ or 10″ drivers. Clark Bendall, (219) 365-7308, Dec. 15 through Jan. 7, (317) 495-4231 otherwise.

Complete set of Dynaco A-10 speaker components, used but in perfect working order; (2) 6½″; SEAS woofer/midbass drivers; (2) SEAS tweeters; (2) two-way crossovers, $75 plus shipping. Mr. Willes, (800) 227-6121, weekdays.

(2) SAE A202 power amps 100w/channel, used, $175 each; Ace Audio model 5000 electronic subwoofer crossover 200Hz 18dB, used, $40; RG Dynamics X-15 Dynamic processor, used, $75. Roger Daniels, Rt. 5, Box 612, La Grange, TX 78945, (409) 247-4260, before 9:00 p.m. CST.

Lowther corner enclosure, teak wood, mint condition, with driver. Anthony Lumkin, 31012 Camino Capistrano, San Juan Capistrano, CA 92675, (714) 661-8531.

Two pair Gold Ribbons 3.0 latest models, $750/pair; Swan Pedal Coupler, $125. Will trade ribbons for pair of B&K Sonata Monos. Carl, (916) 967-1065.

One JBL LE85 horn driver, excellent condition, best offer. David Adams, 2015 Paisley Dr., Arlington, TX 76015-2820.

Dynaco PAS preamp, unmodified, $75; pair Madisound 15258DVC 15" subwoofers, new, $85; Technics SLJ2 turntable, $50; Bell and Howell oscilloscope, $40; pair Dahlia-Debra speakers, $600. Phil, (408) 266-0543, after 7 p.m. PST or leave message.

SOTA SS vacuum clamp, SME III titanium arms, Grado/MCX used 8 hours; Monster Alpha Genesis 1000, 5 hours; Thorens TD-320, Shure V15YMR, 8 hours; Sony CDP-705ESD. All like new. Best offers. Sam Goda, 1815 N. Woodside St., Orange, CA 92665, (714) 637-3989.

Rare and unusual KEF model K-2 Celeste MK-2 two-way speakers made in 1966 in England. Solid wood construction, never abused, first class condition, woofer is oval shape, truly collector items. Good deal for the right person, cash price, $200/pair. I pay shipping. Call Ed, (305) 891-2267.

(4) Radio Shack 40-1022 woofers, original version, new,$16 each; (4) Audax TX2025RSC, new, $25 each; (2) SEAS H400 tweeters, new,$25 each; (2) Vifa D26TG05 tweeters, $10 each; (2) Wood-style oak towers, new, $100 each. Reasonable offers accepted. Al Vanneste, 45814 Kensington, Utica, MI 48317, (313) 739- 0305, after 5 pm, EST.

WANTED

Circuit board or kit for Audio Research ST-70-C3 modification. Bill Swafford, 3121 Bell Dr., Boulder, CO 80301, (303) 449-0831.

Old Klipsch catalogs, JBL literature; Books: TM11-690, *Basic Theory and Applications of Transistors*, (Army Manual); *Throne of Merlin* (R.C. Schaller). D.R. Schaller, 6704 Schroeder Rd., Suite 6, Madison, WI 53711.

SWTPTC 275 Tiger amplifier. Harold Berg, 9809 53rd Ave., College Park, MD20740.

Four 10K515 Focals, crossover for Aria 5, Richter Scale III. Chris (314) 993-1603 before 10 p.m. CST.

Two used Audax HD20 B25 H 8Ω. Stanley H. Grycx, 2935 Crehore St., Lorain, OH 44052, (216) 288-9480.

Circuit diagrams for tube crossover at 550Hz to 750Hz (premier grade parts) use for Apogee calipers and duettas signature series. Knowledge to form high-end clubs. Moktar BUD Ari, PML/1 BSP Seria 7082 Brunei Darnssalam (Borneo).

Heil AMT tweeters. Broken or singles also wanted. Literature about the ESS Transar full-range speaker. Rod Baird, 1249-A Ninth Ave., San Francisco, CA 94122, (415) 681-7149.

Electrostatic speakers/parts/direct drive amps, Peerless output transformers, share tube schematics/ modifications. Dennis Boyle, (214) 428-3901.

