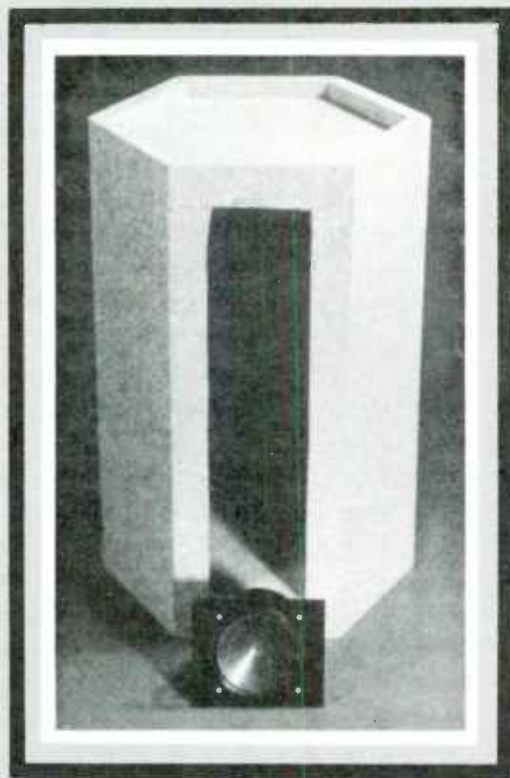


SPEAKER BUILDER



TED JORDAN

—TALKS ABOUT AUDIO—

—BUILDING HIS FIVE—

Good News

The British loudspeaker manufacturer **TANNOY** has come out with four new speaker systems. Added to the company's Planet series is the Saturn, a deluxe two-way system intended as a step-up model from Tannoy's best-selling Mercury system. It sells for \$498 per pair. The Titan is a new entry-level model in the Planet series. This two-way system offers high power handling and sensitivity, with excellent dispersion for "big speaker" performance from a compact unit. It costs \$278 per pair.

Tannoy has also added two units to its Dual Concentric line. The Stirling is a deluxe model offering a new approach to acoustic cabinet design. It allows a choice between distributed port (bass reflex) and infinite baffle (acoustic suspension) operation, while permitting a wide choice of speaker positioning in any room. Suggested retail price of the Stirling is \$2,098 per pair. The second addition to this line is the Dover, the smallest system in the line. It was designed for bookshelf or floor use in more restricted listening rooms. Suggested retail price is \$1,199 per pair.

To request additional information, write to Tannoy, 97 Victoria Street North, Kitchener, Ontario, Canada N2H 5C1.

FAST REPLY #BG780

AUDAX has developed a new plastic loudspeaker diaphragm material called TPX, formally known as AFP (Advanced Formulation Plastics). TPX's qualities of low density, high internal loss and high Young's Modulus combine to produce a loudspeaker cone material that is optimized for the low distortion and extreme transient response demands of digital audio. For details, contact Polydax Speaker Corp., 2 Park Ave., New York, NY 10016.

FAST REPLY #BG668



The winter catalog of precision tools and computer and telecommunication equipment is now available free from **JENSEN TOOLS INC.** Illustrated in full color, the 80-page catalog contains more than 1,000 tools of interest to engineers, technicians, computer and telecommunication service persons, and electronics hobbyists.

Major categories covered are test equipment, micro-tools, soldering equipment, tweezers, screwdrivers, cutters, drafting supplies, power tools, computer accessories and circuit board equipment. Also included are service kits and tool cases. To obtain a copy of the catalog, write to Jensen Tools Inc., 7815 S. 46th Street, Phoenix, AZ 85040.

FAST REPLY #BG25

The 6500-DSB Mark II electronic crossover from **ACE AUDIO** extends bass response with stereo subwoofers into the 20 to 35Hz region. It is an extensively redesigned version of the earlier 6500-DSB.

The unit features a 12dB/octave slope on both sides of the crossover and a plug-in module that controls the crossover frequency (from 30 to 200Hz). You can change the crossover frequency by installing another module. Distortion is in the 0.002 percent region at a nominal 2V output level.

The manufacturer can supply the Mark II with a summing output for use with a single subwoofer or stereo subwoofers. It features the newly developed twin "movable" level controls, which can be on the upper outputs (satellites) or woofer outputs. A separate level control is used for each channel.

Wired and tested, the Mark II costs \$156. Extra plug-in, frequency-change modules cost \$36 each. Contact Ace Audio Co., 532 5th St., East Northport, NY 11731.

FAST REPLY #BG11

YAMAHA ELECTRONICS has introduced two new moving-coil cartridges. The MC-1000 is targeted for the audio purist, while the MC-21 will appeal to listeners who do not have a moving-coil input on their amplifier or do not want to add a head amp to their system.

The MC-1000 has a tapered cantilever of diamond-coated beryllium, which adds strength and ensures tracking precision. Its light weight and high rigidity make it useful for tweeter construction and pickup cantilevers. Yamaha's low temperature dependent (LTD) damping enables the MC-1000 to yield its best results over a 30-degree spectrum. The unit features Yamaha's cross-matrix coil system and a one-piece, resonance-free housing. It tracks at 1.4g, $\pm 0.2g$, and has a suggested retail price of \$280.

The MC-21 is a high-output/high-impedance moving-coil design that will operate equally well in the moving-magnet or moving-coil input position. Neither a head amp nor an amplifier with a moving-coil input is required to use the cartridge. Yamaha's special equalizing damper maintains optimum vertical compliance for high trackability. The cross-matrix coil design minimizes cross-talk and provides precise imaging and musical detail. The MC-21 has an optimum vertical tracking force of 1.8g, $\pm 0.2g$, and costs \$70.

For additional information, write to Yamaha Electronics Corp., 6660 Orange-thorpe Ave., Buena Park, CA 90620.

FAST REPLY #BG406

AUDIO-TECHNICA has unveiled its AT-SP5 full-range power loudspeakers. Despite their diminutive size (3.9 by 5.9 by 3.1 inches), the speakers deliver sound over a surprisingly broad range of 150Hz to 18kHz, thanks to a special aspherical center dome driver amplifier. This is powered by four "C" cells or a 6V DC, 300mA power source, which provides sufficient volume for comfortable close-range listening.

Jacks are provided for an external power supply/battery eliminator and for the audio input. An LED power/on indicator is mounted behind the front grille. The speakers are encased in high-density, high-impact engineering resin to withstand years of hard use. A pair of AT-SP5s costs \$79.95.

Contact Audio-Technica, 1221 Commerce Drive, Stow, OH 44224.

FAST REPLY #BG22

ACOUSTIC RESEARCH (AR) has added to its line of automotive loudspeaker systems with the new AR2CS and 4CS speakers. These two-way, flush-mount systems join AR's three existing automotive models.

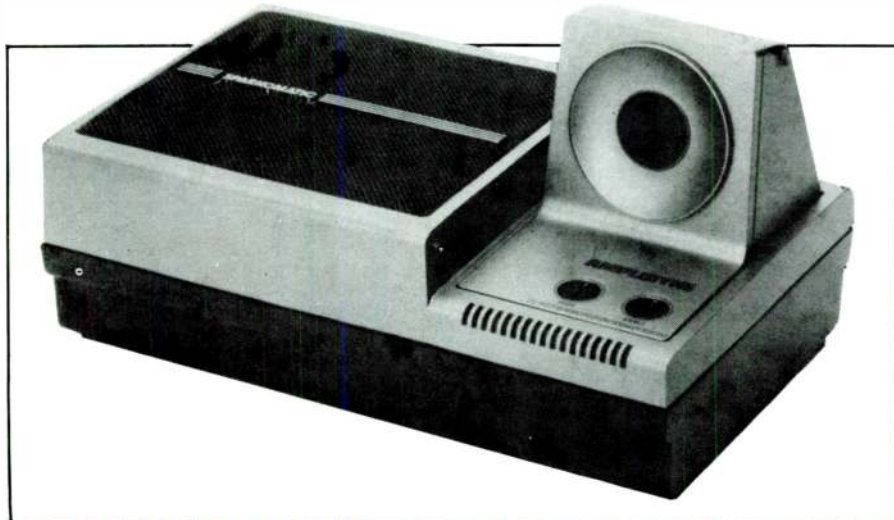
The AR2CS employs a 4½-inch woofer and AR's ¾-inch dome tweeter in a plate-type, high-temperature housing. It is rated at 5W minimum, 30W nominal and 75W maximum program peaks. Suggested retail price is \$199.98 per pair.

The AR4CS is this company's first concentric or coaxial design using its 5¼-inch woofer and a new ¾-inch, horn-loaded tweeter. The system has an ultra slim mounting height, just ⅝ inch above the surface, with a 5W minimum, 20W nominal and 50W maximum rating. Suggested retail price is \$139.98 per pair.

To find out more about these systems, contact Teledyne Acoustic Research, 10 American Drive, Norwood, MA 02062.

FAST REPLY #BG324

An innovative biamplified speaker component system is now available from **SPARKOMATIC CORPORATION**. The new Amplidyne Series includes a coaxial speaker system, two deck-mount systems and a subwoofer. Each incorporates separate amplifiers for the woofers and tweeter, with each pair offering 120W of additional power. The subwoofer also incorporates an amplifier and provides an additional 80W of power. All the speakers feature a low silhouette (ranging from 2½ to 4 inches deep) and are designed for easy surface mount installation.



FAST REPLY #BG781

INFINITY SYSTEMS has introduced the A462 and A32 two-way, dual-cone automotive loudspeakers. These are designed as affordable, drop-in replacements for the original equipment in virtually any imported or domestic car. Requiring no drilling or cutting, they offer a simple way to improve the sound quality of average automobile stereo systems.

The 4-by-6-inch A462 and 3½-inch A32 are equipped with a polypropylene woofer, which is linked to a separate polymer cone through a mechanical crossover for reduced distortion, improved clarity and reliability. The rugged driver materials give the speakers prolonged resistance to temperature extremes, moisture, and normal wear and tear.

Suggested retail price is \$44/pair for the A462 and \$36/pair for the A32. Write to Infinity Systems, 7930 Deering Ave., Canoga Park, CA 91304.

FAST REPLY #BG354

Additional advantages are a lower speaker impedance of 2 ohms; soft dome tweeters with high power-handling capability; low-resonance woofers; separate treble and bass controls; strontium cobalt magnets; and long aluminum voice coils for efficient heat dissipation, stability, increased low-frequency power handling and minimum distortion.

Suggested retail prices range from \$200 to \$300 per pair. The subwoofer costs \$200. Contact Sparkomatic in Milford, PA 18337.

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FAST REPLY #BG152

Important facts about INDUCTORS

The most important parts of your crossover are the inductors. Their quality can mean the difference between strong, clean bass and weak, distorted bass. A quality inductor means: low DC resistance, no saturation (a cause of distortion) and exact tolerances. Unfortunately, this usually means outrageous prices and inductors the size of Volkswagens. **Sherman Research** inductors offer a low cost/no compromise solution to the inductor dilemma. For high inductance values use steel lamination core inductors with ultra-low DCR, low hysteresis, and no saturation up to 1000+ watts. For lower values, use Sherman Research air core inductors that feature nylon bobbins and high temperature SNSR wire.

For more information, contact: Sherman Research, 14105 Inwood Rd., Dallas, TX 75234, or these distributors:

Soundbox
7057 Rt. 38
Pensauken, NJ 08110
(609) 662-4530

SRC Audio
3238 Towerwood Dr.
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FAST REPLY #BG12

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FAST REPLY #BG20

SPEAKER BUILDER MAGAZINE

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About This Issue

Small changes adorn this issue in the form of little codes below each space advertisement and each new product mentioned in the "Good News" section on pages 2 and 3. These "fast reply" codes are your way of getting information quickly by using one of the cards bound into the magazine. We hope you find them useful.

By a fortuitous coincidence, we have two complementary articles on the Jordan Module. **Bruce Edgar** visited Ted Jordan the last time he was in England and put together another of his excellent interviews, the first part of which begins on page 6. We also received an article from a free-lance author living on a Mediterranean island who needed a new pair of speakers. His choice was the Jordan System 5, including eight of the tiny Jordan drivers. **Harold Hirsch** tells all in "Tenth Row, Center" beginning on page 11.

Art Newcomb is back with an IC realization of his clever power indicator. Those who liked his first design (SB 1/83) will welcome this new one (p. 17). As an added bonus, Mr. Newcomb tells us how to make good-looking front panels. **G.R. Koonce** demonstrates more of the intricacies of Thiele/Small theory in his "Trade-Offs in Closed Box Systems" beginning on page 21.

As promised, **Robert Carlberg** concludes his speaker-building odyssey (p. 28), while readers **Kaufman, Berg, Schubert** and **Meraner** provide "Tools, Tips & Techniques" suggestions (p. 30). Don't miss Rion Dudley's egg-shaped enclosure in "Craftsman's Corner" (p. 34).

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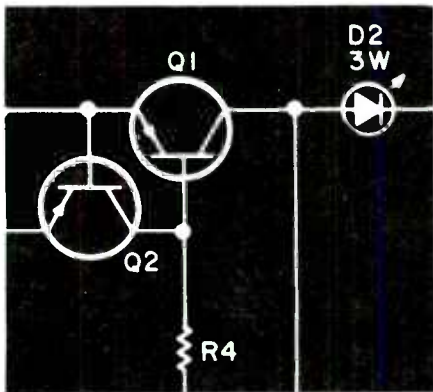
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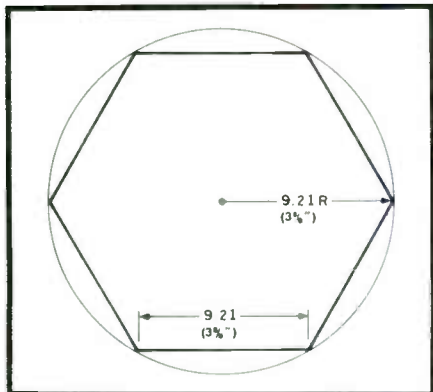
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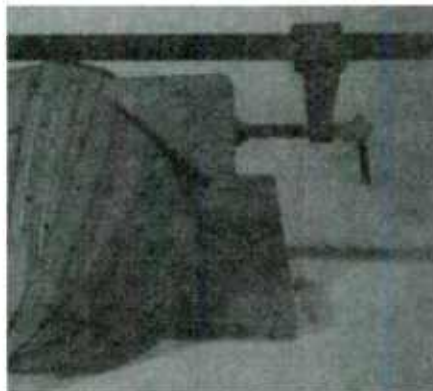
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A VISIT WITH TED JORDAN

BY BRUCE EDGAR
Contributing Editor



Sometimes spur-of-the-moment ideas can produce long-lasting effects. This is precisely what happened two years ago when I was visiting London. At the last minute, I decided to phone Ted Jordan, designer of the Jordan 50mm Module, and set up an appointment to chat with him about his work.

Mr. Jordan picked me up at the rail station in Maidenhead, which is about a 40-minute journey from London, and drove me out to his home in the Buckinghamshire countryside. I had expected to see a small factory turning out Jordan Modules, but to my surprise all his business is conducted out of his home, which is a combination office, demonstration room, and shipping and quality-control point.

Jordan is known as a maverick in the loudspeaker world, and you may or may not agree with his ideas. But I think you will find, as I did, that his discourses are most stimulating and edifying.

Speaker Builder (SB): *How did you get started in audio?*

Ted Jordan (TJ): My interest in hi-fi started when I was two or three years old. One Christmas, my parents bought me a toy car that had large wheels. Instead of playing with it as you would normally play with a car, I would lay it on its side, spin the wheels around with my finger and sing loudly. My parents got very worried: they thought they had produced a nut case. Then they realized that I had seen a gramophone, which was what I was trying to recreate. When I was five years old, my dad took an old headphoned and made me a gramophone. And it went on from there. I have always had a gramophone and records; I have always liked music. I can't read or play a note, but I love listening to the stuff.

I studied architecture in college because after World War II, everybody said that was the business to be in. I didn't like it, though, so I drifted back into radio and TV. I got involved with GEC (General Electric Co.-England) servicing TV sets. One day I heard some above-average music playing through one of the sets, and a colleague said, "Just listen to that top." "What's top?" I asked, and that was my introduction to hi-fi.

Now that I knew what "top" was (high frequencies), I wanted more of it. Having read a few books and chatted with a few friends, I tore my dad's radio to pieces and built my first hi-fi amplifier. I got so involved with hi-fi that I decided to earn my living in the business.

SB: *At that time, wasn't GEC developing an aluminum cone speaker, which was a fairly revolutionary driver?*

TJ: Yes, the cone was made of aluminum alloy. This was developed by Hugh Britain.¹ I was not in on the development, but I got involved as much as I could. The cone also had an alloy coil former turned out of solid metal and a plastic surround, which was very new at the

time. It had a quality that was far ahead of everything else. I taught myself about loudspeakers by messing around with a pair of cones. At that point, I built a steel-reinforced concrete enclosure for two GECs, which was bought many years ago by Laurie Fincham, now technical director of KEF.

SB: *How did you get into commercial loudspeaker design?*

TJ: I saw an ad for a development engineer with Goodmans Industries. Somehow, I convinced the managing director that I knew all there was to know about loudspeakers. When I joined Goodmans, I read everything, decided that most of it was rubbish and took it from there. I then had an idea for a cone shape—hyperbolic. I had good reason for this: if you depress the center of the cone and stretch the diaphragm, the resulting shape is a hyperbola.

SB: *Do you still believe this reasoning?*

TJ: To a large extent, yes. It is still a good shape.

SB: *Did Goodmans like it?*

TJ: Well, I went to Mr. Newland, the managing director, and said, "What we ought to make, sir, is hyperbolic cones." "You realize it will cost thousands of pounds to tool up for this damn fool idea," he replied. "But we'll do it. If it works, I will double your salary, and if it doesn't, I'll sack you."

It worked, and that was the beginning of the Axiette (Fig. 1), which had the flat-test response of any cone speaker yet produced.

SB: *How big a speaker was the Axiette?*

TJ: It was an 8-inch speaker with a paper cone and hyperbolic shape, but they never made them as well as I had designed them in the lab. Our "production

engineers" wanted a 1/8-inch gap filled with glue because it was easier to do.

I thoroughly enjoyed my life at Goodmans when Mr. Newland, "the old man," was alive. He was a real character. He posed a challenge, and if you won, you were in. If you lost, you were out.

SB: What other loudspeaker projects did you start?

TJ: In 1955, *Wireless World*² announced the large electrostatic loudspeaker by Peter Walker of Quad. Mr. Newland called me in and said, "Could you make me one of these?" "Probably," I answered. "Do you know anything about it?" he demanded. "No." "Go away and make me one anyway."

I took my aluminum foil and perforated plates and connected two oscilloscope power supplies to it all. Lo and behold, it sparked, but it did not play. Problem number one was to stop the sparking, which we eventually did.

Even though Quad had been working on its speakers for five years, we had only three months to get ours ready for the Audio Fair. The whole thing was quite hush-hush. I was given a special laboratory, where the windows were painted so nobody could peep in. Nobody knew what we were doing, but by the time the Audio Fair rolled around, I had an electrostatic speaker working.

Across the entrance to the fair was a banner reading, "Come see the world's first electrostatic loudspeaker by the Acoustical Mfg. Co." This was the big trade issue of the year. The rooms in the hotel were selected by ballot, and by incredible coincidence, the Goodmans room was right next to the Quad room. People started to come in at 11 a.m., and at 11:30 Peter Walker came running into my room with a big grin. "The people are saying you have an electrostatic loudspeaker in here," he said. "So we have, and there it is," I replied. His jaw dropped.

"It's not, is it? Does it work?" I played an appropriate big organ passage, just as he always did. "I don't believe it. You've got a bass unit in there," he remarked. "No bass unit in there," I answered. "How long have you been developing that?" "Oh, about three months."

SB: How big was it?

TJ: It was about 4 by 3 feet.

SB: Did you do anything beyond a flat radiator?

TJ: Yes, there was a phase delaying on the way through. The radiators were all in strips. It was quite a sophisticated beast.

SB: Did Goodmans ever market it?

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Fundamental Resonance	- - -	65 c/s (nominal)
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GOODMANS

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FIGURE 1: The Goodmans Axiette loudspeaker was Jordan's first full-range speaker design. This ad for the Axiette appeared in *Audio*, August 1954.

TJ: No, we went on for about three years, exhibiting an improved version at each show, but it became obvious that the world was not going to become electrostatic. So they shelved the whole thing, and that ended the electrostatic phase of my life.

SB: What other speakers did you design at Goodmans?

TJ: I spent the rest of my time at Goodmans (about 12 years) trying to make a better speaker than the Axiette. I designed the Axiom 301, 401, M-80, and so on, but none of them was as good as the Axiette. The Axiette became very popular and made the company a fortune. I always wondered how good it could have been if it had been built as a super, money-is-no-object speaker. If the Axiette had cost 30 pounds instead of 5 pounds, and if the production people

had made it the way I wanted, it would have been a world beater.

SB: What was the last project you did for Goodmans?

TJ: The last thing I did was the Maxim (Fig. 2).³ As a result of writing a book⁴ on loudspeakers, I had learned the three-way tie-up between enclosure size, efficiency and bass extension. I knew that if I accepted a low enough efficiency, I could make a loudspeaker that was the size of a book and had an acceptable bass response. In 1962, that seemed unlikely, but I made the Maxim, which was very inefficient and would not handle much power, but provided acceptable bass. It was the first of the "micros," and nobody came close to it for years.

SB: Tell us about your book.

the MAXIMUS 1

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15 WATTS

Only 10½" x 5½" x 7¼" . . . fits everywhere . . . book shelf . . . end table . . . wall! Takes no more space than a few books, a small lamp, or a modest picture frame. True bass from the specially designed MAXIMUS woofer. Exceptionally large magnet provides high acoustic efficiency and power capability. Uniquely designed L-C crossover network transfers power at 1900 CPS to a newly developed backloaded mid-range/high frequency unit. Ideal for wide range mono . . . two for stereo. Designed for 8 to 16 ohms.

Net price: \$59.50

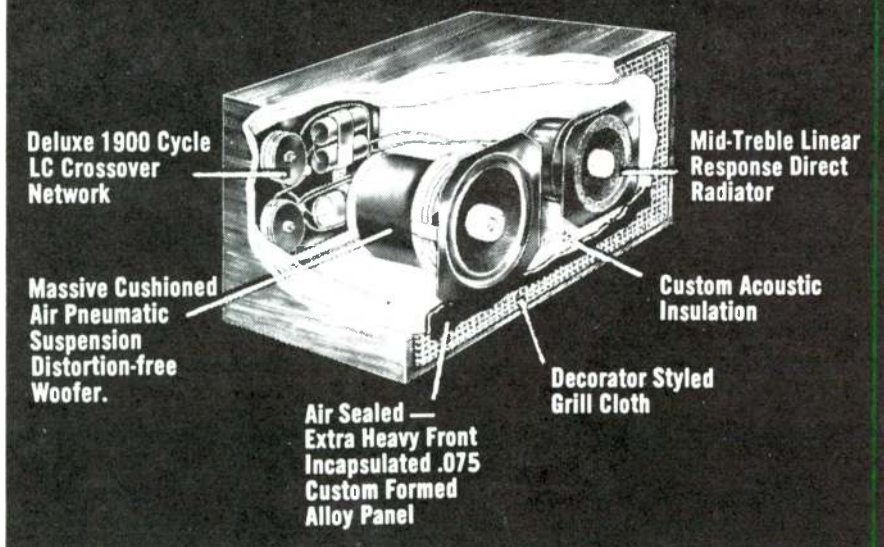


FIGURE 2: The Goodmans Maxim (English market name), or Maximus I (US market name), miniature loudspeaker system was Jordan's last design effort for Goodmans. This ad appeared in *Audio* in 1964. The unit was the forerunner of the "micro" loudspeakers on the market today. A home constructor's version was described by Wœms in *Popular Electronics* (March 1968).

TJ: I had done my homework at Goodmans: I had studied my math and gone into every aspect of sound and loudspeakers. My book was published in 1962. I regarded it as a reference for myself. Although I hardly ever use it, it's nice to know the theory. If people want to argue technicalities, I can argue technicalities—but it's not the way I work.

SB: Getting back to loudspeakers, how did you get involved with the Jordan-Watts driver?