Fujitech A1033 integrated tube amp. with all papers. Harvey Otis Lewis, Rt. 1, Box 272, Stephens City, VA 22655, (703) 869-3066, after 6 pm.

Yamaha MX10000. Sam Goda, 1815 N. Woodside St., Orange, CA 92665, (714) 637-3989.

Power transformer for a Dynaco SLA 35 integrated amp and a single Dynaco Mark III stock in working condition. Robert Morrison, JG-15 U.W. Speech and Hearing Sciences Dept., Seattle, WA 98195, (206) 543-1575.

Information on high-pass crossover modification to Aria 5 to replace T90K with Accuton CII (4Ω?). No change in 5K013 crossover desired. P. Hessemer, 1355 Greenleaf, Chicago, IL 60626.

1–8 pairs of Distech Blue interconnect, especially 1–2 meter lengths; Audio Research RMV-3 rackmount ventillator; Phase Linear 500II, 700II, 400II amps; Crown and Bryston amps; Altec 416, 411, 515, woofers; older Altec and JBL furniture type speakers, such as Magnificent A7-500. David Rubenstein, (914) 688-5024.

CLUBS

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.

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.

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, 1756 Hilt Rd., Yellow Springs, OH 45387, (513) 767-1457.

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!

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.

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.

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.

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.

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.

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.

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.

WASHINGTON AREA AUDIO SOCIETY Meetings are held every two weeks, on Fridays from 1900 hrs. to 2130 hrs. at the Charles Barrett Elementary School in the city of Alexandria, Va. Prospective members are welcome but must register in advance in order to be admitted to the meetings. No exceptions please. If interested please call Horace Vignale, (703) 578-4929.

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.

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.

CHICAGO AREA ENTHUSIASTS WANTED for audio construction club. Call Tom, (312) 558-3377 or (708) 516-0170 evenings for details.

THE OREGON TRIODE SOCIETY is seeking men and women who are interested in good sound reproduction and the msuic it re-creates. We are 80+ members strong and meet bi-monthly in various locations in the Portland area. Our bi-monthly newsletter is *Positive Feedback*, a vital forum on audio and a host of related subjects. For information on our next meeting and newsletter, contact Richard Eggerston, 3623 S.E. Hawthorne, Portland, OR 97214, (503) 238-1957 or Ian Joel (503) 233-1079.

LONDON LIVE D.I.Y. HI FI CIRCLE has formed in London, England. We meet quarterly, with an open agenda of anything to do with any aspect of audio design and construction. For information contact Dick Bowman, (801) 520-6334.

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. Call: Chuck Bruce, (404) 876-5659, or Denny Meeker, (404) 872-0428, or write: PO Box 361, Marietta, GA 30061.

Advertising Index

INFINITY SYSTEMS, INC. has announced delivery of a new three-piece speaker system, the Infinitesimal Four, the first in a new line of Infinitesimal products. The system is the result of evolutionary engineering and development, going back to Infinity's $50,000 IRS V Reference Standard speaker system and the MODULUS system.

The Infinitesimal Four consists of a pair of two-way satellites equipped with planar tweeter design, the EMIT-R™, and a 5¼″ long throw woofer constructed with injection molded graphite (IMG) cone material. Housed in a Time Aligned and vented enclosure, the satellite has a frequency response of 100Hz–20kHz, ±3dB. Power handling is 10–80W per channel.

The tweeter delivers frequency and transient response through a design which allows the tweeter's moving mass to be a fraction of that of conventional dome tweeters. The benefit is clean frequency response and harmonic balance of the top end. The seamless transition from tweeter to woofer is accomplished by careful crossover design and Time Aligned mounting of the drivers. This also assures balance and imaging at all frequencies.

The satellites are matched with a cube shaped, powered 10″ subwoofer also equipped with an IMG cone. The 100W servo controlled subwoofer features a volume control, both high and low inputs, as well as a crossover circuit to blend smoothly with satellites. The subwoofer features switchable low-end cutoff points at 40Hz and 60Hz, allowing woofer response to be tailored to room and listening requirements. Finished in matte black, the Infinitesimal Four Satellites, are priced at $419.95 and are available from audio specialist showrooms nationwide. The Infinitesimal servo subwoofer's suggested retail is $629.95.