TJ: Les Watts was the export manager for Goodmans. When "the old man" died, the company stopped being an intimate family where you were paid according to results. All the developments were to

keep up with fashion, rather than to get better results. I got fed up and bored, so I left Goodmans and joined Les Watts.

SB: At Jordan-Watts, you decided to build a speaker as good as the Axiette?

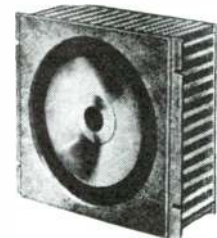
TJ: Combining our earlier experience at GEC with the aluminum cone and hyperbolic flare of the Axiette, we went to the Jordan-Watts driver (Fig. 3).⁵ It was the devil to make and not very reliable. It was never as good as I would have liked, but it was never intended to be one of the world's better loudspeakers.

SB: What was the Jordan-Watts driver intended to be?

TJ: Good value for sound. People either

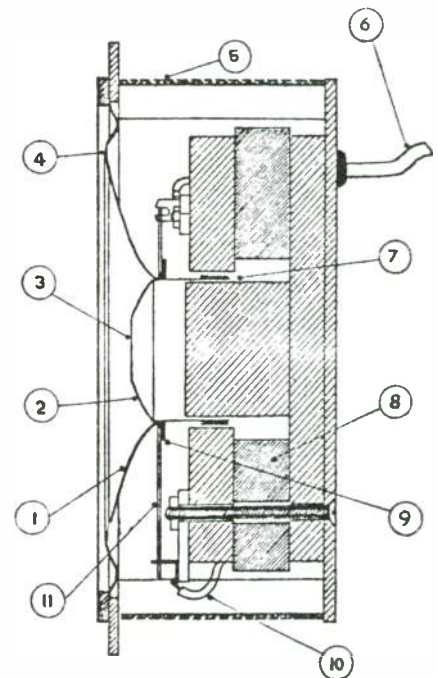
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FIGURE 3a: The Jordan-Watts driver unit. Its design and construction was a radical departure from contemporary lines in 1964. This first appeared as part of a product review in *Audio* during 1964.



Key to Diagram

1. Metal cone contoured to hyperbolic law.
2. Phase correcting dome.
3. Resistive termination to dome centre.
4. Resistive termination to cone edge.
5. Acoustic damping.
6. Direct input signal cable.
7. Coil completely immersed in magnetic field.
8. High efficiency "Feroba" magnet.
9. Resistive termination at junction of cone, coil and suspension.
10. Connections to coil via suspension.
11. Silvered beryllium copper suspension cantilevers.

FIGURE 3b: A cutaway drawing of the Jordan-Watts driver.

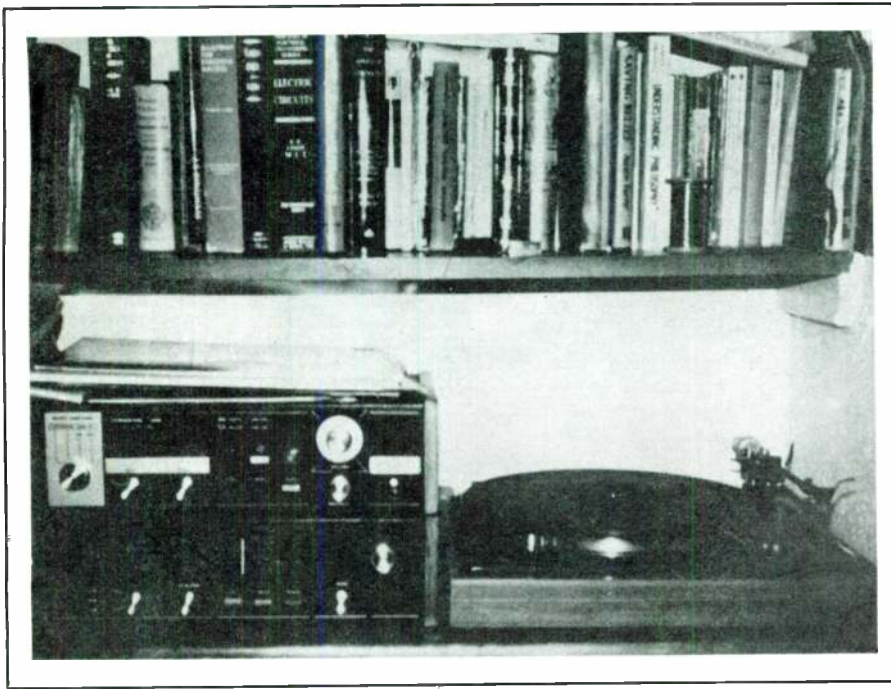


FIGURE 4: Ted Jordan's simple bookshelf hi-fi system. The amplifier (upper left unit) is Jordan's design. The tuner was designed by another engineer, but it was produced during Jordan's consulting period. The turntable is a Connoisseur BD-1.

loved it or hated it, which indicates it had some key advantages and also some deficiencies.

SB: What did you use for the surround?

TJ: That's where we had problems. We used a coated foam, but we had problems finding the right adhesives for it. The surround has so many jobs to do that it is as important as the cone. The technology and principles were right, but we did not have the materials to pull it off.

SB: It had a box behind it, didn't it?

TJ: That was a type of chassis. We thought we would get away from the usual basket format. There was nothing acoustically clever about it. We made the driver square so it could be stacked, which is a principle I have followed ever since.

SB: How long were you at Jordan-Watts?

TJ: About 18 months. Mr. Watts and I did not see eye to eye, so we parted company.

SB: What did you do then?

TJ: I went into a rather complicated consulting phase.⁶ I produced another couple of speakers similar to the Jordan-Watts, but then I got involved in designing equipment for other people. They were modest pieces—mostly record players, tape players, amplifiers, tuners and the like. I would set up the production plant and get the whole thing organized.

Few interesting products came out of that part of my life, but I learned all about production and running a company.

One product that did come out of this activity is the amplifier I still use (Fig. 4). If I were a sensible, up-market designer like all the others, I would have some esoteric amp that would have cost me 1,000 pounds. Instead, I have a little amplifier that I designed ten years ago and cost 60 pounds. It's only 15W.

Next time, Mr. Jordan will discuss his 50mm module and the new Jordan amplifier.

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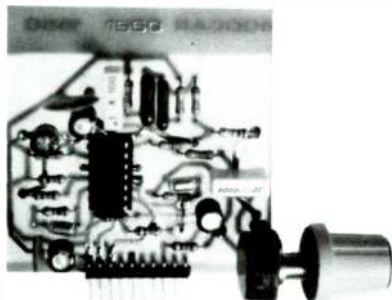
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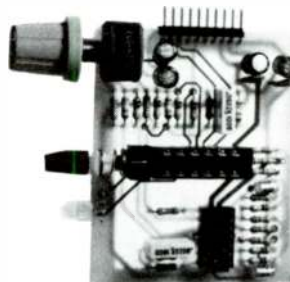
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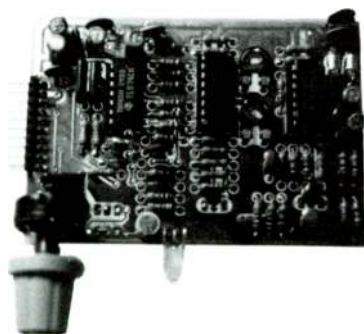
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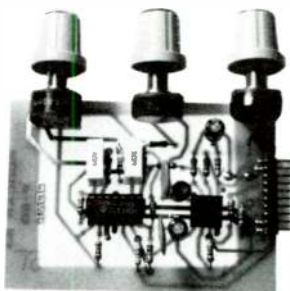
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TENTH ROW, CENTER

BY HAROLD HIRSCH

My old Spanish speakers had finally collapsed: the humidity that plagues the Mediterranean island on which I live had been too much for them. I decided to pamper myself and replace them with high-end English units. But when I learned about current costs, I realized that even a standard product, let alone the enthusiast quality I was after, would explode my fragile budget. And, at the end of my planned visit to the UK, I would also have the problem of weight and bulk, as I would be carrying my new speakers by hand back to my island home. These two considerations ruled out the purchase of a complete system. I would have to buy drivers only—and the smaller and lighter the better.

I subscribed to a respected English hi-fi magazine. After two or three issues, I began to feel that I was in the swim. I wrote for manufacturers' literature and sorted out English sound in my head. On the one hand, there was the low-coloration, BBC monitor-oriented type of sound, prime examples of which were KEF, Rogers and B&W. On the other hand, there was the LP-oriented, or "dynamic resolution," type, characterized by manufacturers such as Heybrook, ARC and Linn. Celestion's SL-6 was the only successful product to mate these two philosophies. All this research made my personal objective—lightweight quality sound for a penny—seem more and more remote.

And then one day I saw an advertisement. E.J. Jordan Ltd. was offering "miniature moving-coil loudspeakers of very advanced design." The word "miniature" caught my eye. Those 50mm modules would be just the thing for me to carry home. But who

had ever heard of serious 2-inch, wide-range speakers? Was there more to these tiny drivers than mere portability?

A few days later, I came across a news item in one of my magazines. The ultra-top-end, three-way, Max Townshend Elite speaker systems, retailing at around \$3,000 a pair, used four-unit vertical arrays of the Jordan 50mm Modules as their midrange drivers. That did it. I wrote for the Jordan manual.

The manual is a 36-page general introduction to sound reproduction, thickly written. It includes plans for five standard systems, along with parts lists and complete construction information for each system. The systems increase in complexity up the ladder from 1 to 5. The material in the manual was abstracted from Jordan's advanced design textbook, *Loudspeakers* (Focal Press, London, 1963). It conveys a carefully reasoned philosophy about loudspeaker systems. It ends with an articulate dedication to the moving-coil principle in driver design and embraces a similar dedication to the bass-reflex principle for the reproduction of the lower frequencies. Faced with all this, how could I resist? I determined to see and hear the modules in the UK, and, if possible, to see and hear Mr. E.J. Jordan, too.

MEETING MR. JORDAN. Ted Jordan's home in Marlow is only a short run from London's Paddington station. Jordan, jovial and pleased by my visit, met me at the station in a beat-up, dull green Daimler. I liked him at once, aromatic pipe and all. We talked about the car, the precious good weather and the next war. But we did

not talk about his 50mm modules. It was clear they would talk for themselves later.

Over coffee, Jordan recounted his experience in the hi-fi industry and the theoretical underpinnings of the Jordan Module. (See *Bruce Edgar's interview with Mr. Jordan beginning on p. 6.—Ed.*) Embracing a frequency range from 100Hz to above audibility, the unit features high power-handling capacity (up to 50W peaks), an outstanding transient response and an exceptionally low distortion level, typically one-tenth of conventional units. It will trace the most complex waveforms with minimal translation loss and great accuracy of detail. It is intended for use with suitable bass units at a crossover frequency of 150Hz. The units may be used singly or in multiples.

"The design philosophy," Jordan said, patiently relighting his chronically recalcitrant pipe, "is based on the fact that if the output of an amplifier could be coupled directly to the air load without any intervening mechanical or electrical impedances, there would be no loss of detail or distortion of the input waveform. The modules, using very advanced technology and materials, have been developed to approach this ideal as closely as possible."

There was a long silence while his

Nota Bene

Since this article was prepared for publication, Dalesford has gone out of business. Although you still might be able to find the D30/110 drivers, Mr. Jordan has suggested substituting the KEF B110/A.

words sank in. What he had said was moving enough in itself, but what was even more exciting to me was the knowledge that at any moment I would be hearing the actual musical result of all this theory.

My coffee was cold by then, but I

sipped it gratefully, using it as a time consumer. I had a good deal to digest, and I could see that Jordan was going to give me more. Suddenly, I was aware of music—the opening bars of Beethoven's violin concerto.

"There was no sense of reproduced

music...the ambience, atmosphere and involvement were total. . . ." So read my scribbled notes. On top of a low bookcase stood two hexagonal enclosures not more than 14 inches high and 6 or 7 inches in diameter at their longest diagonal. The music seemed to

The Jordan System 5: A Woodworker's Approach

By Bruce Edgar, Contributing Editor
Photos by Manfred Buechler

I first auditioned the Jordan System 5 when I visited Ted Jordan at his home in England. (See my interview with Mr. Jordan beginning on p. 6.) Its sound clarity, cohesive stereo image and small size appealed to me, but the plans for the System 5 (Fig. S-1) are somewhat lacking from a woodworking point of view. Most notably, the joints between the sides leave too much to the reader's imagination for this to be a practical construction project.

My approach to building a System 5 is similar to building a six-sided bucket or planter. You can make the beveled sides (Fig. S-2) either by cutting out six rectangular pieces and then beveling the sides or by setting up your table saw so that one angled cut produces two beveled sides. The second approach is preferable because it requires only one-third of the saw cuts required by the first method. This production "shortcut" saves time and effort and produces a more uniform piece.

Begin by cutting out a 12½-by-24-inch rectangular piece of ½-inch particle board or plywood. (I used industrial-grade particle board that does not chip on the edge.) Then set your table saw blade to an inclination of 60 degrees with a drafting triangle. Cut off a 60-degree edge along the 12½-inch side to give a beveled edge, as shown in Fig. S-3a. Use the miter gauge to push the piece by the blade. After cutting off the edge, the acute pointed edge will be lying on the saw table surface. Next, flip the piece over toward you so that the acute pointed edge is up, as illustrated in Fig. S-3b.

Now you are ready for the shortcut. Mark off 4⅞ inches from the acute pointed edge along the 24-inch side. Set the saw fence so that the blade will cut the complementary beveled edge on the first side piece, as shown in Fig. S-3b. After this cut, the side piece should have a trapezoidal profile when viewed end on (Fig. S-2). Flip the remaining large piece so that the acute pointed edge is again above the saw table and against the fence, as shown in Fig. S-3c. Again, push the board through the saw blade to get a 12½-inch length that is beveled at 60 degrees along both long sides. By repeating the operation in Fig. S-3, you can quickly obtain your six beveled sides for the System 5.

With a ½-inch dado blade, cut a ¼-inch-deep dado groove, which is inside the trapezoidal side and is spaced ½ inch from the ends. Make this cut with the miter gauge for each end of the six beveled sides. You can achieve a uniform cut if you clamp a short block of 1-by-2 stock (a gauge block) to the fence just in front of the blade. (The latter will prevent binding between the blade, the fence and the board.) This arrangement is schematically shown in Fig. S-4. Set the fence so that the dado cut is spaced ½ inch from the small end of the beveled side piece. If you do not have a dado blade set, you can make several passes through the saw to cut out the rectangular groove, using a gauge block to set the edges of the groove uniformly. The dado grooves allow easy alignment of the hexagonal top and bottom parts in assembly.

Next, measure the length across the bottom of the dado groove. If the groove is exactly ¼ inch deep, the bottom groove should be 3⅞ inches long. In my case, I cut the groove slightly deeper and had to cut my top and bottom pieces larger than I had planned. Subtract ⅛ inch from the groove measurement and set a circle compass to that length. Draw a circle with the

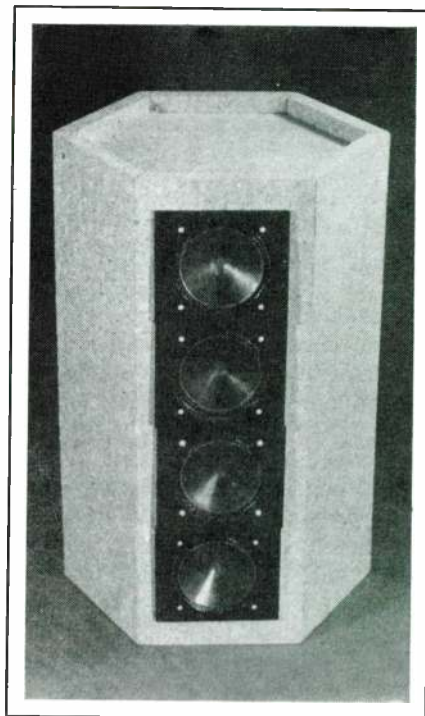
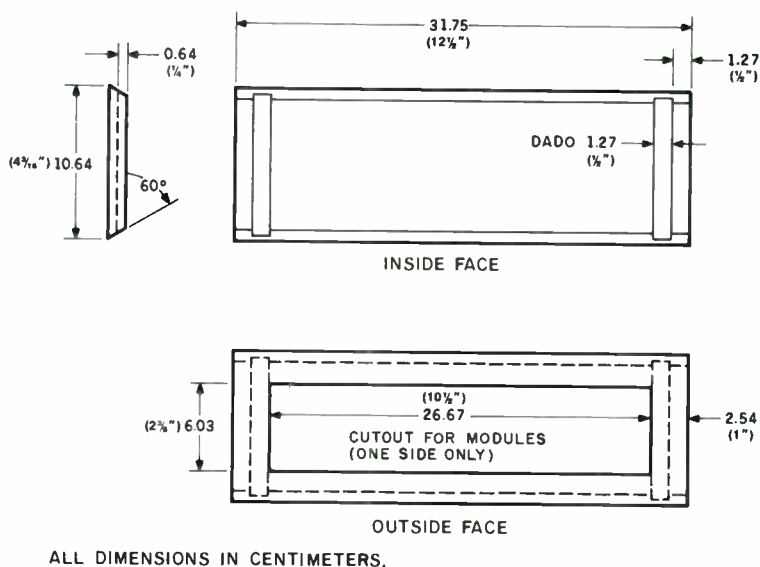


FIGURE S-1: A woodworker's version of the Jordan System 5.



ALL DIMENSIONS IN CENTIMETERS.

FIGURE S-2: Cutting diagram for the beveled side pieces.

come from between these two inconspicuous constructions.

The bookcase also contained bass-reflex enclosures, but they blended in with the books. They were about 50cm long and were unobtrusive. They handled everything below about

150Hz. Everything else came from those incredible hexagons with their four-unit linear arrays of 50mm modules, stacked vertically in one of the inward-facing sides.

I walked across the room at a right angle to the soundstage, but the soloist

remained stationary in the center of the clearly spread-out orchestra. He was just slightly to the left of the conductor, and he stayed there, just there, no matter where I moved in the room. It was an astonishing demonstration, not only of superb musical reproduc-

compass on two 9-by-9-inch pieces of 1/2-inch particle board. By marking off lengths equal to the radius around the circle, you can construct a hexagon, as shown in Fig. S-5. Cut out hexagons for the top and bottom pieces.

Now do a dry run on the assembly by putting the top and bottom pieces into the grooves of one side and pushing additional sides onto the top and bottom pieces. If the ends are too small, gaps can appear in the dado joints. Conversely, if the ends are too large, the beveled sides

will not join properly. After checking that all pieces mate correctly, disassemble them, apply glue to all the joints and reassemble the pieces. Use strap clamps to squeeze the beveled joints together for airtight bonding.

After the glue has set, cut a slot 2 3/8 inches wide by 10 1/2 inches long in one face of the enclosure with a saber saw, as shown in Fig. S-6. Drill an access hole for wiring either in the back or the bottom. Seal the hole with silicone rubber after you have pushed the speaker wire through. Wire

the Jordan modules together in a series-parallel arrangement to give an 8Ω impedance. Mount the modules with silicon rubber glue. (One of the questions I forgot to ask Ted Jordan was why he didn't put screw mounting holes in his modules.) Use some large, heavy books as a weight to hold the modules flat while the glue sets. Otherwise, the interactions between adjacent magnets will tend to buckle the alignment.

For finishing, I suggest you use a router to cut a rabbet around the speaker slot so that the modules lie flush with the surface. Wrap the enclosure with grille cloth, bringing the cloth's edges around the top and bottom ends. Then make a hardwood hexagonal top that press-fits into the top recess to hide the grille cloth ends.

The stereo version of the System 5 requires eight Jordan modules, which involves considerable expense. An alternative would be an enclosure that uses two modules. For this version, shorten the beveled side pieces to 8 inches long and make the cutout 6 inches long.

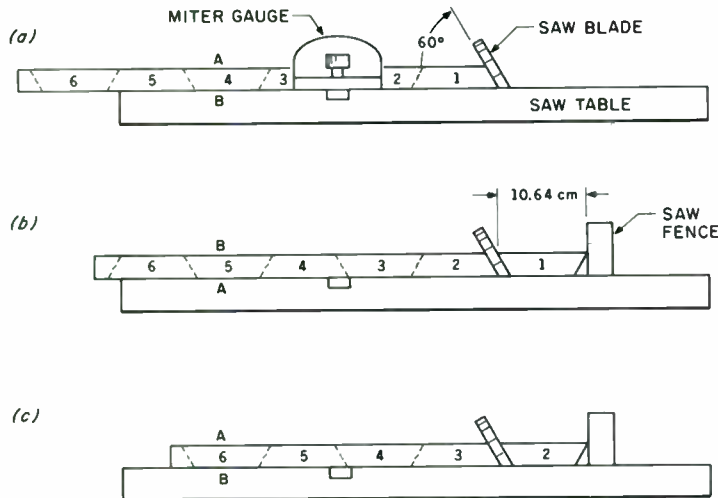


FIGURE S-3: A production shortcut for producing the beveled sides on a table saw saves time and effort and results in a more uniform piece.

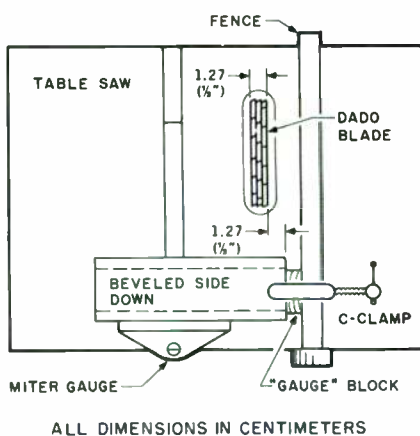


FIGURE S-4: Cutting the dado groove on a table saw is a fast, efficient way to align the hexagonal top and bottom parts.

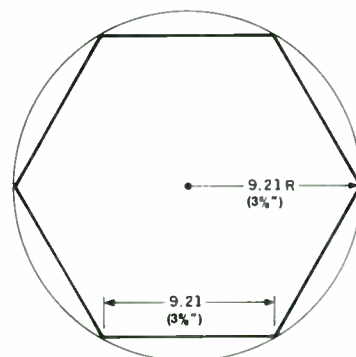


FIGURE S-5: To construct the hexagonal top piece out of 1/2-inch particle board, draw a circle and mark off lengths equal to the radius around the circle.

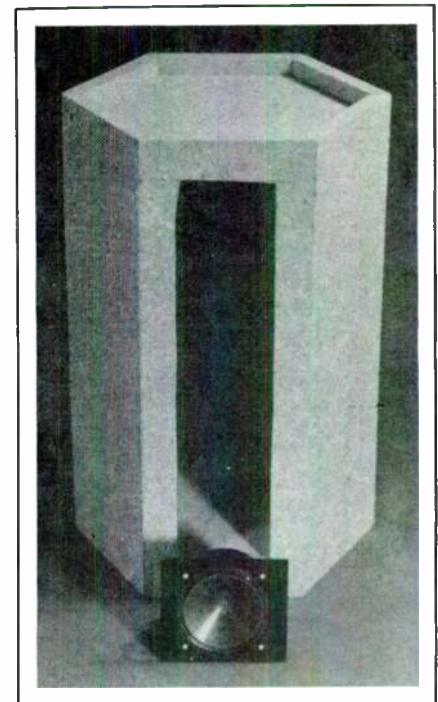


FIGURE S-6: Cut out a slot 2 3/8 inches wide and 10 1/2 inches long in one face of the enclosure. The four Jordan modules will fit in the opening. Perfectionists may wish to rabbet a shallow recess on each side of the opening to mount the modules flush with the cabinet face.

tion, but also of a stereophonic effectiveness I had never experienced before. The overall quality, like that of the Celestion SL-6, seemed to be a blend of the two types of English sound—low coloration fused with dynamic resolution. But that hardly does it justice: given the virtues of the modules, you must also remember the following.

While crossover circuits can at best be regarded as necessary evils, their problems can be substantially minimized by using as few components as possible, crossing over at one frequency only (and the lower that frequency, the better), using adequately sized cores in the inductors, shunting all electrolytic capacitors with small, non-polarized capacitors, and ensuring that the voice-coil impedances of the bass drivers are as resistive as possible. *All* of these conditions exist when you use the Jordan 50mm Modules in conjunction with the Jordan crossover and its recommended bass-reflex-mounted Dalesford 5-inch bass/midrange D30/110 drivers.

JORDAN CONSTRUCTION. At last, I was ready to build the enclosures. The plans for the five standard enclosure systems offered by the manufacturer looked straightforward enough. The systems are as follows:

- *System 1*—one 50mm module, plus one 100mm bass unit (Dalesford D30/110 recommended), reflex-housed with one Jordan crossover (150Hz), in an integrated enclosure. Two enclosures make stereo.
- *System 2*—one 50mm module plus two 100mm units in a push-pull reflex configuration, housed in one integrated enclosure with a crossover. Two make stereo.
- *System 3*—two miniature treble enclosures each with one 50mm module and two separate bass-reflex enclosures. Each bass enclosure has two 100mm bass drivers in push-pull operation and a crossover where wanted. (This turns out to be identical with the bass enclosures in System 5.)
- *System 4*—two vertical arrays of four 50mm modules each, combined with two 100mm push-pull bass units mounted in reflex, hexagonal, floor-standing, integrated enclosures with crossovers. (The unusual shape makes accurate angling easy for optimal stereo imaging.)

- *System 5*—two small, hexagonal treble enclosures housing vertical arrays of four 50mm modules each (wall or shelf mounted) and two separate bass-reflex enclosures, a la System 3.

The large dimensions of my listening room (9 by 6 by 3.5 meters) demanded that I use either System 4 or 5. But I was still apprehensive: could 2-inch drivers for the mids and highs, with 5-inch woofers (push-pull and bass-reflex notwithstanding) really be expected to do the job? I was asking a great deal. I finally settled on System 5 because of its greater flexibility in room-placement options.

When I actually began to work on the enclosures, I immediately ran into an unexpected problem. Somewhere along the line, somebody in the Jordan establishment had slipped up in specifying cutting list and diagram dimensions in the manual. The dimensions were inconsistent. The dimensions I used for System 5 in this article are accurate when used with 12mm and 18mm-thick, high-quality, high-density chip board or Medite. Keep in mind that the interior dimensions are critical and should be strictly observed. You can use thicker material to good effect, especially in the bass enclosures, but the interior dimensions must remain unaffected. That means, as you will see, that the reverse speaker boxes and the vent tubes *must* be made of 12mm material.

Having said all that, I must add that the building process itself couldn't be easier. Due to the inherent elegance of the designs, both treble and bass enclosures are small. Given their smallness, they require less—less bracing, time, material, work and cost. Simple butt-joint construction, glued and screwed, is all that is required. A Stanley Screwmate or its equivalent will be very helpful. This ingenious device is a drill bit, which drills pilot holes, counterbores for shank clearance and countersinks—all at the same time.

It was hopeless for me to do the cutting myself. Right angles became curved, straight lines wiggled. Clearly, my hand and hand saw were not made for precision incision. I looked for more skilled help and found Juan, a nearby carpenter who had his own commercial workshop. It was equipped with the whirring blades and screeching band saws required in the mass production of shutters, doors, window frames and the like.

I knew Juan was my man when I discovered that he always hummed while working. Here was a musical man who could respond to my musical project. He did the original cutting of the parts with his power tools. Right angles were right. Straight lines were like a draftsman's ruler. This convinced me of the necessity of using power tools in cutting out the enclosures. See Bruce Edgar's sidebar on page 12 for construction details.

JORDAN WIRING. To wire up the four modules, refer to *Fig. 1*. The modules' magnets are so powerful and light that the modules tend to buckle or jump toward each other while you are wiring and inserting them into their vertical array positions, so be careful. To prevent this behavior, use a nonmetallic weight, such as a heavy book, to hold them down. Also be careful not to dent the alloy cones.

Keeping my caveat in mind, lay the completed treble unit on its back, with side 1 facing up. Drop the wiring assembly into the unit, while carefully bringing the modules close to it and keeping them as far apart from each other as possible. Pass the speaker lead out through the hole in the bottom or back of each unit. Seal this hole airtight.

Pack insulation-grade fiberglass wadding into the interior of the unit, taking care not to stress the wiring. When the unit is full of wadding, *carefully* begin placing the four modules onto their supporting loudspeaker fillets. They should fit easily into place, with their square metal flanges resting securely on the fillets. They should be tight enough so that no spaces are left between adjoining flange edges.

Once the modules are in place, put a generous bead of fresh, pliant, high-grade silicone sealant along all edges, including the adjoining metal flange edges. Make the bead flow as smoothly as possible. Let the unit dry overnight. If you ever have to get inside, you can easily slit the sealant with a razor blade, then reseal the unit. When the sealant is dry, install the grille cloth or acoustically transparent loudspeaker foam.

THE BASS ENCLOSURES. The bass units come next. Finish cutting the pieces, including the two driver openings (11.7cm diameter if you use the Dalesfords), one in the main front

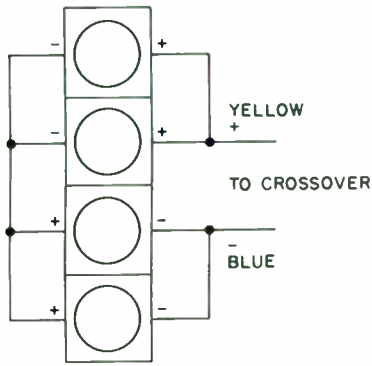


FIGURE 1: Wiring diagram for the Jordan System 5 vertical array.

TABLE 1

MATERIALS LIST

Jordan System 5—One Treble Enclosure

(see sidebar)

Use 12mm (1/2") high-density chip (particle) board or Medite.

Hexagonal top and bottom (2) 20.3 x 20.3cm (8 x 8")

Sides (6) 31.75 x 10.64cm (12 1/2 x 4 1/16")

Jordan System 5—One Bass Enclosure

Use 18mm high-density chip board or Medite.

Bass chamber

Back (1) 50.2 x 26.8cm

Front (1) 42 x 26.8cm (right side from front); 34 x 26.8cm (left side from front)

Sides (2) 50.2 x 29.4cm

Top (1) 30.4 x 29.4cm

Bottom (1) 30.4 x 29.4cm

Use 12mm high-density chip board or Medite.

Reverse speaker box

Back (1) 17.4 x 17.4cm

Sides (2) 15 x 7cm

Top (1) 17.4 x 7cm

Bottom (1) 17.4 x 7cm*

Vent tube

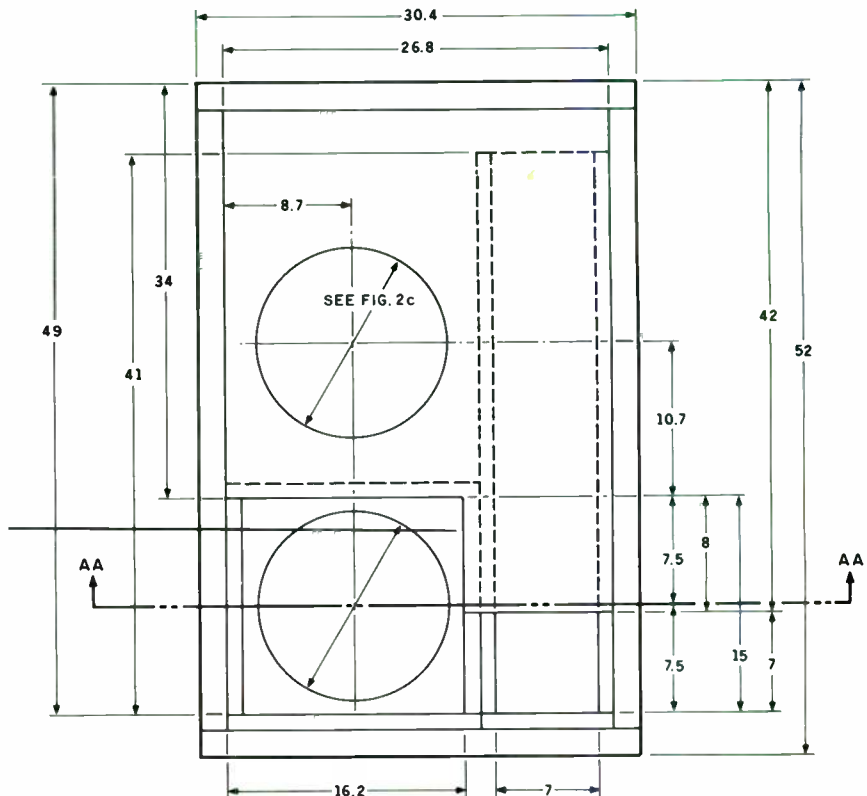
Back (1) 42.2 x 9.4cm

Sides (2) 41 x 7cm

Bottom (1) 9.4 x 7cm*

*The author recommends that you combine the reverse speaker box bottom and the vent tube bottom pieces to form one 26.8 x 7cm piece.

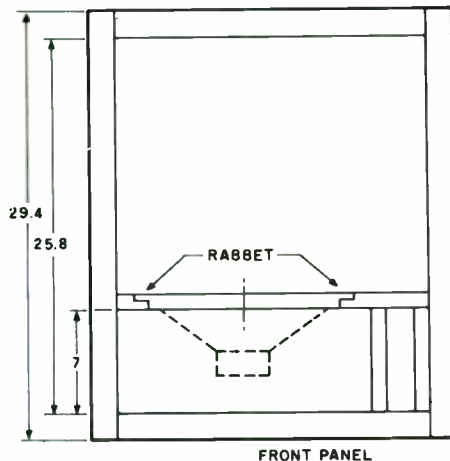
piece and the other in the main piece of the reverse speaker box. When making the main front piece, rabbet the outward-facing surface. When you insert the drive unit later, its magnet will face the rear. Cut this front piece with special care: its dimensions are



ALL DIMENSIONS IN CENTIMETERS.

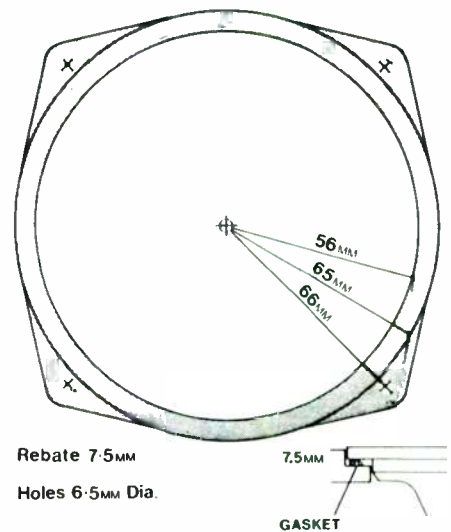
2.54 cm = 1 inch
10.16 cm = 4 inches
30.48 cm = 12 inches

FIGURE 2a: Cutting guide for the bass chamber, front view. Note especially the front panel's irregular dimensions, which require special care in cutting. See Fig. 2b for a close-up of the cross-section (AA).



ALL DIMENSIONS IN CENTIMETERS.

FIGURE 2b: Cross-section (AA, Fig. 2b) of the bass chamber, top view.



Rebate 7.5mm

Holes 6.5mm Dia.

GASKET

FIGURE 2c: Dalesford D30/110 driver mounting data.

irregular (Fig. 2a), and the precision with which it is cut helps to minimize unwanted resonances.

The main piece of the reverse speaker box (17.4 by 17.4cm) is critical, as you will fit the rearward-facing speaker of the push-pull pair into it.

Be careful with the rabbeting. A sharp chisel and a steady hand are mandatory. Power tools cannot help here. Only slow, careful chipping will do. Handle the drivers with the greatest care when testing for fit. It would be tragic to put a chisel through those

beautiful Bextrene cones. The Dalesfords come with self-explanatory cutting diagrams (Figs. 2 and 3).

Now assemble the reverse speaker box and vent tube (Fig. 3). Everything else depends on this assembly, so it should be as nearly perfect as possible. Make sure it is exactly 26.8cm wide and don't settle for anything more or less. Glue the two pieces together where their inner side surfaces touch, even if you make a common bottom piece, as I suggest in my note at the bottom of the materials list (Table 1). You should use screws to fix this large surface-to-surface joint. Drive the screws through the inside surface of the right side piece of the box. They must pass into the left side piece of the vent, but *not* bulge or pierce its inner surface.

Before assembling the box, drill a speaker lead hole through the left inner corner of the top panel. Before assembling the vent, round, smooth and varnish the top inner edges to enhance air flow. Do the same to the inner edge of the lower right portion

of the front panel, which will form the upper edge of the vent exit. Keep in mind that the reverse speaker box and the vent tube *must* be made of 12mm material.

How strong should the construction be? How many screws should you use? I spaced the screws about 2½ inches apart, where feasible. I also glued every joint and all touching flat surfaces, small or large. I located and drilled all foreseeable screw holes before assembly. First marking each line of screws and each screw hole with a pencil, I then drilled the hole at a right angle to the surface.

Once you have this basic building block finished, you can construct the rest of the bass enclosure. Figure 2b shows a cross-section of the bass chamber. Fit the front panel to the reverse box-vent tube unit, and glue and screw it in place. The fit must be exact. If you have been exact with the cutting, you will have little trouble with the fitting. Use screws generously, driving them through the front panel directly into the 12mm edges of

them together, with 2½ inches between screws. Inside distances between sides should be 26.8cm. Use fiberglass wadding, 60mm thick, on all interior surfaces of this construction.

Carefully fit your bass drivers into the prepared, rabbeted positions. The upper unit, with access only through the front panel, should face outward, into your listening room. The lower speaker, with access only through the rear surface of the 17.4 by 17.4cm panel of the reverse speaker box, should face *inward*, toward the rear panel of the bass chamber. Be very careful when mounting the drivers: the Dalesford-supplied nuts and bolts are tricky and the magnets so strong that the hardware dances out of your fingers like mercury blobs.

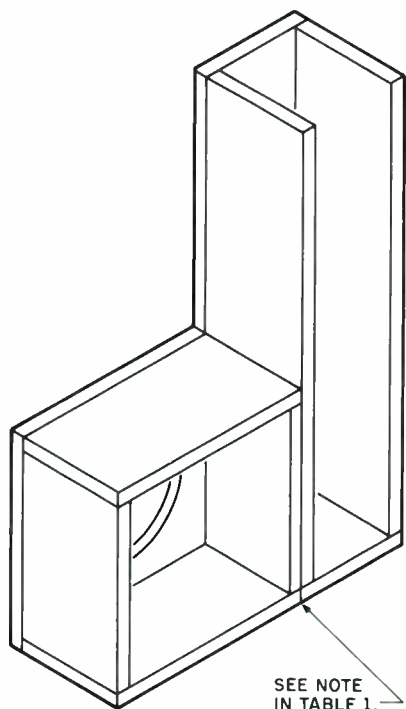
Figure 4 will help you in wiring your speakers. Solder thoroughly. No dry joints, please. Pass the lead wires through the prepared holes in the top panel of the reverse speaker box (to the interior) and into the bottom of the back panel. These holes must be absolutely airtight. If you are going to mount crossovers inside the enclosures, now is the time to do so. My crossovers are outside the enclosures for greater flexibility.

Now bring your units together. Fit the sides and top along your front panel and fix them provisionally with hold screws. If everything is square, start gluing. Countersink the screws, use wood putty on the screwheads and sand the surface. Finish with paint, varnish, cloth, formica or whatever. Finally, attach the bottom panel. Don't forget the fiberglass, 60mm thick, which must be fastened to the center of this panel. Do not glue the panel on. Instead, use rubber draft-excluder strips, which will maintain the airtight integrity of the unit and also permit easy access. The grille and velcro-edged grille frame are optional. You are now the owner of a quality, flexible loudspeaker system.

My relatively tiny units fill my enormous room with music at a sound pressure level you would expect only from behemoths. You must hear them to believe them. As the title says, tenth row, center.

SOURCES

1. E.J. Jordan Ltd., [Lindenfels] Spurgrove, Freith, Henley-on-Thames, Oxon, England.
2. KEF Electronics Ltd., Tovil, Maidstone, Kent, England ME15 6QP.



INT. DIMENSIONS OF BOX - 15 x 15 x 7
INT. DIMENSIONS OF TUBE - 41 x 7 x 7
ALL DIMENSIONS IN CENTIMETERS.

FIGURE 3: Reverse speaker box and vent tube assembly. This is the heart of the bass enclosures, so it should be as perfect as possible.

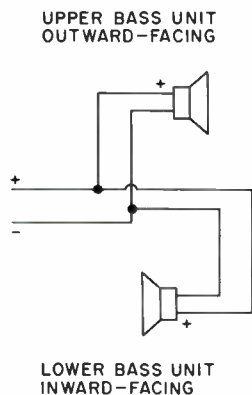


FIGURE 4: Wiring diagram for the upper and lower bass units.

the small box and vent pieces. I used 20 screws for this purpose. Remember that the 12mm panels beneath the main front panel also act as brace units, so take advantage of their presence. Once again, you should end up with what appears to be a single unit, exactly 26.8cm wide and very solidly made.

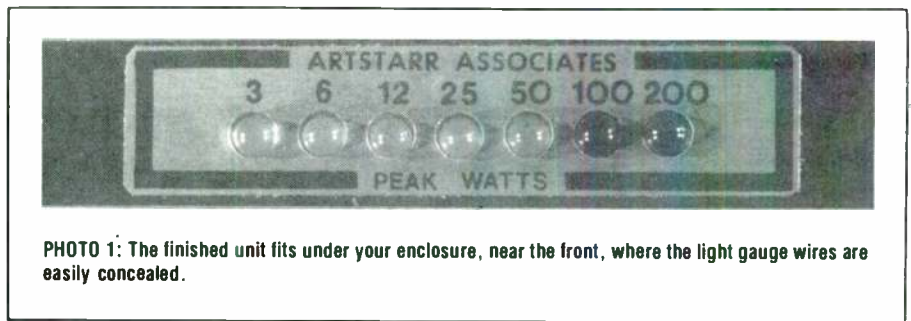
Now put together the back, sides and top of the bass chamber. Make sure you have correct right angles between the back and sides. Glue and screw

EASY PEAK POWER INDICATOR REVISITED

BY ART NEWCOMB

In *Speaker Builder* 1/83 (p. 26), I described an easy peak power indicator that you can install in or near a speaker system for less than \$5 per channel. Since then, I have extended the basic principles set down in that article, using National Semiconductor's LM 3915 bar/dot generator to produce a multicolor bar graph display. The updated version (*Photo 1*) adds only the generator IC, two resistors and the necessary LEDs, and it costs just \$10 per channel. See *Table 1* for a summary of its specifications.

The LM 3915 consists of a stack of ten comparators with a logarithmically scaled reference divider, a temperature-compensated voltage reference and an input buffer amplifier. Although the unit usually requires a power supply, it operates quite well on the half-wave rectified waveform applied here (principally because no reactive components are used). Each alternate half-cycle pulse individually activates the voltage reference and the comparators over the full audio fre-



quency range, with bandwidth to spare.

Indication is instantaneous. Very fast transients will elude the eye, but the display is useful in assessing when speaker system operation approaches rated limitations. Incidentally, since the IC uses differential comparators to switch the LEDs, indication is more defined than the one-transistor circuit described in my earlier article. I borrowed one trick from National's *Linear Data Book*. I used the chip in the "dot" generator mode, which

allows "bar" graph display with the LEDs in series. This avoids the parallel accumulation of LED currents, which would increase amplifier loading.

INSIDE OUT. A current source (Q1 and Q2 in *Fig. 1*) assures full brightness at low power indications, although maximum LED current is established by the IC at about ten times the current flowing through R5. Along with the current source, the LED accumulated voltage drops provide a

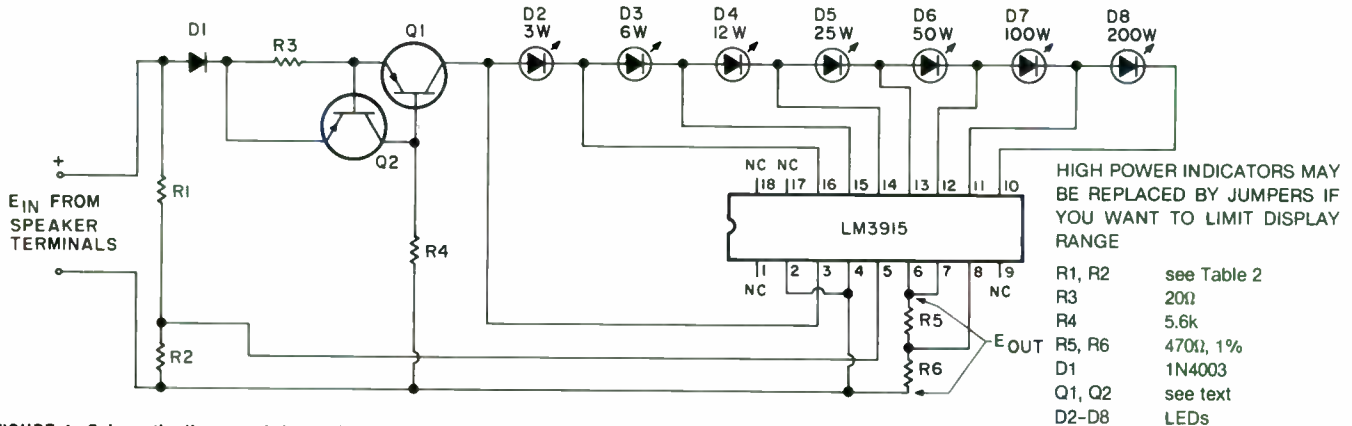


FIGURE 1: Schematic diagram of the peak power indicator with the LM 3915 bar/dot generator.

voltage limiter to protect the IC from over-voltage. For this reason, you should test the LEDs. An open LED can cause the IC voltage rating (25V) to be exceeded. R5 is across the 1.28V reference brought out to pins 7 and 8. The voltage dropped across R5 and R6

(E_{out}) establishes the reference voltage for the comparator stack.

With the input scaling resistor (R1), you can scale the unit to read different step values. The minimum is about 3W, which comes from the voltage necessary to overcome diode drops

and operate the IC internal reference. R1 is computed as follows:

$$R1 = R2 \left(\frac{E_{in}}{E_{out}} - 1 \right)$$

where E_{in} is the voltage across the

Front Panel Preparation

The 3M Company's Scotchcal® system has been a boon to professional and amateur users with short-run nameplate needs. It is the most efficient method to use when making the front panel for my peak power indicator (Fig. S-1).

The system produces professional results with minimum effort and equipment investment. It is available with colored printing on clear or opaque plastics or black anodized printing on natural or gold-dyed aluminum. Both have a bull-dog adhesive backing. The aluminum versions are especially durable (rated at three years outdoor service) and are suitable for electronic project nameplates. Protective Mylar cover sheets are also available where high abuse levels are expected.

All materials are available on 10-by-12-inch sheets of negative photosensitive materials, which are contact exposed to high ultraviolet (UV) content sources such as photo-floods, fluorescent UV lights and the sun. You develop the material simply by swabbing it lightly with an aqueous alcohol solution, which contains the developer and is sold separately. 3M also sells disposable pads recommended for application of the developer.

The system is relatively inexpensive—about 6¢ per square inch. Based on a full package of ten 10-by-12-inch sheets, one quart of developer and one package of developer pads, the total cost is about \$60. It is available from 3M distributors. Old Colony will offer a special kit for speaker builders.

ARTWORK AND PRINTING. You can prepare artwork in one of two ways. The *direct* method (negative—light on dark) uses black dry transfers (rub-ons) for lettering designs and shapes, along with stick-ons like those used in circuit board layouts. A thin, clear plastic base provides an instant one-to-one contact negative for direct transfer. You can prepare a scaled sketch on graph paper as a guide, then use the plastic overlay for rub-on application.

In the *reversal* method (positive—dark on light), you prepare art on a white paper base and have a printer make a negative. This gives you the opportunity

to do more detailed art at two or more times the finished size. 3M also sells a photosensitive film for contact reversals, but I have not used it.

I use a Kepro UV light box, which is primarily for circuit boards, but I have also used a photographic print frame (available at photo equipment retailers) with incandescent photo-floods. This takes a long exposure time (15 to 20 minutes), and the materials get hot.

You can improvise a print frame as shown in Fig. S-2. The cheapest method is to put the frame in the sun. Cut the Scotchcal to size in subdued indirect light (the photo materials are very slow), mount the negative (legible side up), secure it in the print frame and expose it perpendicularly to the sun's rays. *Good contact is important.* If some of the artwork is raised, as with stick-ons, you might have to back the Scotchcal with foam to get good contact with the irregular surface. I need about five

minutes of exposure in Virginia's cool October sun, but you might want to experiment with the exposure time for your project.