For further information or materials, please contact Richard Frank, Frank Marketing Associates, 8 Mohave Rd., Medfield, MA 02052, or call (508) 359-5977, FAX (508) 359-5343.

Fast Reply #KE146

MOREL introduces a series of automotive loudspeakers. The MDT-204, MDT-205, MDT-206 tweeters, and CW-5 midbass. The tweeters emphasize mounting flexibility.

At least five mounting configurations are possible, from original locations as specified by the automobile manufacturer for flush and/or surface installations. Surface mounting may be in flat position or angles to 20° or 82°, with hardware supplied. Their compactness allows installation in door panels, rear or front shelves, or nearly any location.

Fashioned of highly-durable materials, the mini-tweeters are designed to withstand the rigors of automotive environments. The steel grille provides protection while enhancing the driver's modern look.

The designs use large diameter (1⅛″) ferrofluid-cooled voice coils with soft domes, assuring high-power handling capability and wide dynamic range. With low resonant frequency points, these mini-tweeters have smooth sound quality, and are ideal for use with minimum phase shift 6dB crossovers, or a single film capacitor. All models have replaceable, self-centering dome coil assemblies.

The 5″ automotive midbass driver, Model CW-5, features a double-magnet structure with a 3″ voice coil, DPC (dampened polymer composite) cone, rubber surround, and removeable grille.

For information contact, Morel Acoustics USA, 414 Harvard St., Brookline, MA 02146, (617) 277-6663.

Fast Reply #KE142

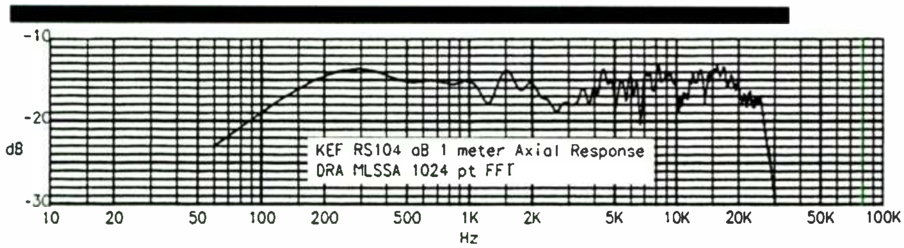
Seattle-based **SOUNDINGS-ELECTROTEC** announces its appointment as North American import agents and distributors for Minim Ambisonic Surround Sound Decoders and Processors for the consumer hi-fi and professional recording markets.

Minim currently manufactures two decoders for the consumer market: the AD10 decoder, a high specification full-feature system including loudspeaker aspect ratio control, focus, and position (the listener may move forward or backward in the soundfield for more or less audience or ambience). It also features stereo enhance for normal stereo recordings, variable from central mono image to a complete surround. The AD10 is priced at $595.

The AD7 decoder, priced at $325, is a simplified version of the AD10 and includes loudspeaker layout, focus, and stereo enhance controls.

For further information, please contact Nigel Branwell at Soundings-ElectroTec Inc., PO Box 10004, Winslow, WA 98110, (206) 842-7128, FAX (206) 842-5026.

Fast Reply #KE676

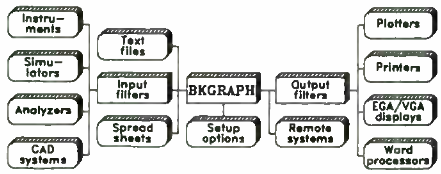


BKGRAPH, an audio data graphing utility, has recently been released. It accepts data from a wide variety of sources, such as design and simulation programs, measurement and analysis systems, and simple text files. It produces high-quality presentation- and publication-ready plots on a variety of media.

The system supports high-resolution color and laser plotters, and graphs simulation and measurement data together on one graph. It produces a universally-accepted format for all these systems.

BKGRAPH-generated plots meet industry standards for presentation of audio data, and replicate the style of plots produced by industry-standard graphic level recorders (such as the Bruel & Kjaer 2307 or the Neutrik 3302). The plots are 8″ × 4″, and their accuracy and resolution is limited only by the input data and the printer or plotter capabilities. It can use multiple color, and multi-pen plotters.

Plotting modes on the Y-axis are linear,



decibel, phase angle, and logarithmic, each available in six scale widths. The X-axis provides 10Hz–100kHz logarithmic frequency, and linear frequency or time, also in several ranges.

BKGRAPH is available for IBM PC/MS-DOS compatible systems on 5¼ and 3½″ media. The software kit includes all the necessary executable programs, complete user and interface documentation, and several demonstration files. It is also available for UNIX systems.

The BKGRAPH single-user binary license is $150. For input conversion filter prices and other options, contact Richard Pierce, 17 Sartelle St., Pepperell, MA 01463, or call (508) 433-9283.

TDL ELECTRONICS has developed the Studio 0.5, possibly the world's smallest transmission line loudspeaker. It provides exceptional bass performance, giving the illusion of a loudspeaker system many times larger. The design was tailored to the typical domestic environment.

TDL developed a miniature long throw bass unit for the new speaker. It uses Kapton, which allows an increase in the driver's Q, allowing it to more easily load the line. With smooth midrange transition, this driver is integrated with a metal dome tweeter via a simple crossover.

The speakers are ready for bi-wiring or for bi-amplifying. Bass and treble frequencies can be separately accessed using different interconnect leads. The treble and bass can be driven by a choice of amplifiers with different operating principles. Bridging the terminals (as supplied) allows for conventional single wire, single amplifier operation.

Custom stands are available. Constructed from square section steel, they allow for the insertion of spikes supplied with each unit. The use of stands is recommended, especially when the loudspeakers are on wooden floors. For information contact, TDL Electronics, 652 Glenbrook Rd., Stanford, CT 06906, (203) 324-7269.

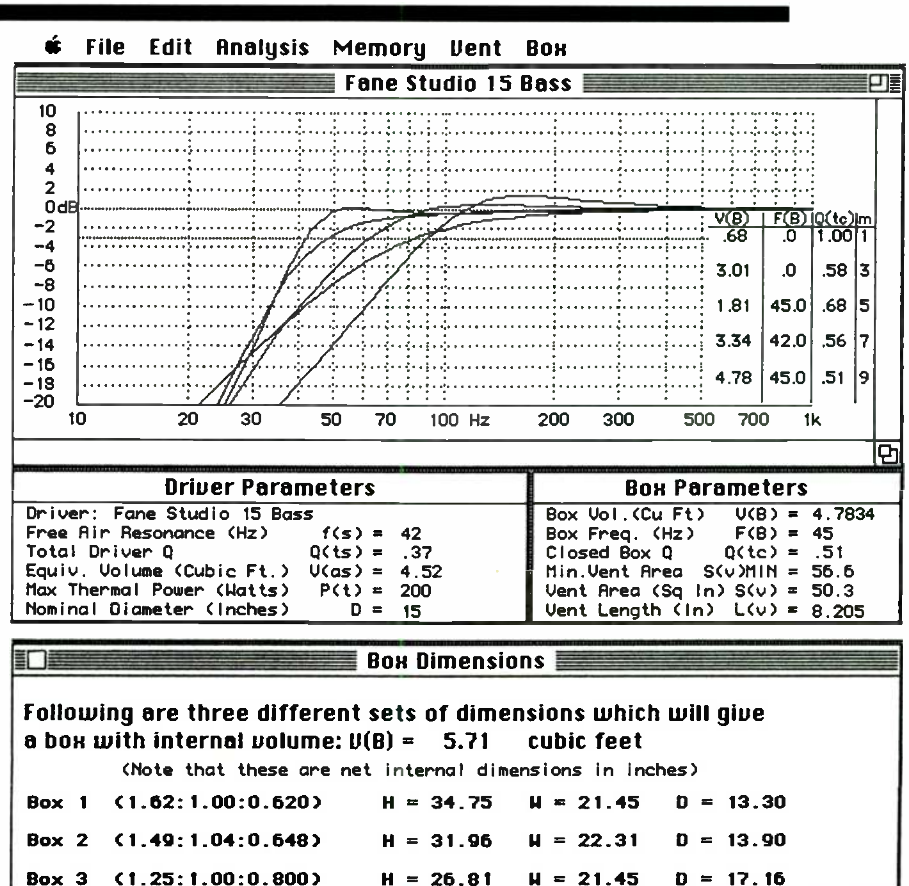
Fast Reply #KE677

TRUE IMAGE announces availability of version 1.5 of Mac*Speakerz*™, a loudspeaker design application for the Macintosh™ computer. Mac*Speakerz* was written for the Macintosh and takes full advantage of its interface.