After exposure, return to subdued light, remove the Scotchcal and lightly swab on the developing solution. This washes away the unexposed photosensitive material. When the Scotchcal is thoroughly dry, you can trim the plate with household scissors to fit your project. Remember that the adhesive-backed edges will not be sticky until the Scotchcal is completely dry.

Then peel off the protective back and carefully press the plate onto a clean, dry surface. I use the mounted nameplate itself for a punch/drill template whenever possible (Fig. S-1), but you can cut holes in the mounted nameplate with a small knife blade if the surface has already been drilled. Once your operation is set up, the whole process takes just 15 or 20 minutes.

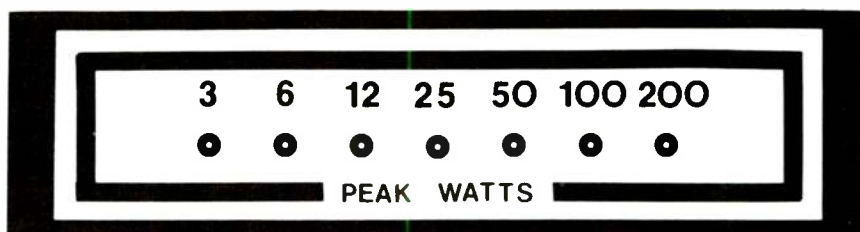


FIGURE S-1: A 2× negative for the front panel of the peak power indicator.

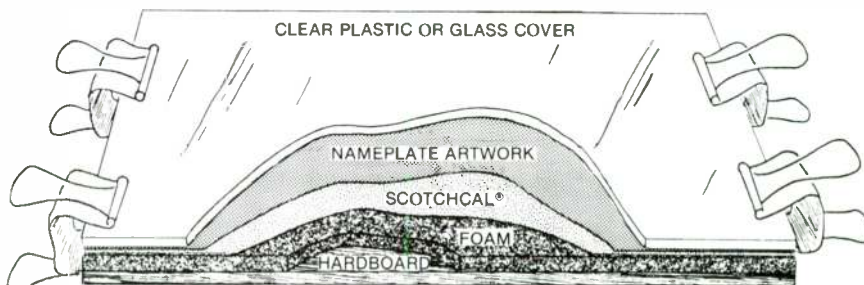


FIGURE S-2: Improvised print frame used in making Scotchcal labels.

TABLE 1

SPECIFICATIONS	
Indication	3-200W peak (1.5-100W RMS) in seven 3dB steps within 1dB
Accuracy	> 150Ω @ 3W to > 1,000Ω @ 200W
Amplifier Loading	80V RMS, 115V peak AC

TABLE 2

VALUES OF R1*			
R2	4Ω**	8Ω	16Ω
1.0k	9.8k	14.3k	20.6k
1.2k	11.8k	17.1k	24.7k
1.5k	14.7k	21.4k	30.9k

*Use nearest 1% value or hand select (measure) from 10% values. A series or parallel combo might be easier.

**Minimum indication at 4Ω is 6W; 3W and 6W LEDs will operate at nearly the same level.

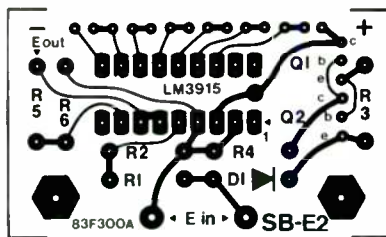


FIGURE 2: Peak power indicator circuit board.

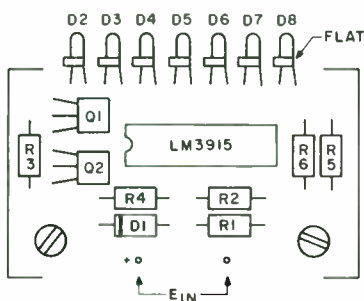


FIGURE 3: Stuffing guide for the peak power indicator.

Old Colony is offering the board and kit for Mr. Newcomb's design. The board alone costs \$2.50, while the cost of the kit is \$9.00. Send your order, along with payment, to Old Colony, PO Box 243, Peterborough, NH 03458.

speaker terminals. Compute E_{in} as follows:

$$E_{in} = \sqrt{PZ}$$

where P is the maximum peak power to be indicated by LED (D8) and Z is the speaker nominal impedance. Therefore, for a peak power of 200W (P) and 8Ω (Z), E_{in} equals 40V peak. To find E_{out} , use the following formula:

$$E_{out} = 1.28 \left(1 + \frac{R6}{R5} \right) + I_{bias} (R6)$$

I_{bias} is the reference circuit bias current and is equal to about 120μA. When $R5 = R6 = 470Ω$, E_{out} is 2.62V.

I have computed R1 for three speaker impedances and several values of R2 (Table 2). R1, R2, R5 and R6 should all be 1 percent resistors and will yield an accuracy within ½dB. You can get closer by actually measuring E_{out} and recomputing the proper value for R1 (½dB is about 12 percent error in power).

The current source transistor (Q1) must handle the total applied voltage (E_{in}) minus drops for D1, Q2 (V_{BE}) and the cumulative LEDs. This is about 15V when seven LEDs are used. Compute the maximum current through Q1 (I) as follows:

$$I = \frac{V_{BE}}{R3} = \frac{0.65}{20} = 32.5mA$$

Since this is peak half-wave current, it is well within the safe operating area for the MPSA55 (according to Motorola) up to 60V (or an E_{in} of 75V), which is the equivalent of about 700W peak input at 8Ω. The 80V MPSA56 will get safely to more than 1,000W. Q2 can be any PNP transistor with a VCEO greater than 5V and a beta of more than ten. I designed Fig. 2 with the TO-92 case in mind and used 2N5400 because it was handy.

Figure 2 shows my circuit board layout sized for the miniature T-1 LED case. You can use larger LEDs with a little flange filing to fit the 0.2-inch center-to-center spacing. For a colorful display, I suggest using green LEDs for D2 and D3, yellow for D4-D6 and red for D7 and D8. With the TO-92 transistors placed flat side against the board, the finished unit is only 0.3 inch thick and can be mounted beneath and toward the front of many enclosures so that its two light gauge wires are easily concealed. You might have to modify the feet or pedestal on some enclosures to provide the ½-inch clearance.

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TRADE-OFFS IN CLOSED BOX ALIGNMENT

BY G. R. KOONCE
Contributing Editor

Mr. Koonce takes a break this time from his modular construction series to give us a new perspective on applying the Thiele/Small parameters to home projects.

Varying the total system Q (Q_{TC}) of a closed box system involves some trade-offs in performance. Small discusses this in his classic work,¹ but he does not present the information from the standpoint of a home-builder trying to design an enclosure. In some cases, Small's information can be misleading.

For example, Small and Weems² both present curves of the low-frequency response of closed box systems for various values of Q_{TC} . These curves are normalized for system resonant frequency (f_C). They show the -3dB frequency (f_3) moving lower as Q_{TC} increases, leading the unwary builder to believe that high- Q_{TC} alignments have lower f_3 frequencies. They do not.

I have tried to explain the parameter trade-offs as a function of Q_{TC} from the standpoint of someone who owns a bass driver and is selecting a closed box alignment for it. The fundamental difference is that the Thiele/Small (T/S) parameters for the driver are "fixed" and cannot be varied as part of the trade-offs.

To determine the effects of fixed driver T/S parameters, I have examined f_3 ; peak amplitude ($|G_{j\omega}|_{\text{max}}$) and frequency of occurrence ($f_G \text{ max}$); maximum displacement limited acoustic power (P_{AR}); net enclosure volume (V_B); and closed box "effectiveness." My figures show the effects as you change alignment (i.e., Q_{TC}),

while Table 1 gives actual value computation. The recommended range of Q_{TC} for closed boxes is between 0.7 and 1.0, but I will describe parameter trade-offs over the 0.5 to 1.5 range.

I have assumed that the driver is "known," with the following T/S parameters fixed:

- f_S = driver free-air resonance;
- Q_{TS} = total driver Q (assuming the driver will be driven from a low-impedance source);
- V_{AS} = air volume, having the same acoustic compliance as the driver suspension.

BASIC EQUATIONS. Small established some basic equations for a closed box system.¹ With the T/S parameters fixed and the driver directly coupled to a low output impedance amplifier, the alignment variations are accomplished by varying the enclosure volume (V_B). This work assumes that the enclosure will be lined with damping material, not filled with it. Therefore, the following relationships hold:

$$\alpha \equiv \frac{V_{AS}}{V_B}$$

where α is the compliance ratio and V_{AS} and V_B have been defined;

$$\frac{f_C}{f_S} = (\alpha + 1)^{1/2}$$

where f_C is the resonant frequency of the driver-closed box system, and f_S has been defined;

$$\frac{Q_{TC}}{Q_{TS}} = (\alpha + 1)^{1/2}$$

where Q_{TC} and Q_{TS} have been defined.

1. *Lower -3dB Frequency.* Small and Weems' data for f_3/f_C at various Q_{TC} values agrees. Noting from the basic closed box equations that:

$$\frac{f_C}{f_S} = (\alpha + 1)^{1/2} = \frac{Q_{TC}}{Q_{TS}}$$

Then:

$$f_C = \frac{Q_{TC}}{Q_{TS}} \times f_S =$$

$$Q_{TC} \left(\frac{f_S}{Q_{TS}} \right) = (\text{a constant}) \times Q_{TC}$$

as f_S and Q_{TS} are "fixed" driver parameters. Thus:

$$f_3 = f_C \left(\frac{f_3}{f_C} \right) = (\text{a constant}) \times Q_{TC} \left(\frac{f_3}{f_C} \right)$$

In Fig. 1a, I have calculated the relative values of f_3 as Q_{TC} varies. For convenience, I selected $Q_{TC} = 1$ for normalization. Table 1 shows the equation to compute f_3 at $Q_{TC} = 1$. You can find f_3 at other Q_{TC} values by multiplying the value at $Q_{TC} = 1$ by the relative f_3 value from Fig. 1a. Note that the lowest value obtainable for f_3 is at $Q_{TC} = 0.707$, where f_3 equals $0.7 \times (f_S/Q_{TS})$. Selecting any Q_{TC} value between 0.5 and 1.0 produces only about a 0.18 octave variation in f_3 .

2. *Peak in Bass Response.* Small¹ gives equations for the magnitude of the peak ($|G_{j\omega}|_{\text{max}}$) and the normalized frequency ($f_G \text{ max}/f_C$) at which this peak occurs. Figure 1b shows the height of the peak in decibels versus Q_{TC} . No peaking occurs for a Q_{TC} less than or equal to 0.707.

The same procedure used with f_3 allows removing the f_c factor from f_G max so that the results in Fig. 1c relate only to Q_{TC} . The frequency at which the peak occurs is minimized at Q_{TC} around unity and rises as Q_{TC} moves either way. At $Q_{TC}=0.8$, the peak amplitude is down to less than 1/4dB, so the frequency at which the peak occurs for Q_{TC} values below 0.8 is of little importance. Remember, as the amplitude of the peak increases, the transient response of the system will degrade. Table 1 shows the equation to compute f_G max for $Q_{TC}=1$.

3. *Maximum Displacement Limited Acoustic Power.* The maximum acoustic power that a driver can deliver at a fixed peak displacement (X_{max}) will vary with closed box alignment. Small¹ shows that the relationship for sine-wave RMS power (CW) is:

$$P_{AR}(CW) = k_p(f_3)^4 V_D^2$$

where V_D is the volume displacement for the driver ("piston" area times X_{max}), and k_p is a function of alignment.

Small gives a curve of k_p versus Q_{TC} . I have shown how f_3 varies with Q_{TC} , and V_D is "fixed" for my driver. Thus, you can compute the relative value of P_{AR} (CW) and normalize it to $Q_{TC}=1$. This result is shown in Fig. 2. Again, Table 1 gives the equations to calculate P_{AR} (CW) at $Q_{TC}=1$. Note that determining the actual value of P_{AR} requires additional driver parameters. In the equations shown in Table 1, these are:

- D = "piston" diameter of the driver (inches);
- X_{max} = peak cone displacement (inches).

Parameter determination is outside the scope of this article, but is developed in Weems.² These parameters are fixed for the evaluations of closed box alignment effects on P_{AR} with a specific bass driver.

Figure 2 also represents relative maximum sound pressure level (SPL), as this is directly related to P_{AR} . Table 1 shows how to approximate the actual SPL level at $Q_{TC}=1$. Because the SPL might mean more to the homebuilder than acoustic watts, Fig. 2's ordinate axis is in decibels. Thus, you can find the SPL at any value of Q_{TC} by finding the relative SPL value from Fig. 2 and adding it to the SPL at $Q_{TC}=1$ obtained from the equations in Table 1. The multiplier for relative P_{AR}

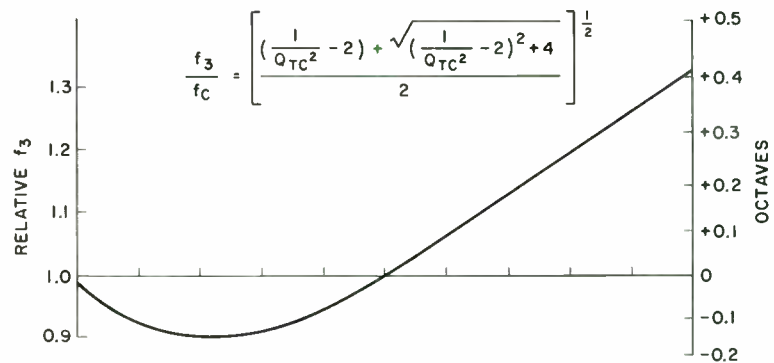


FIGURE 1a: Relative f_3 vs. Q_{TC} .

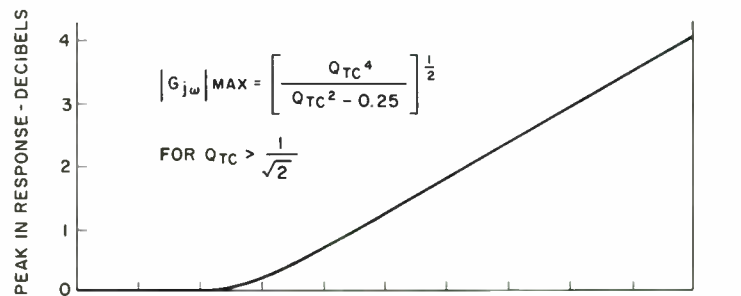


FIGURE 1b: Magnitude of response peak.

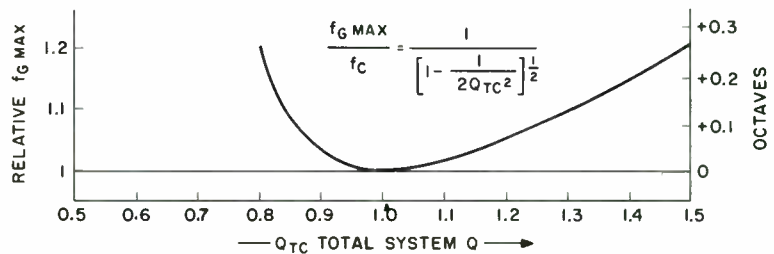


FIGURE 1c: Relative f_G max vs. Q_{TC} .

Definitions

- f_3 = driver free-air resonance (hertz).
- f_3 = system -3dB cutoff frequency (hertz).
- Q_{TS} = driver total Q (source = 0Ω).
- f_G max = frequency at which the peak in response is at its maximum (hertz).
- $P_{AR}(CW)$ = sine-wave acoustic power limit at displacement X_{max} (watts).
- X_{max} = maximum peak displacement (one way from center) for which the driver stays linear (inches).
- D = piston diameter of driver cone (inches). Usually taken as the cone diameter plus the surround width on one side only.
- $P_{AR}(P)$ = program acoustic power limit at displacement X_{max} (watts). Applies to material with all frequencies restrained to be above f_3 .
- SPL = approximate sound pressure level in an average reverberant room (decibels). It is actually the approximate SPL at 1 meter for 2π steradian free-field radiation.
- V_B = net enclosure volume (units the same as those used for V_{AS}). I like to work in cubic feet.
- V_{AS} = volume of air with the same acoustic compliance as the driver suspension. I normally work in cubic feet.

Conversions

- 1 meter = 39.36 inches
- 1 liter = 1 cubic decimeter, or 10^{-3} cubic meters
- cubic feet = $35.29 \times$ cubic meters, or $(35.29 \times 10^{-3}) \times$ liters

TABLE 1

COMPUTATIONS FOR $Q_{TC}=1.0$ ALIGNMENT

1. $f_3 \cong 0.786 \left(\frac{f_s}{Q_{TS}} \right)$
2. $f_C \text{ max} \cong 1.41 \left(\frac{f_s}{Q_{TS}} \right) \cong (1.8)(f_3)$
3. $P_{AR} (CW) \cong 5.26 \times 10^{-11} \left(\frac{f_s \times D}{Q_{TS}} \right)^4 (X_{max})^2 \cong 1.38 \times 10^{-10} (f_3 \times D)^4 (X_{max})^2$
4. $P_{AR} (P) \cong 5.38 \times 10^{-11} \left(\frac{f_s \times D}{Q_{TS}} \right)^4 (X_{max})^2 \cong 1.02 \times P_{AR}(CW)$
5. $SPL \cong 112 + 10 \log_{10} P_{AR}$
6. $V_B \cong \frac{(Q_{TS})^2 \times V_{AS}}{1 - (Q_{TS})^2} \cong \frac{V_{AS}}{(Q_{TS})^2 - 1}$

is also shown in Fig. 2 for those who prefer not to work in decibels.

Figure 2 shows that low- Q_{TC} alignments have very low sine-wave power limits. Small has pointed out, however, that the frequency at which maximum displacement occurs ($f_x \text{ max}$) is below f_3 when Q_{TC} is less than 1.1. For enclosures where f_3 is

below any frequency at which you will require major output power, you can raise the maximum power limit to what Small calls the program maximum acoustic power [$P_{AR} (P)$]. This is also plotted in Fig. 2; the equation is given in Table 1 for $Q_{TC}=1$. Again, program acoustic power can be expressed as SPL, allowing easy decibel

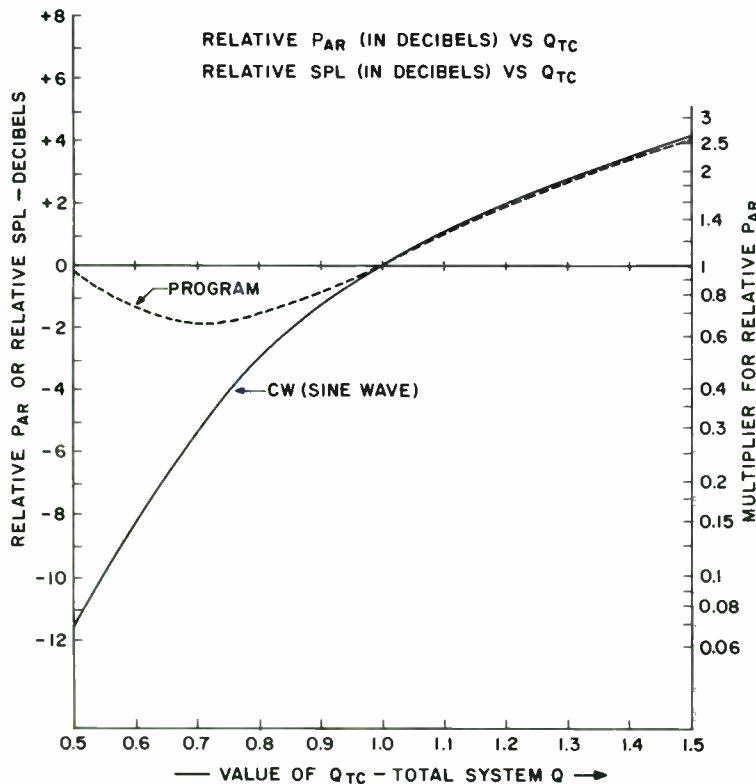


FIGURE 2: Effects of alignment on acoustic power

manipulation as you vary Q_{TC} . This result is much kinder to low- Q_{TC} alignments, but is applicable only when power input is kept at frequencies above f_3 . It usually applies only to full-range systems (f_3 down in the 20-40Hz range) in high-fidelity applications.

4. *Box Volume.* By combining the basic closed box equations, you can see that:

$$V_B = \frac{V_{AS} Q_{TS}^2}{Q_{TC}^2 - Q_{TS}^2}$$

where all terms have previously been defined. This expression is a function of both Q_{TS} and Q_{TC} and thus requires a family of curves (Fig. 3). I have normalized the results to $Q_{TC}=1$. Table 1 shows the equation for V_B at $Q_{TC}=1$. V_B at other values of Q_{TC} is, of course, the V_B value at $Q_{TC}=1$ multiplied by the relative V_B value from Fig. 3. Use the above equation to find the box volumes for driver Q_{TS} values other than those shown in Fig. 3, noting that V_B will have the same units as those used for V_{AS} .

It is evident from Fig. 3 that low- Q_{TC} alignments pay a severe penalty in terms of enclosure size. This is especially true if driver Q_{TS} is high and starts to approach the desired Q_{TC} value. Of course, if Q_{TC} equals Q_{TS} , then V_B goes to infinity, and the alignment is unattainable.

5. *Closed Box Effectiveness.* Closed box "effectiveness" is a term I use to indicate how well an alignment uses the capabilities of a given driver in all the following ways:

- high efficiency (acoustic watts out divided by electrical watts in);
- low f_3 value;
- a small enclosure (low V_B).

Small¹ demonstrates that the efficiency of any closed box can be expressed as:

$$\eta_o = k_n f_3^3 V_B$$

where η_o is efficiency, and k_n is a function of driver and alignment parameters.

It has been demonstrated mathematically and by testing that η_o is a function of driver parameters only ("Mailbox," SB 3/80, p. 40, and "Closed vs. Vented Box Efficiency," SB 3/81, p. 10). Thus, with a fixed driver, the effectiveness of various alignments will show up as variations in f_3 and V_B . I have already shown

how f_3 and V_B vary with alignment (and Q_{TS}). Combining these shows the effects of Q_{TC} on effectiveness.

Figure 4 includes a family of curves of relative effectiveness versus Q_{TC} at various values of driver Q_{TS} . Note that the ordinate axis of Fig. 4 is in decibels. Basically, the results show that with low- Q_{TS} drivers, the most effective alignment for a good combination of low f_3 and small enclosure occurs when $Q_{TC} = 1.1$. With higher- Q_{TS} drivers, the alignment of maximum effectiveness moves up to slightly higher values of Q_{TC} .

The equation in Fig. 4 allows you to calculate the actual value of effectiveness. This is of little interest in closed box alignment, but is useful in comparing the performance of a given driver in vented versus closed box applications. It is really in effectiveness and not efficiency that the vented box holds a potential 3dB advantage over a closed box using the same driver (see "Closed vs. Vented Box Efficiency," SB 3/81, p. 10).

Using closed box alignments with high effectiveness values will produce a small enclosure with a good f_3 value for the driver under consideration, but effectiveness does not represent any optimization of the closed box system. While Fig. 2 shows that the power capability will be good, Fig. 1 indicates that the peak is starting to rise, making transient performance suspect.

TWO SAMPLE DRIVERS. Table 2 shows results for two drivers examined for various closed box alignments. Each driver is shown in three alignments. The first alignment is $Q_{TC} = 1$, with the results coming from the equations in Table 1. The second alignment is at $Q_{TC} = 0.7$, an enclosure with the minimum possible f_3 . I obtained these values with the relative correction factors from Figs. 1-3. The final alignment is at the Q_{TC} value that Fig. 4 shows to have the highest effectiveness. Again, I used the relative correction factors from Figs. 1-3.

Driver A is a moderately low- Q_{TS} unit with a rubber half-roll suspension. This fares poorly in closed box alignments in terms of f_3 . Note that the best f_3 value obtainable from this 10-inch unit is 52.8Hz, some 2¼ times its free-air resonance. Small has developed a technique to indicate whether a given driver will fare better in vented or closed box applications in terms of low f_3 . The approach is shown briefly in the sidebar on page 26.