It calculates and displays the frequency response of any loudspeaker driver/box combination specified, and gives corresponding enclosure dimensions for that response. Dimensions are also displayed for vented enclosures. A library of loudspeaker drivers is provided and can be expanded to include new drivers. The application prints reports on finished speaker enclosures listing driver parameters, box parameters, enclosure dimensions, and frequency plots.

Mac*Speakerz* used the mathematical models of Thiele and Small for both vented and closed box systems. A bibliography of the engineering papers which first revealed the mathematical models is included in the technical references. You can run Mac*Speakerz* on any Macintosh computer with at least 512K memory and one 800K disk drive. Software and manual are available for $145 from True Image. For information, contact True Image, 349 West Felicita Ave., Suite 122, Escondido, CA 92025, (619) 480-8961.

Fast Reply #KE544



FERROFLUIDICS CORPORATION has introduced a new series of audio-grade ferrofluids developed to withstand extreme temperatures while maintaining ultra-high stability. The APG 900 Series operates safely at voice coil temperatures of 200°C (392°F) for an extended time without significant evaporation. Voice coil operating temperatures are reduced when ferrofluid is used as a heat transfer medium.

As a result of the long-term thermal stability of APG 900 Series ferrofluids, transducer engineers developing high-efficiency speaker systems, such as those used for studio monitors, sound reinforcement, sirens, and voice warning devices, are now able to utilize ferrofluid as a design component.

The ferrofluids, which are offered in low to medium viscosity ranges, complement the current line of high viscosity ferrofluids used in tweeters and midrange drivers.

Application notes as well as performance differences between the various series of ferrofluids, are available. For further information contact, Customer Service, Ferrofluidics Corp., Customer Service, 40 Simon St., Nashua, NH 03061-2009, (603) 883-9800.

Fast Reply #KE117

ELECTRO-VOICE has recently implemented Kevlar™ fiber composite speaker cones into their EVX-180 woofers.

The ribbed Kevlar cone provides a high stiffness-to-weight ratio, giving the EVX-180 increased resistance to cone collapse and deformation, without sacrificing efficiency. A rubber mounting-flange gasket provides a reuseable seal for front or rear mounting, completely surrounding the frame flange.

It provides excellent power capacity, linearity and excursion due to EV's exclusive HeatWick™ thermal engineering design, which "wicks" heat away from the speaker's voice coil, increasing power handling and long-term reliability.

A special frame extension and elongated pole piece provide a metal surface close to the voice coil, creating a heat-transfer path. The 100mm (four-inch) diameter voice coil is longer than conventional medium-efficiency woofers to give additional power handling, and eliminate dynamic-range power compression.

The EVX-180 also features a Flux Demodulation Device™ (FDD) which reduces distortion in the midband.

It offers 1kW continuous program power capacity for high output with low distortion. The woofer has a recommended frequency range of 20Hz–1.5kHz.

For information, contact Electro-Voice 600 Cecil St., Buchanan, MI 49107, (616) 695-6831, FAX (616) 695-1304.

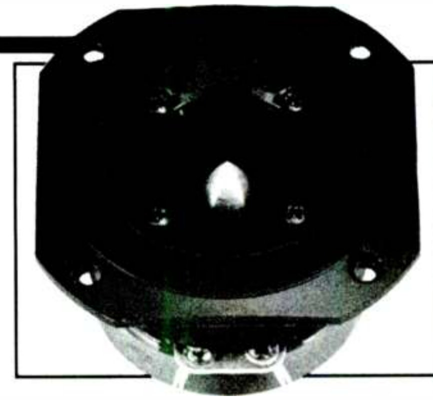
Fast Reply #KE453

POLYDAX SPEAKER CORP., a subsidiary of Audax Industries, has developed a comprehensive line of loudspeaker components which have been introduced into the professional sound industry.

The most recent model is the PR 120. Engineered to meet exacting industry demands, this bullet tweeter uses a titanium diaphragm for better transient response, increased efficiency, and reliability.

The voice coil design employs a two-layer copper coil based on an aluminum former and is ferrofluid cooled. The PR 120 is rated at a sensitivity level of 104dB (1W/1M).