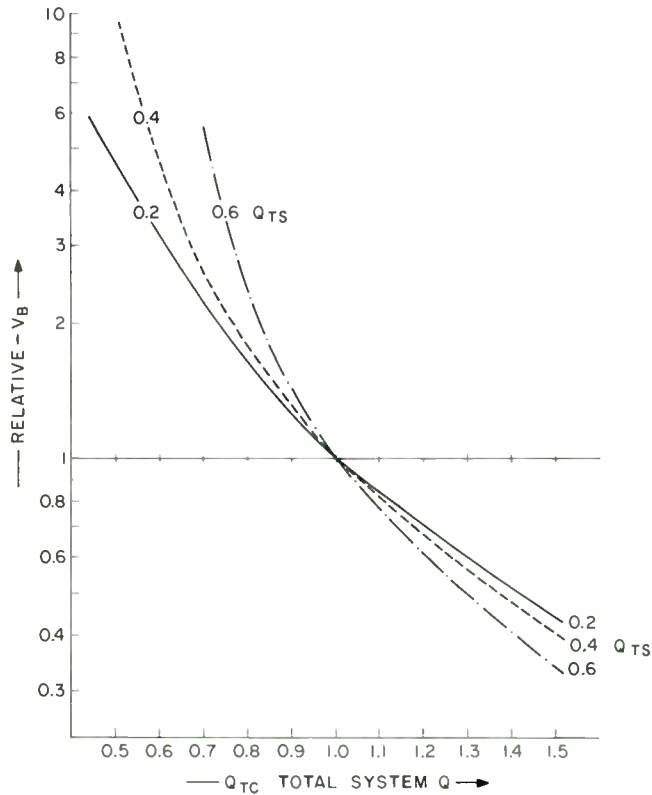


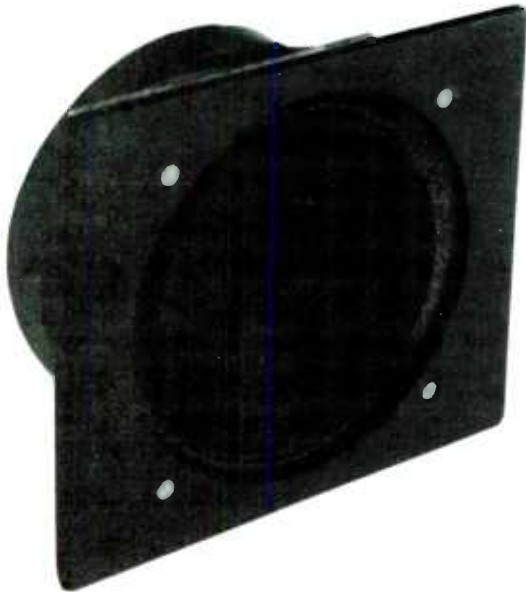
FIGURE 3: Relative box volume vs. Q_{TC} .

TABLE 2

SAMPLE DRIVER EQUATIONS

Driver Parameters	Driver A 10", 30 oz. mag, 8Ω	Driver B 10", 20 oz. mag, 4Ω		
f_s	23.3Hz	25.7Hz		
Q_{TS}	0.312	0.470		
V_{AS}	7.39ft ³	6.18ft ³		
D	8 inches	8 inches		
X_{max}	0.2 inches	0.2 inches		
Alignment Data at $Q_{TC} = 1$ (peak = 1.2dB @ f_G max)	Driver A Final Value*	Driver B Final Value*		
f_3	58.7Hz	93.3Hz		
f_G max	107Hz	78Hz		
$P_{AR}(CW)$ [SPL]	0.268W (106.3dB)	0.08W (101.1dB)		
$P_{AR}(P)$ [SPL]	0.273W (106.4dB)	0.083W (101.2dB)		
V_B	0.8ft ³	1.75ft ³		
Alignment Data at $Q_{TC} = 0.7$ (no peak)	Driver A	Driver B		
	Relative Value	Final Value	Relative Value	Final Value
f_3	0.9Hz	52.8Hz	0.9Hz	39Hz
$P_{AR}(CW)$ [SPL]	-5.4dB	0.077W [100.9dB]	-5.4dB	0.023W [95.7dB]
$P_{AR}(P)$ [SPL]	-2dB	0.173W [104.4dB]	-2dB	0.053W [99.2dB]
V_B	≅ 2.3ft ³	1.83ft ³	≅ 3.1ft ³	5.43ft ³
Alignment Data at Q_{TC} for maximum effectiveness				
Q_{TC}	1.2	1.2	1.3	1.3
f_3	1.13Hz	66Hz	1.16Hz	50.2Hz
peak amplitude	—	2.4dB	—	2.95dB
f_G max	1.05Hz	111Hz	1.1Hz	85.4Hz
$P_{AR}(CW)$ & $P_{AR}(P)$ [SPL]	2W	0.425W [108.3dB]	2.8W	0.155W [103.9dB]
V_B	≅ 0.675ft ³	0.54ft ³	≅ 0.53ft ³	0.93ft ³

*Relative values from figures. Final values at $Q_{TC} = 1$ from Table 1 equations.



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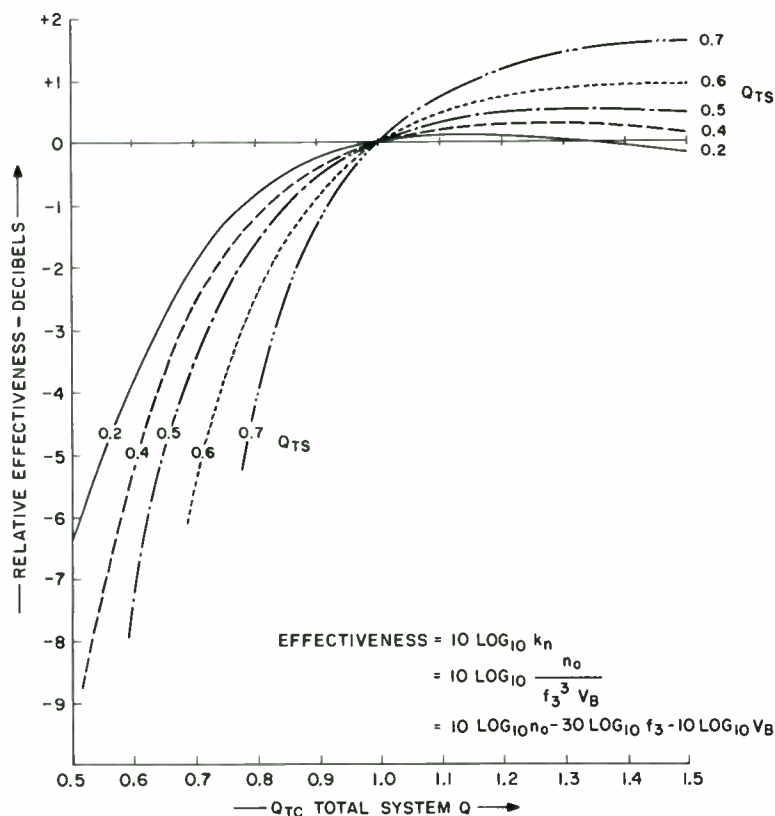


FIGURE 4: Relative "effectiveness" vs. Q_{TC} .

Suitability of Driver for Vented vs. Closed Box

In his investigation of driver suitability for horn loading, Small has defined an efficiency-bandwidth product (EBP).³ He points out that for low system cutoff frequency (f_3) in direct radiator applications, you should use an EBP of about 50 for closed boxes and an EBP of around 100 for vented boxes.

$$\text{EBP} \cong \frac{f_s}{Q_{ES}}$$

where Q_{ES} is the electrical Q of the driver.

If you do not know the value of Q_{ES} and have applied no intentional damping to the driver (e.g., glass wool insulation over the driver or damping fluid in the voice-coil gap), you can set Q_{ES} approximately equal to 1.1 times Q_{TS} . In this case,

$$\text{EBP} \cong \frac{f_s}{(1.1)(Q_{TS})}$$

For the two drivers I tested in the article, Driver A's EBP is approximately 68, while Driver B's EBP is approximately

50. Driver A's EBP is a little high for good f_3 performance in a closed box, while Driver B is ideally suited to this type of enclosure.

If obtaining a low value of f_3 is your goal, my article has demonstrated for a closed box that:

$$\text{at } Q_{TC} = 1, f_3 \cong 0.79 \left(\frac{f_s}{Q_{TS}} \right)$$

and

$$\text{at } Q_{TC} = 0.7, \text{ min. } f_3 \cong 0.7 \left(\frac{f_s}{Q_{TS}} \right)$$

You can weigh these values against the potential in a vented box, where Small³ shows normal flat response alignments give f_3 in the 0.3 to 0.5 EBP range (approximately 0.27 times f_s/Q_{TS} to approximately 0.45 times f_s/Q_{TS}). Therefore, the vented box has an advantage in allowing a low value of f_3 , but you must investigate the trade-offs in box volume, transient response and maximum acoustic power capability to get the full picture.

While Driver A does not show good f_3 results in closed box alignments, it does use very small enclosures and produce reasonably high sound levels with a 0.2-inch peak displacement. You should compute the driver reference efficiency to establish the electrical input power required to produce high acoustic output for any driver. This will show whether the driver runs into a thermal power limitation before reaching the computed acoustic power limit. Calculation of reference efficiency and electrical input power are shown briefly in the sidebar on page 27. Driver A might thus be a good choice for an application where a small box with high SPL capability is desired and f_3 near 60Hz can be tolerated.

Driver B is another 10-inch unit with rubber half-roll suspension. It is better suited to closed box applications than Driver A. In fact, attempts at vented box alignments produce impractically large boxes, which usually have very low power limits. In a closed box alignment with $Q_{TC} = 0.7$, this driver yields an f_3 of 39Hz, only 1½ times its free-air resonance, but the box is quite large and has a low maximum acoustic power limit. You derive the box volume in Table 2 at $Q_{TC} = 0.7$ by interpolating on Fig. 3 for a driver Q_{TS} of 0.47. Direct calculation of V_B shows the correct value to be 5.07ft³, or some 7 percent lower than Table 2 indicates. The relative volume functions in Fig. 3 move rapidly, so it is difficult to obtain accurate relative volume values for driver Q_{TS} values other than those plotted. This is why I recommend that you compute V_B directly.

At maximum effectiveness, around $Q_{TC} = 1.3$, Driver B will deliver higher acoustic outputs from a much smaller box, but f_3 has increased, and a high peak exists in the amplitude response, making me question the transient response capabilities of such an alignment.

SUMMARY. Several trade-offs in alignment parameters are now clear. For instance, the minimum cutoff frequency is obtained at $Q_{TC} = 0.707$, but you must settle for reduced acoustic power capability and greatly increased enclosure volume. The alignments of highest effectiveness in terms of combined small-box and low cutoff frequency are with Q_{TC} up near 1.1 to 1.3, thus sacrificing something in transient response. In addition, the

Reference Efficiency and Input Power

Small⁴ has shown that the reference efficiency of any driver in direct radiator application is given by:

$$n_0 = 2.7 \times 10^{-8} \left(\frac{f_s^3 V_{AS}}{Q_{ES}} \right)$$

where n_0 is efficiency (acoustic watts out divided by electrical watts in), f_s is driver free-air resonance (in hertz), V_{AS} is the volume of air with the same acoustic compliance as the driver suspension (in cubic feet), and Q_{ES} is the driver electrical Q .

As noted in the sidebar on vented versus closed box enclosures (p. 26), if Q_{ES} is unknown and no undue losses are introduced on the driver motion, then Q_{ES} approximately equals 1.1 times Q_{TS} . Thus:

$$n_0 \approx 2.45 \times 10^{-8} \left(\frac{f_s^3 V_{AS}}{Q_{TS}} \right)$$

In a closed box of any alignment (Q_{TC} value), a driver will exhibit this efficiency up in the mid-band, or "flat" portion of the response band.

Once you have computed the maximum acoustic power output [$P_{AR}(CW)$ or $P_{AR}(P)$], you can find the equivalent

electrical input power to produce this output (P_{ER}):

$$P_{ER} = \frac{P_{AR}}{n_0} \quad (P_{AR} \text{ and } P_{ER} \text{ in watts})$$

Compare P_{ER} with the driver's thermal wattage rating to see whether displacement of the cone or thermal considerations set the maximum input power to the driver. Conversely, if you interpret P_{ER} as equal to the driver thermal rating limit, then you can find the corresponding P_{AR} and use it as a factor in selecting a closed box alignment. Selecting Q_{TC} values offering higher acoustic power limits than those set by thermal considerations is unwise from a power output standpoint.

For the drivers used in Table 2 of the article, the reference efficiencies and maximum electrical input powers to reach the displacement limited acoustic power outputs of the highest effectiveness alignments are shown below. Compare these electrical power requirements with the manufacturer's data or your best guess as to how many watts the driver can dissipate in terms of RMS power.

	Driver A	Driver B
Maximum $P_{AR}(CW)$	0.425W	0.155W
Reference efficiency- n_0	0.00734 (0.73%)	0.00560 (0.56%)
Electrical Input Power- P_{ER}	57.9W	27.7W

low- Q_{TS} Driver A should be used in a vented box, while the higher- Q_{TS} Driver B is more appropriate for closed box applications.

For Driver A, no closed box alignment allows a sufficiently low -3dB cutoff frequency, which demonstrates that not all drivers will work well in closed box applications even if the free-air resonance (f_3) is reasonably

low. Driver B, a higher- Q_{TS} , 10-inch driver, fits well into a variety of closed box alignments and allows trade-offs in terms of box volume, acoustic power output and transient response. I used this type of driver in a pair of closed box systems with Q_{TC} approximately equal to 0.85, which results in a large enclosure with very good sonic performance, but limited SPL outputs.

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3. Small, R.H., "Suitability of Low-Frequency Drivers for Horn-Loaded Loudspeaker Systems," *Audio Engineering Society Preprint No. 1251 (K-8)*.
4. Small, R.H., "Direct-Radiator Loudspeaker System Analysis," *Journal of the Audio Engineering Society* (Volume 20), June 1972, p. 383.

Next time, Mr. Koonce will resume his series on test equipment. In Part IV of that series, he will show how to use the voltmeter and power supply circuit boards from Part I and the phase meter from Part III to build a speaker impedance meter (Z meter). The Z meter might not sound exciting, but he considers it the most important instrument for the speaker builder.

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A SPEAKER BUILDER'S ODYSSEY: PART VI

BY ROBERT CARLBERG

Last time, the author described his overall plan and construction of the cabinets for his Yamaha speakers. See SB 4/83 (p. 28) for a drawing of the finished speakers.

My Yamaha drivers arrived late. My "six to eight weeks" had become more than four months, but luckily I would not have been ready earlier. When I opened the little wooden crates in which the drivers were packed, I was in for a shock, albeit a pleasant one. I had not seen the drivers out of a cabinet, so I was not prepared for the size of them. The tweeters weigh more than 4 pounds apiece, and the midranges are nearly 15 pounds. The magnets of both extend almost to the edges of the front plates. With a 3½-inch voice coil, the midranges were a suitable match for my woofers.

A rough test of the Yamahas showed them to be every bit as clear and uncolored as I remembered them, even without a crossover on full-range material. This is my preferred way to test drivers, as it quickly shows the natural rolloffs of the drivers and whether they handle them cleanly or with inherent coloration. The Yamahas passed with flying colors (instead of colorations).

I mounted the midranges, using a stationary screw mechanism so that I could align them without having to remove them repeatedly. (See *Photo*

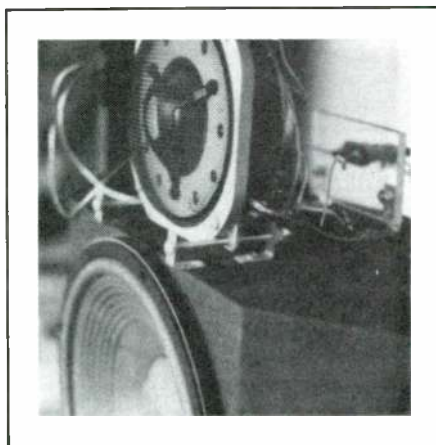


PHOTO 1: Notice the adjustable mounting for the midrange.

1.) I took a short length of flat steel bar, drilled a hole at each end and tapped one of the holes. The other end bolts to the midrange. I then mounted a long bolt horizontally on top of the woofer section, using a double-nut to hold it between two unthreaded upright angles. The midrange mount, threaded on the screw, moves forward or backward when the screw is turned. Due to the weight of the midranges, I added a nut behind the midrange mount to help support the mount and prevent its moving.

It took me several days to decide on an exact location, and several weeks after that I fine-tuned it again. The problem was not in the drivers, but in the source material. So many studio recordings are filled with unnatural and altered phase relationships that the alignment seemed to change with each record. Finally, though, I reached a position that was best for all types of music and superb for excellent recordings. This

adjustment is so fine that a mere ¼ turn of the adjust-screw, about ¼₆₄ inch, is audible.

I mounted the tweeters above the midranges. I used a stationary bracket because a rough test indicated screw brackets might take forever to adjust perfectly. The alignment is still optimized within ¼₁₆ inch or so, though.

For crossovers I went with my idealized arrangement, biamping with an electronic crossover. This allows full amplifier power to each section and has an enormous effect on the dynamic range. I chose the Crown VFX-2 crossover because it has variable turnover frequencies (allowing me to fine-tune the bandwidth) and a defeat switch (allowing me to change to full-range headphones on one amplifier). I'm using a turnover frequency of 450Hz from the midrange to the woofer.

After a couple of months with my speakers, a peculiar anomaly began to bother me. On vocalists recorded monaurally (as many are), the image seemed to spread out in a plane between the speakers, coming forward ahead of the rest of the mix. I thought this might be some sort of distortion caused by capacitance in the speaker wires, so I bought some 12-gauge zip cord for this purpose. This improved damping and general clarity, but made the monaural imaging problem worse. I wired all my line-level connections between the amps and preamp and crossover with low-capacitance cables. Again, I noticed an obvious improvement in overall definition, but a worsening of the imaging problem.

I finally found the solution in a stereo store while I was listening to

Robert Carlberg is the national service manager for a Seattle-based commercial tape machine manufacturer, former co-editor of Synex Newsletter for electronic musicians, and an amateur electronic musician. This concludes his odyssey, and he hopes never to have to build another speaker system.

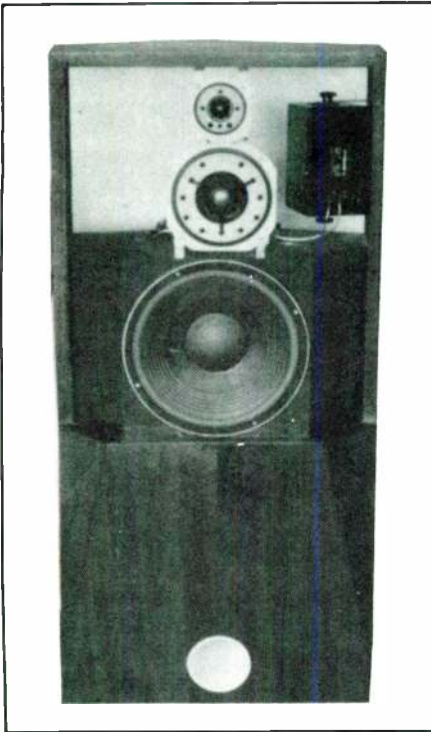


PHOTO 2: The finished speakers include Yamaha midranges and tweeters, the Crown VFX-2 crossover, a Crown O-60 amp to the woofers, and a Nakamichi 410 amp to the high-end and headphones, with a Nakamichi 420 preamp.

some electrostatics. They didn't suffer from this problem. The answer apparently was in dipolar radiation in the high frequencies: the mind requires rearward radiation bouncing off the wall between the speakers to create a believable aural-space for mono signals. I can't explain this phenomenon because, theoretically, rear radiation should only diffuse the image, not sharpen it. But theory never was a match for experience. The addition of two high-quality "mini-speakers" behind the speakers solved this imaging problem. They also improved the 3-dimensionality of better-mixed material.

TIME ALIGNMENT. It occurred to me that one rather large element of my speakers' configuration was still basically unexplored—time alignment of the rear-facing mini-speakers.

I tried all the possible locations within the upper opening in my speakers and found that where I had placed them actually sounded best. (The ideal would have been co-existent with the forward-facing for true bi-polar radiation, but the Yamaha drivers' size made this quite impossible.)

But was I restricted to this upper

area? I realized that I wasn't, so I tried on top, on the sides and finally in the back of the main cabinets. The rear turned out to be the only acceptable position, as all others presented difficulties with interference with forward radiation. Playing with their exact alignment back there, I found that, like the tweeters, a variance of $\frac{1}{16}$ inch was audible. The final location was almost directly in the center of the rear.

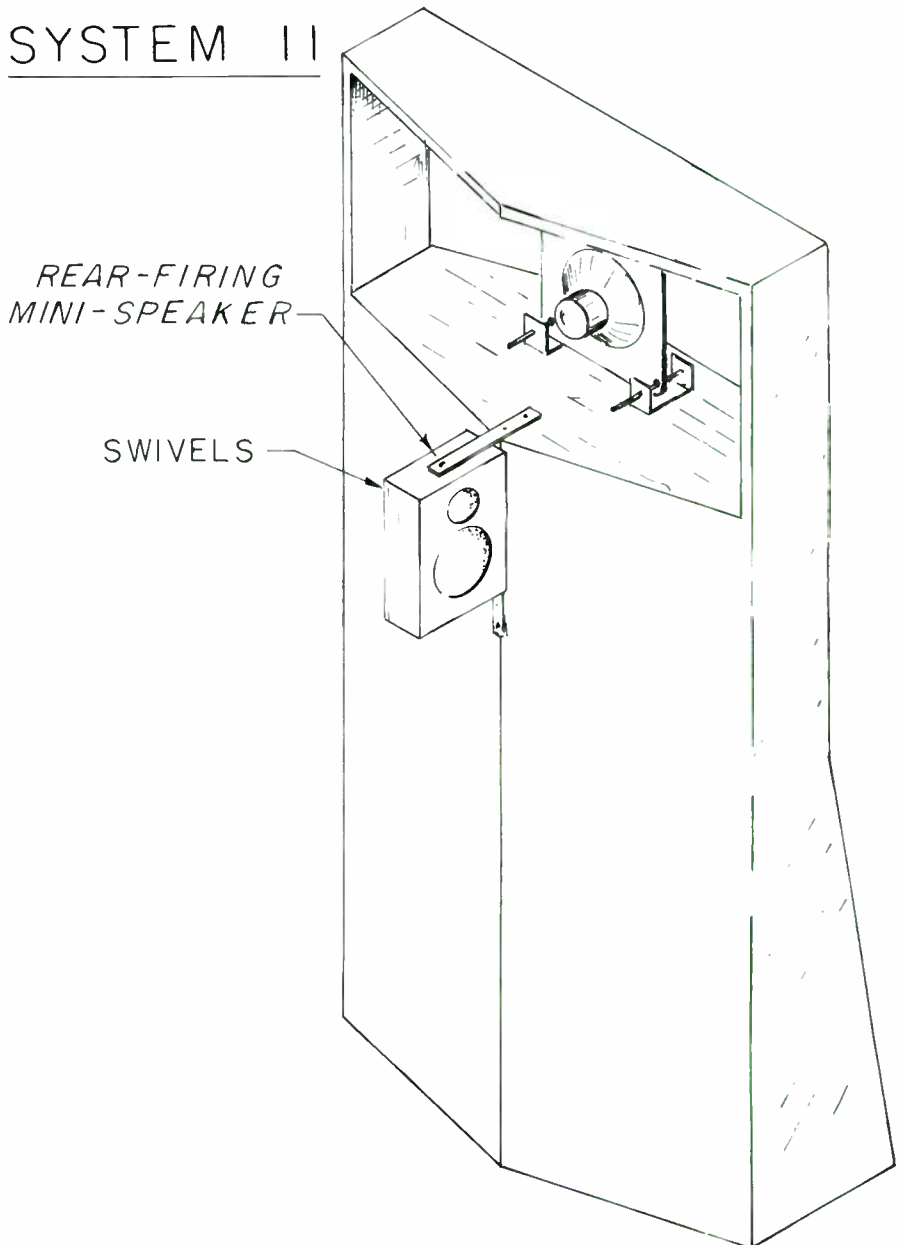
In addition, the mini-speakers sounded much better facing each other, toward the center, than opposed.

My last and most startling discovery was totally by accident. After having mounted the mini-speakers to the rear of my cabinets, I acciden-

tally hooked one of them up backward (positive to negative reversed). It sounded better! As in true bi-polar radiation, rear-facing radiation must be out-of-phase with the front to reinforce it. With both mini-speakers in opposite phase from the front, you can walk right up to, between and even behind the speaker system with no instability of the image. It is an eerie feeling to be able to walk all around the speakers (although mostly between them) with no sense of localization of the "viewing area"—a true projected hologram.

After almost five years, I am still very happy with this system. I believe that must be some sort of record. D

SYSTEM II



Tools, Tips & Techniques

Speaker Resuscitation

I would like to share my experiences in resuscitating a moribund pair of EPI 100s whose woofers were burned out. They belong to a friend who had abused them by overdriving them with a 40W amp. If he had used a 100W or 20W amp, there would have been no problem. With the 100W amp, he would have had enough power not to clip, which would have protected the drivers from transients. The 20W amp would not have generated powerful enough transients to cause any damage.

Usually in this situation, the tweeters go first. They had burned out once, but had been replaced under warranty. This time, the woofers had been driven too hard, and the voice coils were rubbing, producing excruciating distortion. (This was the second pair of woofers he had burned out. Not that I'm criticizing him—I once set a woofer on fire.) The cause this time: "Someone at my birthday party turned the volume all the way up, then dropped the needle on a record."

I chose Speakerlab 808Ps to replace the woofers. These are relatively inexpensive polypropylene drivers, which should have a better midrange than the paper cones. In a closed-box configuration, the 808Ps have a Q of approximately 0.7, as compared with the 0.9 I measured for a working set of EPI 100s. In theory, the system resonance will work out to 57Hz, as opposed to the original 58Hz, and the bass cutoff will be 57Hz, in contrast with the original 48Hz. Although in theory there is less bass, a Q of 0.7 will often sound better than a higher Q with the same resonance frequency. Also, the 8Ω impedance should put less strain on a sensitive amp. When the drivers arrived, I noted that the voice coils seemed to be much more rugged than the original ones.

Since the tweeters were working, I decided to keep them. The original woofer rolls off above 2,000Hz, however, and this is used as part of the crossover design. The 808P rolls off at 2,500Hz. Replacing the 10mF electrolytic caps with 8mF, 50V plastic film caps

eliminated the driver overlap and increased the tweeters' effective power-handling capability. Just to be on the safe side, I wired a pair of Radio Shack dynamic speaker protectors in series with the tweeters. The circuit breakers on the amp were doing a marvelous job of protecting the output transistors, but did nothing for the speakers, so I put a 2A fuse in series with the entire system.

Having finished the modifications, I measured the system resonance at approximately 52Hz, a bit lower than theory and specs predicted, but not disastrously so. My friend would not let me make Q measurements—he wanted to play records instead—but he was very pleased with the sound, saying the new woofers were "better than the originals." The midrange was smoother and less confined, while the bass was much tighter and seemingly deeper. The highs showed less distortion, probably because I had replaced the electrolytic caps with plastic film. (The speaker protectors did not noticeably degrade the highs, although I did not make any direct comparisons.)

It has been several months since I modified these speakers. My friend continues to abuse them daily, but the new woofers appear to be sufficiently durable to meet his needs.

Richard J. Kaufman
New York, NY 10025

Strathearn Superiority

The Strathearn SLC2 midrange/high-frequency ribbon drivers have attained legendary status in the audio field. Because of their reputation, I recently used them to replace a pair of Sanders electrostatics (ESLs) in my home system.

The Strathearn driver offers many of the traditional benefits of ESLs without the drawbacks. It adds a clear and seemingly effortless quality to the mids and highs, radiates in a dipolar pattern, blooms at low volumes and has a little higher efficiency than most of the ESLs I have auditioned. It is also free from the capacitive loading problems that make

ESLs unsuitable for many amplifiers.

Due to the long, narrow ribbon, vertical dispersion is almost nil. This means you should stack two or more units if you do not want those marvelous highs to disappear when you stand up. Two benefits not related to dispersion also result from stacking. First, sensitivity is increased. More importantly, the image height is opened up to realistic dimensions. Some people might find this disconcerting at first, but it is natural.

I have incorporated a two-driver array into my system with a crossover at 220Hz. I did some experimenting with JVC ribbons on the extreme high end, but found that the small amount of extra "air" gained was offset by some smearing of transient information. If you want to try supertweeters, let me warn you about using too little padding. If you do, the result will be incredibly "hi-fi," but will not be real and might color your evaluation of the Strathearns.

Several people in my area use these drivers, so I have had the opportunity to audition several crossover schemes. The best system I have heard mates a three-column stack with Entec woofers, using the Entec bi-amp electronic crossover (first order, 6dB/octave, high pass). I suspect that part of the superior sound is due to the Entec woofers themselves. The worst system I have heard uses the passive crossover recommended by the manufacturer.

Ken Rauen's crossover circuit (*SB* 2/83, p. 26) works quite well for me. I use a 220Hz crossover (*Fig. 1*) partly to avoid pushing the drivers' low end (although the first system mentioned uses a 140Hz crossover). The component values also work out rather nicely here: the capacitor values are low enough to allow the use of polypropylenes, and the resistor values are low enough for acceptable noise. I have included a filter for my sixth-order woofer (Madisound M1054, Box 4283, Madison, WI 53711), which mates fairly well.

Proper baffling is necessary to obtain maximum performance. To avoid cancellation, the path from the rear of the driver to the front must be at least one-quarter of a wavelength at the lowest

All op amps are from the TI Low-Noise BiFet series (e.g., 1/4 TL074).

Values in parentheses are for 220Hz crossover, 6dB boost @ 26Hz.

*To disable auxiliary boost but keep rumble filter, make R6 = jumper, R7 = infinite, or open.

$$R1 = \frac{1.1433 \times 10^6}{f}$$

$$R2 = 0.39253 \times R1$$

$$R3 = 6.87702 \times R1$$

$$C1 = C2 = \frac{1.5915 \times 10^{-6}}{f}$$

$$R4 = R5 = \frac{4.8227 \times 10^6}{f}$$

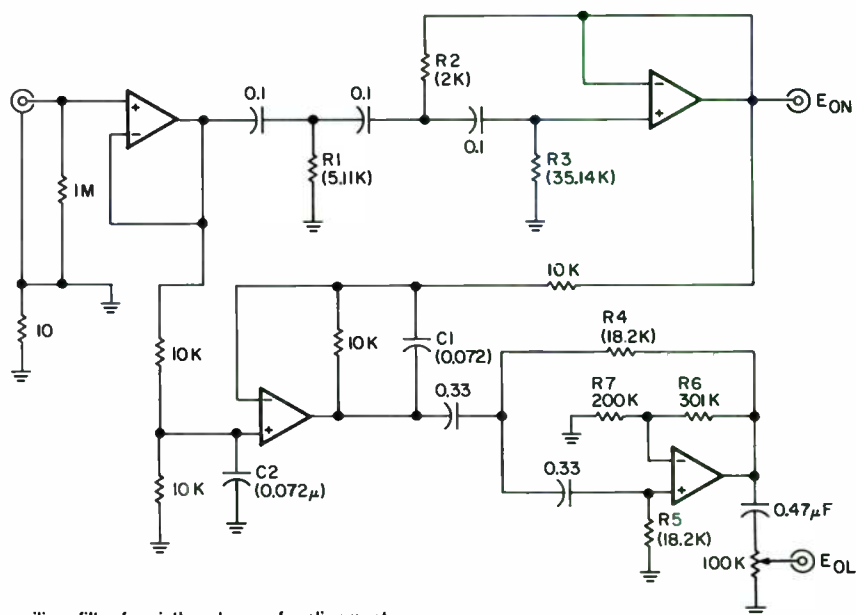


FIGURE 1: Third-order, phase-correct active crossover with auxiliary filter for sixth-order woofer alignment.

frequency to be reproduced (path length equals $1,120/f$). For my crossover at 220Hz, this works out to a touch over 15 inches. A flat panel (such as the Infinity used on the QRS) will accomplish this, but at the expense of some diffraction problems. Another extreme is to angle a panel sharply back at the sides of the drivers. This approach can cause a horn loading of the back wave and make placement (already a minor pain with dipolars) into a major headache.

I opted for a compromise. Using my best engineering judgment, I boldly appropriated the solution that Infinity has recently used in similar systems—an arced "wing" on each side of the driver. Actually, I am using a first approximation of their wing, which is easy to build (on a table saw). In the following description, I will omit board lengths, as those will depend on the number of drivers and whether the column is floor or stand mounted. My system uses 48-inch wings on top of 22-inch bass units.

To approximate a smooth wing, I used three boards per side, each angled back by 10 degrees (Fig. 2a). These are splined together and then splined to a piece that abuts the driver to provide a smoother transition. The drivers are mounted through a 7 1/4-inch-wide piece of 3/8-inch particle board, which is screwed and glued behind the wings. I have exaggerated the angles in Fig. 2 for clarity.

The basic component of the wing is a trapezoidal cross-section of wood. Each side is angled in from the face by 5 degrees from vertical. The exact angle is not critical as long as all boards are cut with the same blade setting. You would use a slightly greater angle to duplicate the Infinity width/depth ratio.

With the saw set at the desired angle

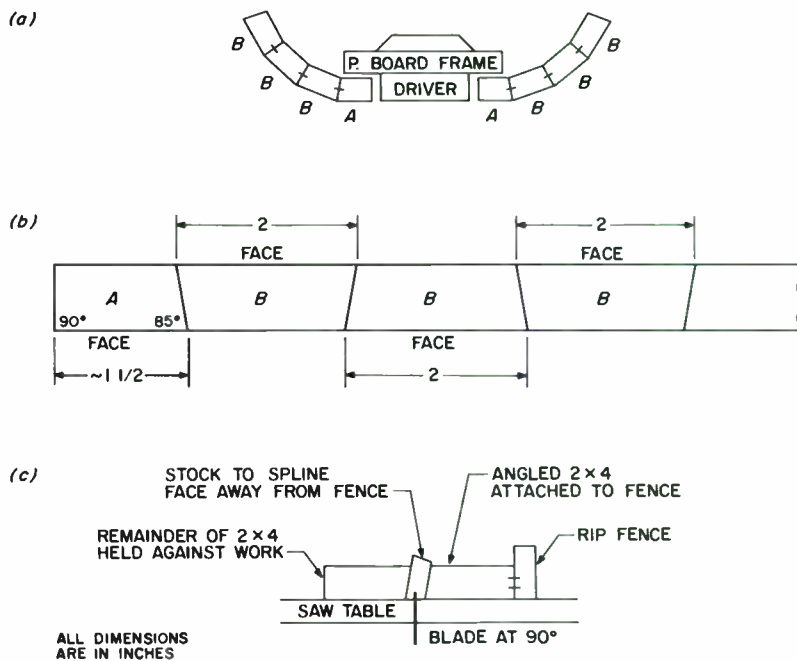


FIGURE 2a: A top view of the "wing" used on each side of the driver. FIGURE 2b: Cutting diagram for the wings. All angles are 5 degrees off vertical for a successive-panel set of 10 degrees. Each driver requires two sets of four pieces. FIGURE 2c: Spline cutting setup. (These drawings are not to scale.)

(Fig. 2b), cut all angled pieces at the same time. Before readjusting the blade, rip a section of 2-by-4 along the 2-inch dimension (Fig. 2c) to serve as a splining jig.

Attach the ripped 2-by-4 to the rip fence to serve as a guide when cutting the slots for the splines. You can use the remaining piece as a guide to hold the boards tightly to this first piece. Any reference on table saw use should include the details of splining.

When you have glued all the pieces together, the shallow angle ensures that

only a few passes with a plane over each joint will result in a smooth curve. If you use my angles, the column will have stability problems, so be sure to mount it securely to a heavy base.

I would like to thank my dealer, Jeffrey Behr of Two Jeffreys Audio (527 W. Butler Dr., Phoenix, AZ 85021), not only for his suggestions, but also for selling the drivers at the lowest price I have found.

B. Kendall Berg
Tempe, AZ 85281

Tools, Tips & Techniques

Cut Your Volume Requirement

If you have found a speaker that is perfect for you, but its compliance (V_{AS})—hence, box volume (V_B)—is too large, consider buying two per channel. Mount them one behind the other, with the air between them enclosed. In this configuration, they will exhibit one-half of the individual V_{AS} and so require only about 50 percent of the volume required by one.

David J. Meraner
Scotia, NY 12302

Simple Damping Technique

I have a simple technique for preparing wool used to damp transmission line enclosures. In my opinion, natural long-fiber wool is the most efficient damping material, but most beginners tend to overdamp their lines. Wool also compresses over time, further reducing its efficiency.

The accepted solution to this problem is to attach nets to the enclosure sides while filling. This is not satisfactory because the wool bunches up and is not spread out evenly. Furthermore, this solution requires a lot of effort, especially in the channels of a small cross-section. In my experience, an equal distribution of damping material over the whole length of the line gives the best results.

Using net curtain is advantageous in many respects, but you will need a sheet for each section of the line, cut to the appropriate section length and width. After you have cut the net, spread the desired amount of wool evenly on each piece and roll up the "curtain" in a spiral to form a circular or elliptical cylinder. Securing the ends of the curtain with thread is effective in keeping the wool in place.

Now you have a handy package of equally distributed wool. It fits smoothly into the desired section of the box and can be removed easily if the damping is not optimum. Some benefits of this method are the following:

- The wool is equally distributed and cannot move.
- You can try different densities and then reproduce the most effective results.
- It is easy to fill the lines of a small cross-section.

- You can change the wool quickly and reproduce damping exactly for several loudspeakers.

Andreas Schubert
D 4930 Detmold 17
West Germany

Tweeter Test Measurements

I have made some discoveries about the Radio Shack 40-1281 tweeter, which Andrew Keller mentioned in his "Tools, Tips & Techniques" submission (*SB* 3/83, p. 32). First, although it is identified as a midrange speaker (600 to 8,000Hz), it has usable output to 10kHz, so it might serve old-timers like Mr. Keller and me quite well as a tweeter.

The application instructions cover 6dB/octave filters (10 μ F for a 1,400Hz crossover, 22 μ F for a 900Hz crossover and 6.8 μ F for a 2,900Hz crossover). When using capacitors over the range of values listed, my measurements of volts delivered to the tweeter showed a "camel's

hump" response. On the high end, the response began somewhat near the published crossover point and had a -5 to -12dB trough around 1,250Hz. It then rose to 0dB at 850Hz with a 15 μ F capacitor and to -7dB at 900Hz with a 4 μ F capacitor, after which it fell to -7 and -17dB, respectively, at 500Hz. Because a high voltage level is delivered to the tweeter near its resonant frequency, I believe it is not safe for the tweeter to operate with a capacitor filter alone.

I then checked operation with a 12dB/octave network having a 10 μ F capacitor and an inductance of about 1.5mH. This helped, but only somewhat. The voltage near the tweeter resonant frequency was still rather high. Below the resonant frequency, the voltage delivered fell off more rapidly.

Finally, mostly through trial and error, I tried equalizing the tweeter impedance with an L-R-C circuit and obtained the results in *Fig. 1*. Note that my original crossover target of about 1,400Hz moved up to about 2,000Hz.

David J. Meraner
Scotia, NY 12302

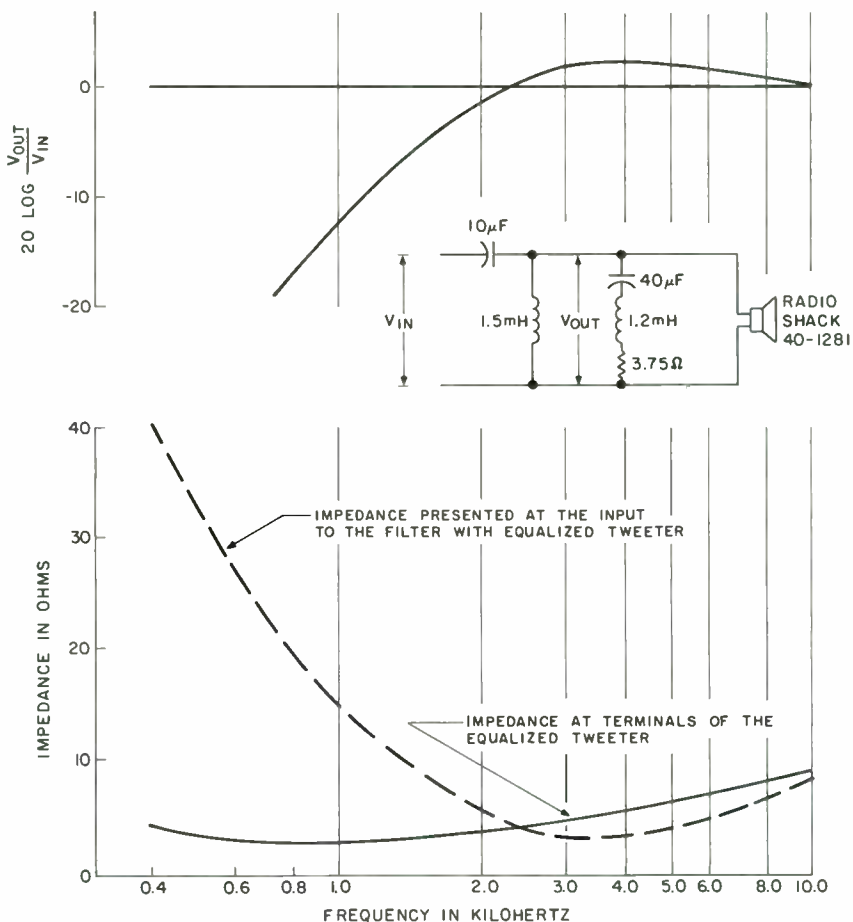


FIGURE 1: Using an L-R-C circuit, the author obtained these results with the Radio Shack 40-1281.

Assemble Exquisite Equipment with Old Colony Kits

MAGNIFICENT MOVING COIL INPUT Moving coil cartridges are marvelous phonograph pickup devices, but their output is far too low for most preamp phono stages. Here's a kit that saves you \$315.00. In addition to an evening of careful soldering, it requires drilling only eleven round holes and filing out two square ones. This unit is probably the world's finest stereo moving coil cartridge step-up device—and at \$335.00 should qualify as a bargain. Canada's RWR Audio offers their finished MCT-1 at \$650.00. The RWR kit is identical in all respects to the built unit, with the exception of the case. The mu-metal doubly shielded transformers, designed by RWR and custom manufactured exclusively for RWR by the Hammond Co., one of the world's leading transformer manufacturers, are not available separately. The other parts are all first quality: gold-plated jacks, ground post, epoxy switching board, gold-plated plugs and Mogami Neglex 2534 cables supplied. The two nine-pole dip switches allow the user to adjust the gain and impedance for almost any MC cartridge available today. The heavy aluminum die-cast housing keeps hum to a minimum. With other high-quality units ranging from \$400.00 to \$1200.00 in price, the KR-1 is an outstanding buy. Editor J. Gordon Holt of *Stereophile Magazine* (PO Box 1948, Santa Fe, NM 87501) Vol. 5, No. 2, says, "...I have no hesitation in selecting the RWR as my all-time favorite step-up device as of now."

CLASSIC CLASS A FROM NELSON PASS Forty watts of Class A power per channel in a design executed by Nelson Pass of Threshold Corporation. It contains 22 pounds of power transformer and 20 more pounds of heatsink. Not a slim pancake of an amp, but a device with all the sterling qualities of a classic. Although a large project, most of each channel's circuitry is contained on a 3" square circuit card, and the rest of the work is mounting transistors on heatsinks and assembling the whole on a sturdy chassis or two of your own choosing. Distortion at 40W output is just above 0.01% below the 1kHz point, rising to 0.03 at 30kHz and 0.3 at 100kHz. Square-wave and step response are phenomenal, and the amp is particularly good with electrostatic speaker loads and very low impedances. The full kit includes everything you need to build the unit except the chassis and heatsinks.

ACCURATE PHONO EQUALIZATION Long Play stereo disks are "equalized" with a standard curve adopted by the Recording Industries Association of America in order to use the LP disk medium efficiently (i.e., smaller lows, larger highs). In testing an equalized phono preamplifier, your signal needs to be shaped at any frequency to an exact copy of the RIAA pre-emphasis standard. Old Colony's Inverse RIAA filter shapes any test signal properly so that your preamplifier's phono stage should produce a ruler-flat response across the frequency band from 20Hz to 20kHz—if its RIAA equalization components are correct. If the preamp isn't doing its job properly and needs modifying, the OC Inverse RIAA network kit is what you need. Designed by Walt Jung and Stanley Lipshitz, it contains only the finest 1% parts with alternate termination resistors. The KL-3C kit is two channel, complete with a cast aluminum box, gold-plated jacks and all needed components with an article reprint.

OLD COLONY'S KIT ORDER FORM

ORDERING INFORMATION: Prices, except as noted, are prepaid in the USA and insured. We prefer to ship via UPS, which requires a street address. If you cannot receive UPS delivery, please include an extra \$2 for insured service via Parcel Post. We cannot accept responsibility for safety or delivery of uninsured Parcel Post shipments. For charge card orders under \$10 please add \$1 service charge. UPS Next Day and 2nd Day Air available to some areas.

PRICES SUBJECT TO CHANGE WITHOUT NOTICE.

<p>NAME _____</p> <p>STREET _____</p> <p>CITY _____</p> <p>STATE _____ ZIP _____</p> <p>Enclose check or money order payable to: OLD COLONY SOUND LAB, Post Office Box 243, Peterborough, New Hampshire 03458-0243, USA</p> <p>For credit card order, please bill my <input type="checkbox"/> MasterCard <input type="checkbox"/> Visa</p> <p>CARD NUMBER _____ EXPIRE DATE _____</p> <p>SIGNATURE _____</p>	<p><input type="checkbox"/> KR-1 Moving Coil Input, two channel.....\$335.00 each</p> <p><input type="checkbox"/> KJ-5-7 Classic Class A.....\$311.00 each</p> <p><input type="checkbox"/> West Of the Rockies.....\$316.00 each</p> <p><input type="checkbox"/> Eight Wakefield heatsinks, set.....\$60.00</p> <p><input type="checkbox"/> KL-3C Phono Equalization, two channel.....\$35.00 each</p> <p><input type="checkbox"/> KL-3R Everything but the hardware.....\$25.00</p> <p><input type="checkbox"/> KL-3H The box, jacks, terminals.....\$13.50</p> <p>SUB-TOTAL _____</p> <p>ANY ADDITIONAL CHARGES _____</p> <p>TOTAL _____</p> <p style="text-align: center;">CHARGE CARD PHONE ORDER SERVICE Mon.—Fri. 9am—4pm (603) 924-6371</p>
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Craftsman's Corner

The Egg and I

The audible effect of cabinet shapes is well documented in speaker design literature. The rectangular box is among the worst, but due to ease of design and construction, most builders are willing to live with its limitations. After building at least 100 rectangular boxes in the early '70s, I became disenchanted with box speakers. Would a spherical box sound better? Theory said yes. The arrival of a large band saw in my shop made it possible for me to build one and hear for myself.

The speaker enclosure described here is the result. *Fig. 11* shows a 5¼-inch Audax woofer and an Audax tweeter mounted in my new shape. Since that photo was taken, I have installed a 6½-inch polypropylene Madisound woofer, which is more suitable for the enclosure size (600 cubic inches). To determine the enclosure size, I made a wild guess, built the enclosure and then measured the volume by filling the finished enclosure with dry sand. I poured the sand into a rectangular box and easily calculated the displacement. The original 5¼-inch woofer's bass response in the enclosure was measured at a Pacific Northwest Audio Society (PAS) meeting. The response rolled off gradually starting at about 140Hz, indicating that the enclosure was too large for the driver. Since I could not easily change the enclosure volume, I changed the driver.

I stuffed the enclosure with four or five handfuls of loosely crushed dacron, which I purchased from a ski-jacket manufacturer. My crossover is in a state of change. I suggest you scale the enclosure and crossover to the needs of your drivers. My enclosure is 15½ inches high by 10¼ inches in diameter. The wall thickness varies between 1½ and 1¼ inches. The shape is similar to an egg's. Construction requires a good band saw with at least an 8-inch throat. The blade must be very sharp.