The competitively priced tweeter is designed for a wide application range, from



professional to high-end automotive installations. For information contact Polydax Speaker Corp., 10 Upton Dr., Wilmington, MA 01887, (508) 658-0700.

Fast Reply #KE668

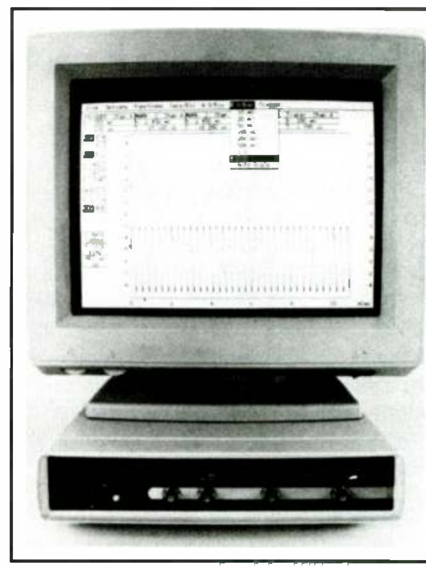
The **BOB WOOD ORGANIZATION** announced it has begun marketing the new home audio/video product CABLEHIDER, to put the finishing touches on installation of interconnect or speaker cables.

CABLEHIDER carrys cables in two hidden slots behind the baseboard with entry and exit panels for easy access.

The baseboards are available in unfinished six-foot lengths in three of the most popular baseboard fronts, and are available in pine for a paint finish and in ash for staining. Oak is also available.

For more information call or write The Bob Wood Organization, 7 Treasure Cove, The Woodlands, TX 77381, (713) 363-4971.

Fast Reply #KE106



RAPID SYSTEMS has introduced the R380 PC-based Spectrum Analyzer and Digital Oscilloscope. The R380 has two 14-bit A/D channels with software selectable input signal gain ranges. Easy triggering allows setting the exact trigger level and conditions needed with easy on-screen tools, and an external trigger for remote control.

The hardware unit connects to a PC's serial port. Signal cursor and two dynamic markers allow for spot measurements of voltage, time difference, and frequency.

Applications include vibration analysis, acoustics, biological sciences, engineering and physics test systems, and teaching lab.

Product highlights offer two channel, 14-bit resolution, 85dB dynamic range, 100kHz sample rate; up to 8K point FFT; EGA, VGA, CGA, and Hercules compatible; 16K data buffer for each channel; and FFT and time domain averaging.

Available from Rapid Systems, 433 North 34th St., Seattle, WA 98103, (206) 547-8311, FAX (206) 548-0322.

Fast Reply #KE948

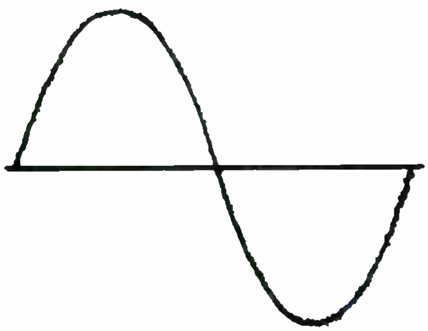


FIGURE 1: Digitized audio signal after feeding through a Digitrap filter.

Clean up your CD sound in seconds, rediscover the spaces around individual instruments, hear up to a 30-fold increase in signal detail.

SAGE AUDIO ELECTRONICS is now offering the CD Digitrap line of filters, a new filtration device based upon a passive "cyclic" filter block. When connected to a CD or DAT player the Digitrap provides up to 30dB reduction in the digital quantization noise, while passing the audio signal unaffected. This results in a 30dB increase in musical detail and resolution.

The Digitrap plugs into the audio output of a CD player, and the output from the Digitrap then feeds into your amplifier. It is compatible with all types of CD players.

Features and benefits include: gold-plated in/out connections, totally passive (no power required), top quality components, two filter blocks for stereo use, and lifetime performance guarantee.

The Digitrap 2 is available for $110 (including airmail), and a catalog is offered for $6 from Sage Audio Electronics, Construction House, Whitley St., Bingley, West Yorkshire BD16 4JH, England.