Construction

Cut 64 rectangles (5¾ by 15⁷/₈ inches) out of ¾-inch particle board or plywood. Glue stacks of four rectangles together. I used aliphatic resin. Using a table saw, square up each stack to 15½ by 5½

inches. You will have 16 blocks that resemble the left object in *Fig. 1*.

Build a simple ripping fence for your band saw and clamp it to the table of the saw as in *Fig. 2*. Set the saw table to 22.5 degrees. Rip cut all the blocks as in *Fig. 3*. The result should look like the center and right objects in *Fig. 1*. You now have 32 wedges.

Make a pattern of a vertical cross section of your sphere. Draw this pattern on all 32 wedges. With the band saw still at 22.5 degrees, cut the wedges to shape.

See *Fig. 4* and the left object in *Fig. 5*. Divide the shaped wedges into pairs. Place the two halves of each pair together, as shown in the center of *Fig. 5*. Look closely at the joint between the two. If your band saw is in top shape, you might have enough contact between the halves of each pair to proceed to the next step. If not, use coarse sandpaper or a hand plane to improve the joint. Perfection is not required; 50 percent contact is sufficient. This joint-checking process is required before each glue

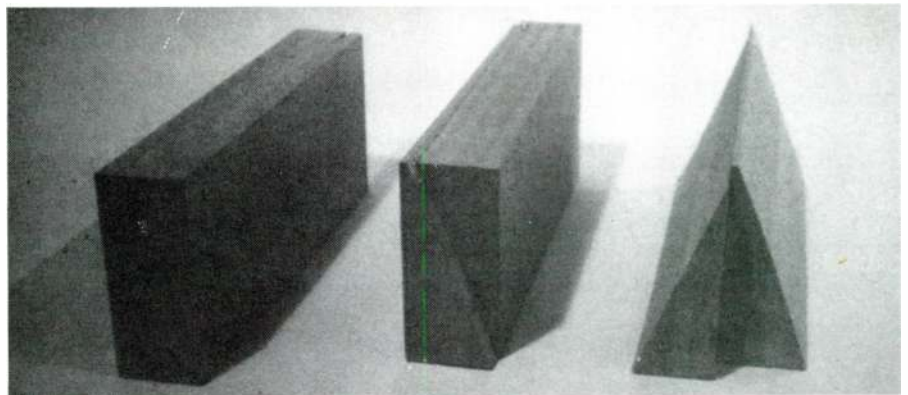


FIGURE 1.

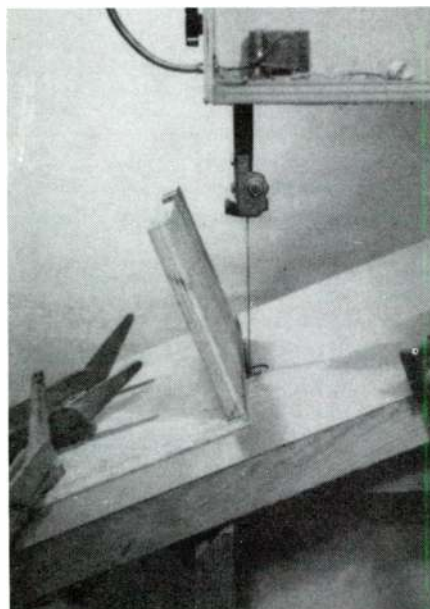


FIGURE 2.

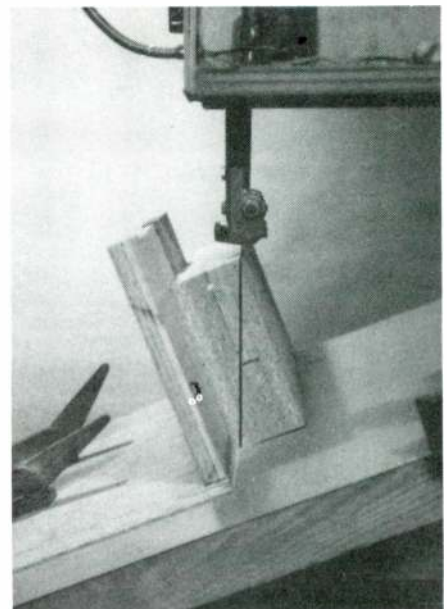


FIGURE 3.

step. Glue each pair together, being generous with the glue. Three or four small clamps should do the job.

After the glue has dried, glue the double wedges to each other, using a clamp and blocks as in *Fig. 6*. Now glue the resulting quarter spheres together. Use two nails standing up in a scrap of wood to hold the wide part of the sphere together. See *Fig. 7*. Nail wedges of wood to the quarter spheres and clamp as in *Fig. 7*. To glue the half spheres together, tie a strong strap around the center. Pound small wedges between the strap and the enclosure until the joints are tight. See *Fig. 8*.

When the glue is dry, use 36 or 40-grit sanding disks to smooth all the rough edges and flatten an area for the woofer and tweeter. Sand a flat spot on the bot-

tom also. Cut the speaker openings as in *Fig. 9*. The woofer opening should be undercut (as in *Fig. 10*) to decrease midrange coloration caused by the thickness of the enclosure walls. Fill all gaps in the joints with Durham's Water Putty. Sand and paint. Now stuff the enclosure and install the speakers and crossover. The finished product should look like *Fig. 11*.

I use my spheres without grilles. Placed on 30-inch stands and accompanied by a subwoofer crossed in at 90Hz, the resulting sound field is wide and open—a clear improvement over a similar-sized rectangular enclosure.

Rion Dudley
Seattle, WA 98119

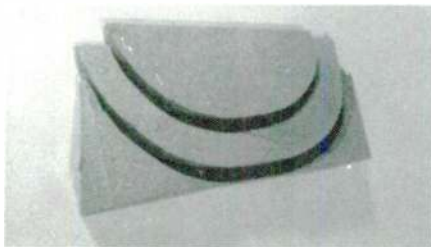


FIGURE 4.

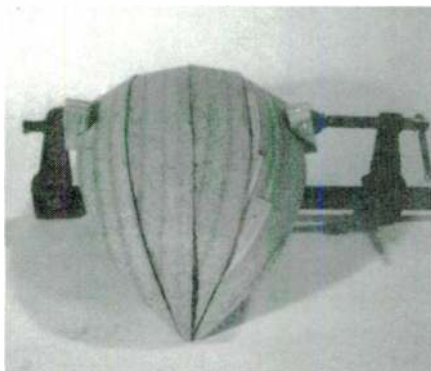


FIGURE 6.



FIGURE 8.

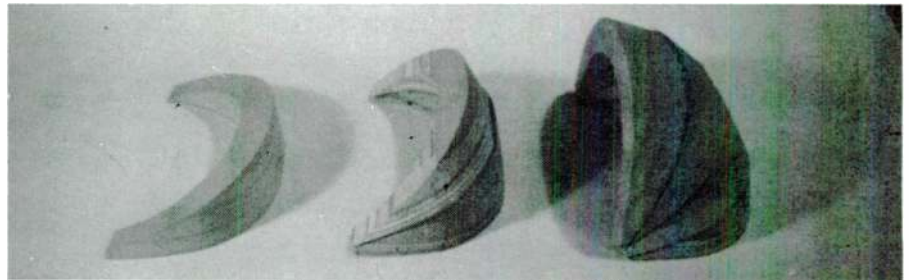


FIGURE 5.



FIGURE 7.



FIGURE 9.

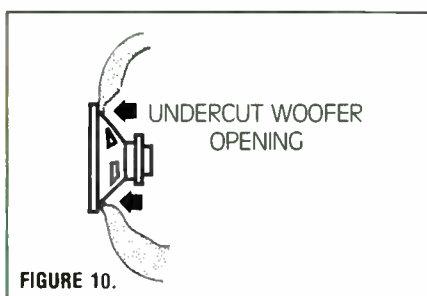


FIGURE 10.

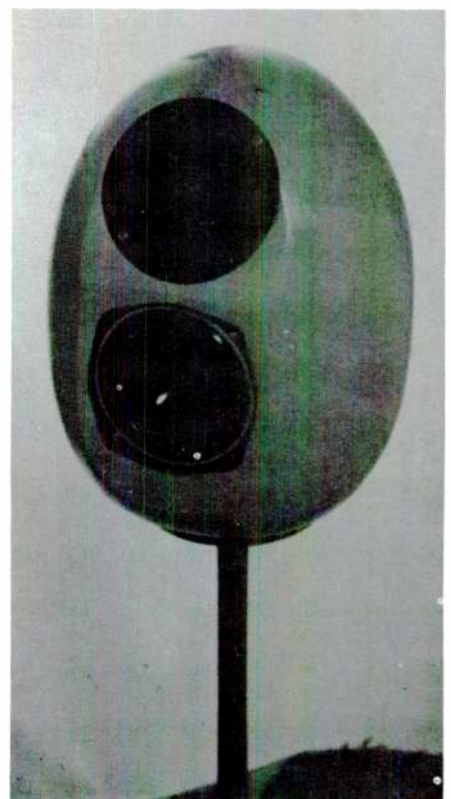


FIGURE 11.

SB Mailbox

CORRECTION: HP-97 PROGRAM

In SB 1/83 (p. 20), we ran a program to determine Thiele/Small parameters with a Hewlett-Packard HP-97 calculator. The reproduction of that program was so poor that we are offering a clearer copy of it to anyone who sends in a self-addressed, stamped envelope. Address your request to Speaker Builder, Dept. HP, PO Box 494, Peterborough, NH 03458.

We have also learned that there is an error in the program as it was published. Lines 140-150 are numbered incorrectly. They should be labeled 141-151. The correct information for line 140 (which is missing from the published program) is as follows: \sqrt{X} in the second column and 54 in the fourth column, which contains the HP-97 key codes.

We apologize for any inconvenience this might have caused.—Ed.

CROSSOVER CLARIFICATION

Joseph D'Appolito's letter about electronic crossovers (SB 4/83, p. 34) prompted me to clarify a few issues relating to my three-way system (SB 4/80, p. 14). The first of these is the interaction between the two crossovers, the second deals with the in-

fluence of high-pass woofer behavior on the woofer-to-midrange crossover, and the third addresses the phase correction for the spatial offset between the woofer and midrange.

1. In Mr. D'Appolito's Fig 3, he shows the correct three-way topologies, with the additional all-passes that might be required under some circumstances. For the LR4 crossovers, these are second-order all-passes with a phase shift (ϕ) of 0.7. Their group delay ($t_g = -d\phi/d\omega$) is shown in his Fig. 2.

For my system, with crossovers at 100Hz and 1.5kHz, the crossover frequencies are separated so much that the phase shift from the 100Hz high-pass amounts to only 12 degrees at the 1.5kHz crossover. I chose to neglect this additional phase shift in the midrange channel and provided no correction for it in the tweeter channel, as it would cause an error of only -0.05dB in the summation of midrange and tweeter outputs. A 400Hz and 3kHz LR4 crossover would give a 23-degree phase error between midrange and tweeter, resulting in a -0.18dB droop at 3kHz, if everything else were correct. (See Fig. 1.)

2. The topologies in Mr. D'Appolito's Fig. 3 presumably are electrical crossovers rather than acoustic crossovers, where the frequency response of the drivers is taken into consideration. To illustrate the additional steps necessary to achieve an acoustic crossover, I will explain the 100Hz woofer-to-midrange crossover in my system (SB 4/80, p. 22, Fig. 29).

The woofer has been equalized with the network of Fig. 25 to be down 3dB at 30Hz,

or 6dB at 19.3Hz. For a review of this network, see R.A. Greiner and M. Schoesow's article, "Electronic Equalization of Closed-Box Loudspeakers" [JAES (Volume 31, Number 3), June 1983, p. 394]. Without equalization, the woofer would cut off at 55Hz, with a phase shift of 1.2. The equalized frequency response of the woofer is equivalent to a 19.3Hz second-order high-pass with a phase shift of 0.5 (Fig. 2). It has the following phase shift (Fig. 3):

$$\phi = 180^\circ - 2 \arctan \frac{f}{19.3\text{Hz}}$$

At the crossover to the midrange (100Hz), the phase shift is $+22$ degrees. To be exact, you could compensate for this shift by inserting an all-pass into the midrange channel, which duplicates the phase behavior of the woofer high-pass. A first-order all-pass with a pole and zero at ($19.3\text{Hz} = \frac{1}{2}\pi\text{RC}$) is the perfect match (Fig. 4). In practice, though, this correction might not be necessary because of the small error (Fig. 1) in frequency response in the transition region between woofer and midrange.

3. In my system, the woofer box is positioned 84cm behind the midranges for reasons of domestic peace and aesthetics. The system requires correction for the phase shift introduced by this offset. The signal from the woofer arrives at the midrange with a phase lag of 91 degrees at the 100Hz crossover due to the offset, but with a phase lead of 22 degrees due to the woofer high-pass nature. The net result is a

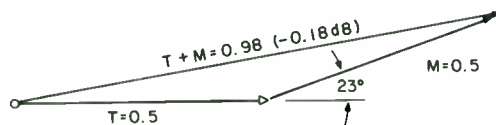


FIGURE 1: Vector addition calculating the phase error between the tweeter and the midrange.

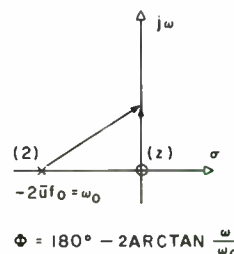
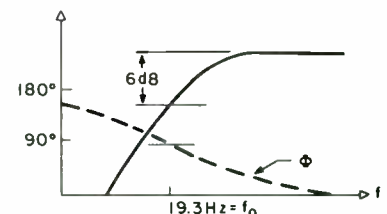


FIGURE 2: Woofer high-pass.



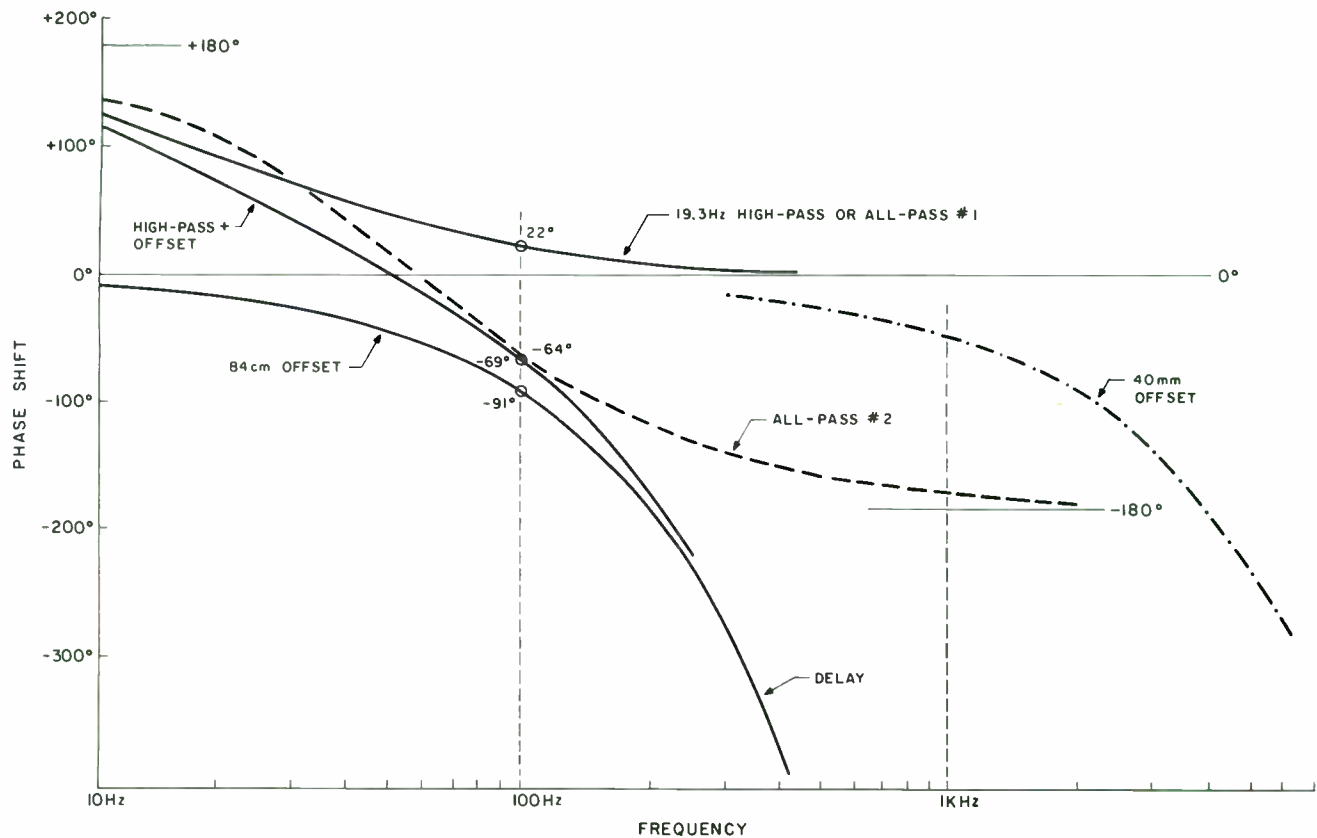


FIGURE 3: Phase response of high-pass, offset and all-pass.

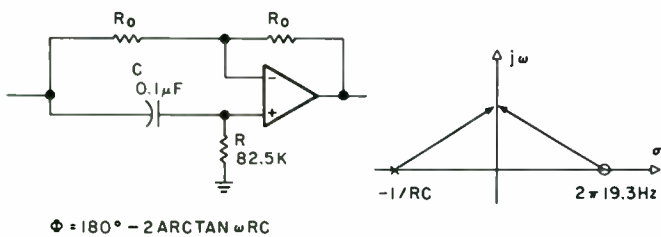


FIGURE 4: First-order all-pass.

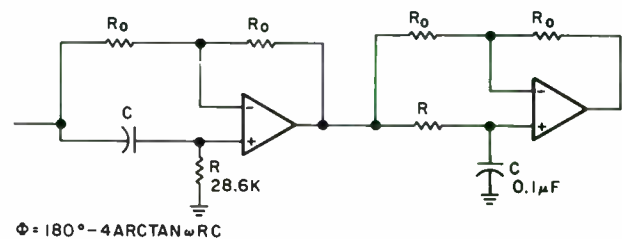


FIGURE 5: Two first-order all-passes in cascade.

69-degree lag at 100Hz and a corresponding 1.7dB drop in response (Figs. 1 and 3).

The phase lag of the woofer sound pressure requires a corresponding phase lag in the midrange so that the signals from both will seem in phase. The midrange should have a -69-degree phase shift at 100Hz, and the slope of the phase response should match that of the woofer (Fig. 3). This last requirement ensures that the signals from the two drivers add correctly not only at 100Hz, but also below and above that frequency. Because of the steep slopes of the LR4 crossover, the transition region is relatively narrow, which makes approximating the phase slope requirement easier.

Two first-order all-passes in cascade (Fig. 5) have a phase response of

$$\phi = 180^\circ - 4 \arctan \omega RC.$$

With Q equal to -69 degrees and ω equal to $2\pi 100\text{Hz}$, RC equals 3.03msec. With standard values of R (28.6k) and C (0.1µF), the phase lag at 100Hz is -64 degrees. Compare this phase response curve (Fig. 3) to the woofer high-pass and offset phase response. The two match well at 100Hz, but their slopes are different. Consequently, above 100Hz, the compensation is not exact. The errors in the vector addition are small, however, because at 200Hz, for example, the woofer will be down 24dB.

I could have matched the slope of the phase shift response more closely, but doing so would have required more circuitry, and I considered it unnecessary. On the other hand, the 40mm offset between midrange and tweeter (Fig. 3) has been matched quite closely with three all-pass sections for absolute phase and slope.

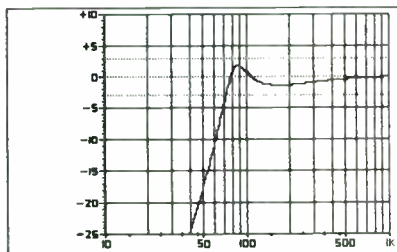
A number of papers presented at the Oc-

tober 1983 AES Convention addressed three-way crossovers with some fascinating mathematics. I hope it is apparent from the above discussion that you can easily estimate and correct the interactions between crossovers. This is certainly true for active crossover circuits. With passive crossovers, the interactions between the filter networks are considerably more difficult to correct, as demonstrated at the recent AES convention, even assuming ideal drivers. Ironically, the reason we need crossovers is that there is no such thing as an ideal driver.

Clearly, the acoustic behavior is all that matters. The whole purpose of electrical networks, passive or active, is to achieve the desired acoustic response when they are combined with the drivers and their enclosures.

I hope these notes have clarified some

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steps in the design of a multidriver
loudspeaker.

Siegfried Linkwitz
Santa Rosa, CA 95404

Mr. D'Appolito replies:

Mr. Linkwitz gives an excellent example of the
proper way to compensate for interdriver
phase differences in multiway loudspeakers.
Three elements of his specific example parallel
the general comments in my earlier letter.

First, Mr. Linkwitz compensates for both in-
terdriver phase difference at the crossover fre-
quency (f_c) and for the phase slope in the octave
or so around that frequency. This is
mathematically and electrically equivalent to
compensating for interdriver time delay in the
crossover region.

Second, Mr. Linkwitz applies this time-de-
lay correction to the midrange driver, which is
clearly ahead of the woofer in time. This em-
phasizes my earlier statement that the mid-
range cannot be arbitrarily selected as the
system reference driver.

Finally, Mr. Linkwitz uses two all-pass net-
works in his compensator and further states
that additional circuitry could be used for
more complete compensation. Matching both
phase and phase slope generally requires more
flexibility than a single all-pass can provide.

I agree completely with Mr. Linkwitz's com-
ments concerning amplitude response. Using
the Linkwitz/Ballard three-way parallel
topology (Fig. 3e of my earlier letter) with
crossover frequencies of 400 and 3,500Hz
(Ballard's choices), the three-way summed
outputs are theoretically flat to within 0.2dB.
This variation is hardly worth compensating
for, as it is within the variability produced by
component tolerances. As the crossover fre-
quency spread is reduced from three to two oc-
taves, the three-way summed output variation
from flat response increases to 1dB. With
third-order Butterworth crossovers, the
parallel topology produces a 1dB variation
from flat response with a three-octave separa-
tion in crossover frequencies and a 2.1dB
variation with a two-octave spread.

Thus, for crossover frequency separations
below three octaves, readers might want to use
the topologies suggested in Figs. 3a and 3b of
my earlier letter. Far from being a theoretical
oddy, they are a correct and practical way to
realize three-way, sum-to-all-pass electronic
crossover networks. Even without the all-pass
phase-correcting section, they provide flatter
summed response than the parallel topology.
Furthermore, without the all-pass network,
they use no more circuitry than the parallel
topology and therefore seem to be the pre-
ferred way to connect high and low-pass filters
to obtain a three-way crossover.

I don't believe anyone can argue with Mr.

Linkwitz's last point that non-ideal driver acoustic response must be integrated into the overall crossover network design.

BALANCING ACT

I have a set of speakers in my living room, dining room and basement workshop and on the screened porch. They are all 8-ohm matched pairs, but have quite different power needs. I have used L-pads to "balance out" the room-to-room listening results and have added a Radio Shack switch module to help out when my Kenwood KR77 runs out of choices.

More to the point, after reading Glenn Phillips' article ("Level Controls and Balancing Pads," *SB* 2/83, p. 20), I had some additional questions. To my ears, the first thing that seems to happen when I "turn down" the L-pads is the loss of the "highs." This does not seem to happen, however, until the pad is turned more than halfway off. What little control there is seems to be in the control's last rotation to "off." Could this be my imagination, or is this an inappropriate use of an L-pad? I used 21-gauge wire from ETCO for the runs between the speakers and the amp. No run is more

than 50 feet long, but I might have used too light a gauge. The amp does not have a particularly high wattage, but I usually don't turn the volume up over one-quarter of the way.

I would be interested in hearing how I could make my system more efficient.