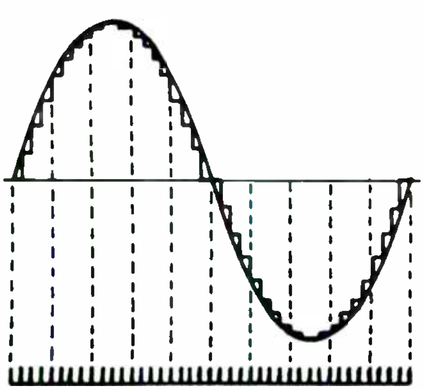


FIGURE 2: Replayed digitized audio signal from a CD player's output, including quantization noise.

ARE YOU MOVING?

Please!

Send us your *new* address 4 weeks in advance. Thank you.

The McNEILL loudspeaker makes use of loudspeaker principles and criteria for studio professionals. Measuring 20″ × 11″ × 12″, the enclosure departs from conventional loudspeaker dimensions to improve stereo imaging and forward soundstaging.

Good linearity coupled with absence of coloration accounts for the Polydax 1″ soft dome tweeter's reputation for reproducing quality natural sound. The heavy-duty 8″ American-made woofer is mounted in an acoustic suspension enclosure with gradual low-frequency rolloff.

The enclosure is coated with a textured jet black finish. All outside corners are rounded to ease diffraction effects. The standard grille is black, but any color or print may be ordered to match home interiors.

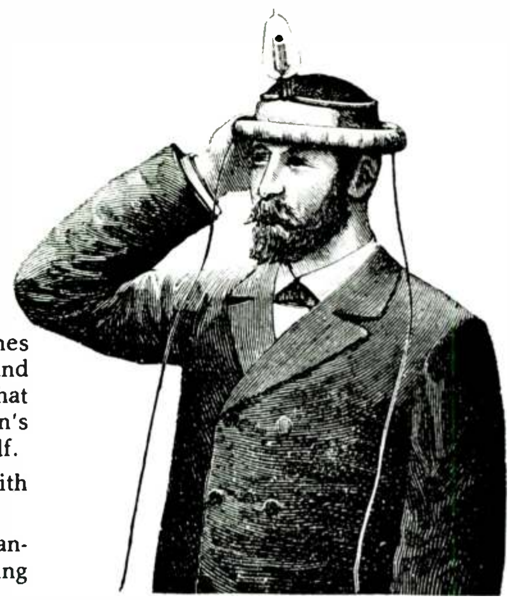
Frequency response is 34-22kHz, ±3dB, power requirements are 1-100W per channel, with sensitivity at 90dB. List price is $319 per matched pair. A free brochure is available upon request. Contact McNeil Engineering and Manufacturing, 417 Temple Rd., Monaca, PA 15061-2843, (417) 375-9203.

Fast Reply #KE151

Pox Humana

FINAGLE'S LAWS...

or why nothing in Research and Development happens the way it should



ON EXPERIMENTS

The first four laws are the only ones dignified by number. Note the beauty and simplicity of the First Law. Also note that the remaining three laws refer to man's reaction to Nature—not to Nature itself.

First Law: If anything can go wrong with an experiment, it will.

Second Law: No matter what result is anticipated, there is always someone willing to fake it.

Third Law: No matter what the result, there is always someone eager to misinterpret it.

Fourth Law: No matter what occurs, there is always someone who believes it happened according to his pet theory.

The Law of the Too Solid Goof:

In any collection of data, the figure that is most obviously correct—beyond all need of checking—is the mistake.

> **Corollary I**—No one whom you ask for help will see it, either.
>
> **Corollary II**—Everyone who stops by with unsought advice will see it immediately.

A further series of rules—or really advice to experimenters—has been formulated. They are a natural consequence of the first four laws reduced to day-to-day practice.

Experiments must be reproducible—they should all fail in the same way.

First draw your curves—then plot the readings. Experience is directly proportional to equipment ruined.

A record of data is useful—it indicates you've been working.

To study a subject best, understand it thoroughly before you start.

In case of doubt, make it sound convincing.

Do not believe in miracles—rely on them.

Always leave room to add an explanation when it doesn't work. (This open door policy is also know as the Rule of the Way Out.)

HUMAN FOIBLES

The remaining rules outline the human problems that follow from the above. To some extent they represent man's reaction to Nature and, even more aptly, man's reaction to man.

Laws of Revision: (Often lumped into the Now They Tell Us Law)

First Law: Information necessitating a change of design will be conveyed to the designer after—and only after—the plans are complete.

> **Corollary I**—In simple cases, where one obvious right way is opposed to one obvious wrong way, it is often wiser to choose the wrong way right off. This is one step ahead of choosing the right way, which turns out to be the wrong way, which has to become a right way.

Second Law: The more innocuous the revision appears to be at first, the further its influence will extend and more plans will have to be redrawn.

Third Law: If, when the completion of a design is imminent, field dimensions are finally supplied as they actually are—instead of as they were meant to be—it is always simpler to start all over.

Fourth Law: Even if it is impossible to assemble a part incorrectly, still a way will be found to do it wrong.

> **Corollary I**—It is usually impractical to worry beforehand about interferences—if you have none, someone will make one for you.

The Law of the Lost Inch:

In designing any type of construction, no overall dimension can be totalled correctly after 4 p.m. Friday.

> **Corollary I**—Under the same conditions, if any minor dimensions are given to 1/16 of an inch, they cannot be totalled at all.
>
> **Corollary II**—The correct total will be self-evident at 9:01 Monday morning.

Deliveries that normally take one day will take five when you are waiting.

When adjusting (or drawing or computing, etc.) remember that the eye of the chief inspector (engineer, draftsman, etc.) is more accurate than the finest instrument.

After adding two weeks to a schedule for unexpected delays, add two more weeks for the unexpected unexpected delays.

In any problem, if you find yourself doing an unending amount of work, the answer may be obtained by inspection.

Finagle's Creed

Science is Truth—don't be misled by facts.

Finagle's Motto:

Smile—tomorrow it will be worse.

(Reprinted from *Oklahoma State Engineering Magazine*, April, 1962, p. 20.)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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 96d8 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.

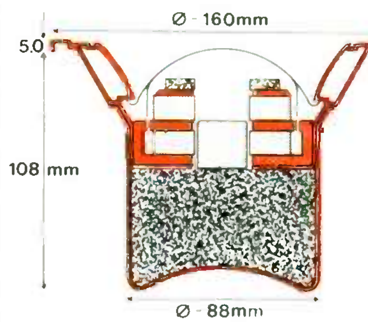
Specification

MDM 85 (with enclosure)

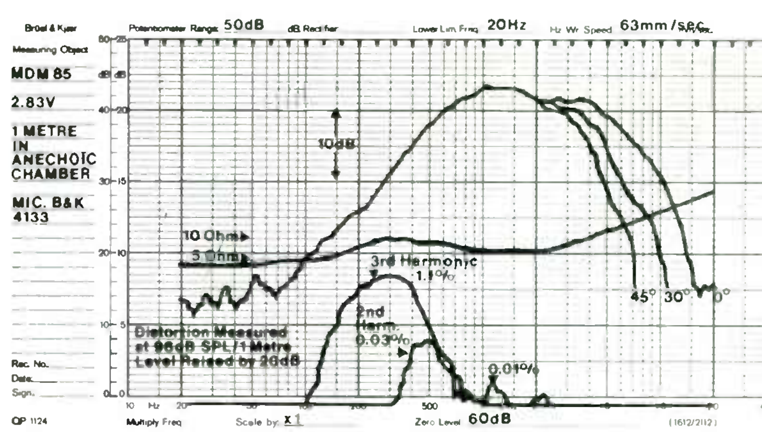
Overall Dimensions	Ø - 160mm x 113mm
Nominal Power Handling Din	300W
Transient Power 10ms	1500W
Voice Coil Diameter	75mm (3")
	Hexatech Aluminium
Voice Coil Former	Aluminium
Frequency Response	300-5000 Hz
Resonant Frequency	250 Hz
Sensitivity	92 dB (1W/1M)
Nominal Impedance	8 ohms
Harmonic Distortion 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 85N (without enclosure)

Overall Dimensions	Ø - 160mm x 60n
Frequency Response	250-5000
Resonant Frequency	170
Rmec	39.
Qms	0.
Qes	1.
Q/T	0.
Vas	0.7 li
Nett Weight	1.05



Specifications given are as after 24 hours of running.



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