John W. Claris Jr.
Hendersonville, NC 28739

LEVELING BALANCING PADS

Glenn Phillips' article entitled "Level Controls and Balancing Pads" (*SB* 2/83, p. 20) contains some interesting tips on using attenuators and L-pads. The equations in Fig. 2, however, have misplaced decimals. They should read:

$$R1 = \left(\frac{10^{(0.05 \times A)} - 1}{10^{(0.05 \times A)}} \right) Z$$

$$R2 = \left(\frac{1}{10^{(0.05 \times A)} - 1} \right) Z$$

where A equals positive decibels of at-

tenuation. For example, for 6dB of attenuation, A would equal +6. The program listing is correct.

The real problem with calculating series (R1) and parallel (R2) resistors for driver attenuators is in deciding what to use for Z, the driver impedance. Mr. Phillips has set Z equal to Re, the driver DC resistance. I use the impedance of the driver in its operating band. Neither is entirely correct, since the driver impedance is a complex quantity (that is, it has both magnitude and phase, or real and imaginary parts). Using Z equal to Re ignores a part of the impedance that becomes important at higher frequencies as the inductance of the driver voice coil becomes significant. Using the actual driver impedance is a little more correct, but the complex properties of the impedance are still ignored when calculating R1 and R2 and their effects on the overall impedance of the system.

To try to determine the best and easiest compromise, I made a number of impedance and attenuation measurements on a typical 8-inch driver (see "Impedance Compensating Crossover," *SB*, pp. 11-14). My goals were to produce a constant and accurate attenuation, and to produce a constant and flat impedance to the crossover. I used the above equations, changing only the value of Z. I also compensated the driver for its voice coil

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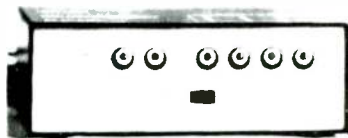
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inductance and repeated the measurements. The driver DC resistance is 7.0 ohms.

If you can wade through all this data, I believe several things are apparent. First, with an uncompensated driver, using Z equal to R_e yields attenuations that are more than 1dB lower than desired, except at low frequencies (where the actual impedance is almost as low as the DC resistance). Second, with an uncompensated driver, using the actual impedance to calculate the attenuator resistor values does not work well for high frequencies (where inductive reactance is large).

However, when the driver inductance is compensated for with a resistor/capacitor network in parallel with the driver (see SB 1/83, p. 11), using either the DC resistance or the actual impedance yields fairly constant impedances and attenuations near those expected for -6dB and -10dB. The advantage of using the actual impedance in the attenuator resistor calculations is that the effective impedance presented to the crossover remains constant regardless of the attenuation.

For example, let's assume that the frequency band in which this particular driver is designed to operate is centered around 1,000Hz. Using the compensated driver and an impedance of 11.5 ohms, for a desired attenuation of -6dB, the measured impedance at 1,000Hz remains at 11.5 ohms, and the measured attenuation is -6.1dB. Similarly, for -10dB, the measured impedance at 1,000Hz is still 11.5 ohms, while the measured attenuation is -10.3dB. Using the DC resistance yields an impedance that changes with attenuation, even with a compensated driver. Also, the attenuation is not quite as large as expected.

This particular compensated driver has a rise in the impedance at about 1,000Hz, which makes it difficult to produce exactly correct attenuations and unchanging impedances across the frequency band. Drivers whose impedances are not flat even after compensation sometimes need changes in their attenuators and crossover components to yield correct results. Making measurements such as the ones presented in these tables ensures that the desired attenuations are achieved and that the impedance presented to the crossover is constant and as expected. If the impedance that the crossover sees changes with either frequency or attenuation, then the crossover for that driver will not have the correct slope or will change frequency as you try different attenuations. The conclusion is that the driver must

have a flat impedance within its operating band and probably for at least an octave outside of it, either inherently or with external compensation. With this proviso, calculating the attenuator resistors with the DC resistance will work fairly well as long as the actual impedance of the driver in its operating band is not much larger than the DC resistance. The new effective impedance presented to the crossover must be measured or calculated to find the crossover parts' values. The best way is to compensate the driver and then use the actual driver impedance in its operating band. This usually results in measured attenuations that approach desired values, and the effective impedance does not change, so the crossover parts never have to change.

Max Knittel
Bellingham, WA 98225

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In questioning authors, please leave room in your letter for replies which should relate to the article, be framed clearly, and written legibly. Please do not ask for design advice or for equipment evaluations.

Letters to authors or other readers cannot be acknowledged, unfortunately. Any letter which does not comply with the requests above will not be answered.

CROSSOVER CALL

I need crossovers for two speaker systems on which I am working. The first system has a 15-inch, 16-ohm Jensen P15LF woofer rated at 40W and 16 to 2,000Hz, an ADS 206-0205 midrange and an ADS 206-0107 tweeter. In an attempt to avoid phasing problems, I have mounted the midrange and tweeter in a small box that is separate from the woofer. My idea is to biamp this system, using an active electronic crossover between the woofer and the midrange and a passive crossover between the midrange and the tweeter. I have a Citation II tube amp, which I thought I

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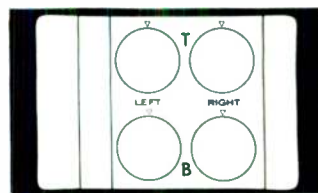
The Old Colony starter kit includes a set of printed sheets containing 250 composers' names (and their birth and death dates). Cut out with scissors, these fit standard $\frac{1}{2}$ -cut 3x5 file guides, available from any good stationer for a few cents each. A tiny dot of white glue holds the names in place on the guide while it is being covered with Scotch magic mending tape ($\frac{3}{4}$ ") for a durable finish.

In addition to the starter kit, you will need to purchase the following locally: 3x5 file cards, 3x5 file guides ($\frac{1}{2}$ -cut), a file box or drawer, an inked stamp pad (cloth, not foam, with permanent black ink), white glue and Scotch magic mending tape ($\frac{3}{4}$ "). Your only added cost for a collection of more than 250 recordings is for labels and index cards. The system works equally well for tapes, multi-record sleeves and boxes, cassettes and video tapes.

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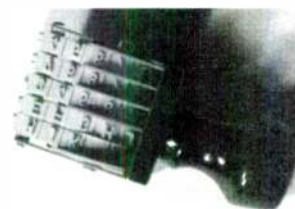


When wrapped around the disk's sleeve, the number appears on the front, back and spine of the package. On multi-disk boxes or tapes, the serial number appears on the spine and front. You can mark four small tone-control knob symbols on the label to note preferred listening settings for each recording.

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An adjustable, five-band rubber stamp. Its characters are turned 90 degrees so they appear vertically. This makes the five-character serial number easy to read on the narrow edge of the sleeve spine.

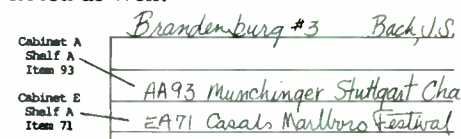
The first two bands of the stamp are the letters A to K (omitting I), and the last three are the numerals 0 to 9. These provide flexibility in coding. The two letters can designate cabinets and shelves; the numerals can designate consecutive serial numbers on those shelves.



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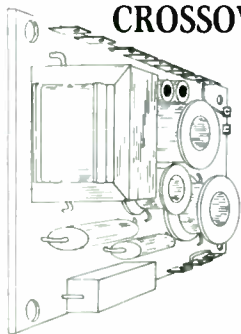


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would use for the high end, and a transistor amp for the woofer. My problem is that I cannot decide whether to use 12dB or 6dB crossovers or a combination of both. I am also uncertain about the crossover frequencies.

My second system is a copy of the ADS BC8. The drivers are all from ADS—the 206-0324 woofer, 206-0201 midrange and 206-0107 tweeter. I have mounted these in a cabinet that has the same dimensions as the BC8. Can anyone help me with the crossovers?

Tony Keppelman
Burlington, VT 05401

VINTAGE DRIVER

With the resurgence of interest in horn designs and early esoteric loudspeakers, I thought some readers might be interested in the specifications of the Western Electric 555 driver.

- Availability—early 1927
- Impedance—16 to 25 ohms (12.8 ohms DC)
- Speech Coil Type—edge-wound aluminum ribbon
- Power Handling—6W
- Field Coil—7V at 1.5A
- Efficiency—30%

I obtained the information from a rare and restricted E.R.P.I. bulletin.

Lachlan Wood
Ashgrove, Australia

CONTRA-BOMBARDE

Can anyone provide or refer me to information regarding the design of the bass section of the Wegerman Pro loudspeaker, which Shahinian Acoustics currently uses as the "Contra-Bombarde" subwoofer? Perhaps we could persuade Mr. Shahinian himself to reveal the design.

Stephen E. Katz
Topeka, KS 66601

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WANTED: DRIVER SUPPLIER

I have written to several US speaker driver suppliers asking them to contact me regarding the export of drivers to me in Australia. Results have been negative, and I am wondering whether anyone could assist me in obtaining at least one supplier willing to export brands such as KEF, Audax, Dynaudio, Peerless and JVC. I should mention that Falcon and Wilmslow Audio of the UK export freely, but they do not carry many of the drivers available from some US suppliers listed in *Speaker Builder* classified ads.

On a different subject, I must say that your interview with Raymond Cooke was a gem. I wonder if you would consider publishing interviews with other industry leaders such as Mr. Adams of B&W Loudspeakers, Brian Pook of Rogers, Mr. Bank of Celestion and Tim Hou of AR. I realize this is a tall order, and corporations and designers are often reluctant to become involved with publications. Such information would, however, broaden *SB's* horizons and be immensely valuable to readers.

Finally, I would like to see KEFTopics made more available to *SB* readers. I have succeeded in obtaining only one issue from the local KEF Australia distributors.

John Kasowicz
Melbourne, Australia

READER SEEKS SATELLITE SYSTEM

I'm looking for any information or plans for a satellite system using a Morel MW160 (6-inch) woofer. I'm now using the Morel driver in a 450in.³ enclosure with a Dynaudio Varavent, but I'm looking for a better system.

Russ Budzileni
Carbondale, IL 62901

DALINE HOTLINE

Having recently learned that my Daline loudspeaker has been the subject of a certain amount of interest in *Speaker Builder*, I would be delighted to enter into correspondence regarding this design.

Robert Fris
6 Waverley Ave.
Basingstoke, Hampshire
England RG21 3JN

KITS

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FILTERS & SPEAKER SAVER

- KF-6: 30Hz RUMBLE FILTER.** [4:75] 2 channel universal filter card, 1% metal film resistors and 5% capacitors for operation as 18dB/octave; 30Hz, 0dB gain only. Each \$19.75
- KH-2A: SPEAKER SAVER.** [3:77] Turn on/off protection & fast opto-coupler circuitry to prevent damage to your system. 4PDT relay & socket for 2 channels. Each \$35.00
- KH-2B: OUTPUT FAULT OPTION.** Additional board mounted components for speaker protection in case of amplifier failure. Each \$6.75
- KH-2C: COMPLETE SPEAKER SAVER KIT.** Includes KH-2A & KH-2B. Each \$40.00
- KL-5 WILLIAMSON BANDPASS FILTER.** [2:80] 2 channel, plug-in board and all parts for 24dB/octave 20Hz-15kHz with precision cap/resistor pairs. TL075 IC's. Each \$31.00

AIDS & TEST EQUIPMENT

- KH-7: GLOECKLER PRECISION 101dB ATTENUATOR.** [4:77] All switches, 1% metal film and 5% carbon film resistors to build prototype. Chassis, input/output jacks are not included. Each \$50.00
- KL-3C: INVERSE RIAA NETWORK COMPLETE.** [1:80] 1 KL-3R and 1 KL-3H with 1% polystyrene capacitors. Alternate 600 ohm or 900 ohm R_2/IC_2 components for 2 channels. Each \$35.00
- KL-3R: INVERSE RIAA.** [1:80] Resistor/capacitor package complete. Contains stereo R_2/IC_2 alternates. Each 25.00
- KL-3H: INVERSE RIAA HARDWARE.** [1:80] Box, terminals, gold jacks, and all hardware in KL-3C. No resistors or caps. Each \$13.50
- KF-4: SINE-SQUARE AUDIO GENERATOR.** [4:75] Morrey's MOD kit for Heath IG-18 (IG5218). 2 boards and parts to modify the unit to distortion levels of parts per million range. Each \$35.00
- KG-2: WHITE NOISE/PINK FILTER.** [3:76] All parts, circuit board, IC sockets, 1% resistors, $\pm 5\%$ capacitors. No batteries, power supply or filter switch. Each \$22.00
- KJ-7: VTVM BATTERY REPLACEMENT KIT.** [4:78] Resistors, capacitors, semiconductors and PC board to replace your VTVM's battery with a regulated supply. Each \$7.50
- KJ-6: CAPACITOR CHECKER.** [4:78] All switches, IC's, resistors, $4\frac{1}{2}$ " D'Arsonval meter, x-fmr and PC board to measure capacitance, leakage and insulation. Each \$78.00
- KK-3: THE WARBLER OSCILLATOR.** [1:79] Switches, IC's, x-fmr and PC board for checking room response and speaker performance w/o anechoic chamber. Each \$56.00
- KL-6 MASTEL. TIMERLESS TONE BURST GENERATOR.** [2:80] All parts with circuit board. No power supply. Each \$19.00
- KM-1: CARLSTROM-MULLER SORCERER'S APPRENTICE** [2:81] 4 boards and all parts for construction of the first half of a swept function generator with power supply. No knobs or chassis. Each \$145.00
- KM-2: CARLSTROM-MULLER PAUL BUNYAN.** [3:81] All parts except knobs, chassis, output connectors and wire. Includes 2 circuit boards and power supply. Each \$85.00
- KM-3: CARLSTROM-MULLER SORCERER'S APPRENTICE/PAUL BUNYAN** [2:81, 3:81] All parts in KM-1 and KM-2. Each \$225.00
- SBK-D2 WITTENBREDER AUDIO PULSE GENERATOR.** [SB 2:83] All parts, board, pots, power cord, switches and power supply included. Each \$70.00

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Jack A \$2.50 Jack B \$2.50 Phono Plug \$2.75 Neglex 2477 Termination Kit \$1.00

CROSSOVERS

- KC-4A: ELECTRONIC CROSSOVER, KIT A.** [2:72] Single channel, 2-way. All parts including C-4 board and LF351 IC's. Choose frequency of 60, 120, 240, 480, 1k, 2k, 5k or 10k. Each \$8.00
- KC-4B: ELECTRONIC CROSSOVER, KIT B.** [2:72] Single channel, 3-way. All parts including C-4 board & LF351 IC's. Choose frequency of 60, 120, 240, 480, 1k, 2k, 5k or 10k. Each \$11.00
- KF-7: CROSSOVER FOR WEBB TLS.** [1:75] Passive 4-way x-over, in pairs, assembled. Components are included for both STC and Celestion tweeters. Made by Falcon of England. Pair \$87.50
- KK-6L: WALDRON TUBE CROSSOVER LOW PASS:** Single channel, 18dB/octave, Butterworth, [3:79] includes Bourns 3-gang pot. Choose 1: 19-210; 43-465; 88-960; 190-2100; 430-4650; 880-9600; 1900-21,000 Hz. Each \$43.00
- KK-6H: WALDRON TUBE CROSSOVER HIGH PASS:** Single channel, 18dB/octave, Butterworth, [3:79] includes Bourns 3-gang pot. Please specify 1 of the frequencies in KK-6L. No other can be supplied. Each \$45.00
- KK-6S SWITCH OPTION.** 6-pole, 5-pos. rotary switch, shorting, for up to 5 frequency choices per single channel. Each \$8.00; ordered with 2 kits above, Each \$7.00
- KK-7: WALDRON TUBE CROSSOVER POWER SUPPLY.** [3:79] Includes board, x-fmr, fuse, semiconductors, line cord, capacitors to power 4 tube x-over boards (8 tubes), 1 stereo biamped circuit. Each \$88.00
- SBK-A1: LINKWITZ CROSSOVER/FILTER.** [SB 4:80] 3-way x-over/filter/delay. 24dB/octave at 100Hz and 1.5kHz and 12dB/octave below 30Hz, with delayed woofer turn-on. Use the Sulzer supply KL-4A with KL-4B or KL-4C. Per channel \$64.00
Two channels \$120.00 SBK Board only \$14.00
- SBK-CIA: JUNG ELECTRONIC 2-WAY CROSSOVER.** [SB 3:82] 30Hz filter with WJ-3 board & 4136 IC adapted as 1 channel x-over. Can be 6, 12 or 18dB/octave. Choose frequency of 60, 120, 250, 500, 1k, 2k, 5k or 10k. Each \$24.75
- SBK-C1B: THREE WAY, SINGLE CHANNEL CROSSOVER.** [SB 3:82] Contains 2 each SBK-C1A. Choose high & low frequency. Each \$49.70
- SBK-C1C: TWO CHANNEL, COMMON BASS CROSSOVER.** [SB 3:82] Contains 2 each SBK-C1A. Choose 1 frequency. Each \$49.70
- SBK-C2: BALLARD ACTIVE CROSSOVER.** [SB 3:82 & 4:82] 3-way x-over with variable phase correction for precise alignment. Kit includes PC board (5 $\frac{3}{8}$ x 9 $\frac{1}{2}$ "), precision resistors, polystyrene & polypropylene caps. Requires $\pm 15V$ DC power supply—not included. Can use KL-4A with KL-4B or C. Two channel \$134.00

SYSTEM ACCESSORIES

- KH-8: MORREY SUPER BUFFER.** [4:77] All parts, 1% metal film resistors, NE531 IC's, and PC board for 2 channel output buffer. Each \$14.00
- KH-9: TONEARM MOUNT BOARD.** For the Thorens TD-124 turntable only. Exact fit, unpainted fine grade hardwood. 3 countersunk holes drilled to fit frame. Each \$3.25
- KF-1: BILATERAL CLIPPING INDICATOR.** [3:75] Single channel, all parts and board for any power amp up to 250W per channel. (Does not work well with Leach Amp). Each \$5.50 Two kits, as above \$8.25
- KJ-3: TV SOUND TAKEOFF.** [2:78]. Circuit board, vol. control, coils, IC, co-ax cable (1 ft.) and all parts including power x-fmr. Each \$21.50
- KJ-4: AUDIO ACTIVATED POWER SWITCH.** [3:78] Turn your power amps on and off with the sound feed from your preamp. Includes all parts except box and input/output jacks. Each \$50.00
- KL-14A: MacARTHUR LED POWER METER.** [4:79] 2-channel, 2-sided board and all parts except switches, knobs, and mounting clips for LEDs. LEDs are included. No chassis or panel. Each \$110.00
- KL-14B: MacARTHUR LED POWER METER.** [4:79] As above but complete with all parts except chassis or panel. Each \$137.50
- SBK-D1 NEWCOMB PEAK POWER INDICATOR.** [SB 1:83] All parts & board. No power supply required. Each \$6.00
- KC-5 GLOECKLER 23 POSITION LEVEL CONTROL.** [2:72] All metal film resistors, shorting rotary switch & 2 boards for a 2 channel, 2dB per step attenuator. Choose 10k or 250k ohms. Each \$36.75
- KR-1 GLOECKLER STEPUP MOVING COIL TRANSFORMER.** [2:83] X-fmrs., Bud Box, gold connectors, & interconnect cable for stereo. Each \$335.00
- KL-2: WHITE DYNAMIC RANGE & CLIPPING INDICATOR.** [1:80] 1 channel, including board, with 12 indicators for preamp or x-over output indicators. Requires $\pm 15V$ power supply @ 63 mils. Single channel. Each \$49.00 Two channels. \$95.00
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What's Included? Kits include all the parts needed to make a functioning circuit, such as circuit boards, semiconductors, resistors and capacitors. Power supplies are not included in most cases. Unlike kits by Heath, Dyna and others, the enclosure, face plate, knobs, hookup wire, line cord, patch cords and similar parts are not included. Step by step instructions usually are not included, but the articles in *Audio Amateur* and *Speaker Builder* are helpful guides. Article reprints are included with the kits. Our aim is to get you started with the basic parts—some of which are often difficult to find—and let you have the satisfaction and pride of finishing your unit in your own way.

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CLUBS

Space in this section is available to audio clubs and societies everywhere free of charge to aid the work of the organization. Copy must be provided by a designated officer of the club or society who will be responsible for keeping it current. Send notices marked Audio Clubs in care of the magazine.

THE ESOTERIC AUDIO RATING SOCIETY (usually known as EARS) is San Antonio's premier audio club. Its members consist of audiophiles and music lovers who share a mutual interest in enhancing their enjoyment of recorded music. EARS meets bimonthly and has been fortunate to offer interesting presentations on audio, recordings and music. The club also has an on-going project of recording local concert activities for radio broadcasts or other purposes. Additionally, EARS is currently trying to launch a club newsletter. Anyone interested in finding out more about EARS should write to the following address to obtain information on the next meeting date and location: EARS, PO Box 27621, San Antonio, TX 78227.

PACIFIC NORTHWEST AUDIO SOCIETY (PAS) consists of 50 audio enthusiasts meeting monthly, second Wednesdays, 7:30 to 9:30 PM at 4545 Island Crest Way, Mercer Island, WA. Be our guest, write Box 435, Mercer Island, WA 98040 or call Bob McDonald (206) 232-8130.

THE BOSTON AUDIO SOCIETY INVITES you to join and receive the monthly B.A.S. **SPEAKER** with reviews, debates, scientific analyses, summaries of lectures by major engineers. The BAS was the first to publish info on TIM, effects of capacitors, tonearm damping, tuner IM distortion, Holman's and Carver's designs, etc. Sample issue \$1, subscription, \$16/yr. P.O. Box 7, Boston, MA 02215.

SAN FRANCISCO BAY AREA AUDIOPHILES. Audio Constructors society for the active, serious music lover. We are dedicated, inventive and competent. Join us in sharing energy, interest, expertise and resources. Send self-addressed stamped envelope to S. Marovich, 300 E. O'Keefe St., Palo Alto, CA 94303 for newsletter.

SAINT LOUIS AUDIO SOCIETY meets monthly for discussion and equipment audition. For information sheet send a stamped, self-addressed envelope to SLAS, 7435 Cornell, Saint Louis, MO 63130.

SERIOUS AUDIOPHILES interested in a central Colorado group (Denver, Boulder, Ft. Collins, Greeley area) contact James S. Upton, 2631 17th Ave., Greeley, CO 80631.

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

A CLUB FOR FM AND TV DXers, offering antenna, equipment and technique discussions, plus updates from FCC on new station data. Monthly publication "VHF—UHF Digest." Annual convention in August. For more info: Worldwide TV-FM DX Association, PO Box 97, Calumet City, IL 60409.

THE AUDIO SOCIETY OF HONOLULU cordially invites you to attend one of our monthly meetings and meet others like yourself who are interested in the how's and why's of audio. Each meeting consists of a lively discussion topic and equipment demonstrations. For information on meeting dates and location contact Bob Keaulani at 1902 South King Street, Honolulu, HI 96826, (808) 941-1060.

CONNECTICUT AUDIO SOCIETY WANTED. Serious audiophiles in Conn., or Putnam or Dutchess Co., NY, contact John J. McBride, 33 Perry Dr., New Milford, CT 06776, (203) 355-2032.

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 quarterly journal plus participation in meetings and lectures. Membership fee is \$10 per year. For more information, send SASE to: CAS, 4506 Osceola St., Denver, CO 80212.

THE NEW YORK AUDIO SOCIETY meets monthly with prominent guest speakers, discussions and demonstrations of the latest equipment. Its \$20 annual membership dues include a subscription to S/N, the society's quarterly publication. For a free invitation to our next meeting, call (212) 544-1222, (212) 289-2788 or (201) 647-2788 or write us at PO Box 125, Whitestone, NY 11357.

SARASOTA AUDIOPHILES interested in forming a club—write: Mark Woodruff, 5700 N. Tamiami, Box 539, Sarasota, FL 33580.

AUDIOPHILES INTERESTED IN FORMING an audio club in the Washington, D.C., area please contact: Joseph Kmetz, 9861 Goodluck Rd., Apt. #10, Lanham, Maryland 20706 or call days (301) 794-7296, eves. (301) 585-3186.

THE VANCOUVER AUDIO SOCIETY publishes a monthly newsletter with technical articles, humor and news of interest to those who share our disease. We have 50 members and meet twice every month. Dues are \$15/year, which includes 12 newsletters (\$15 US outside Canada). Call (604) 874-3225 or write Dave Mann, VAS, Box 4265, Vancouver, BC, Canada V6B 3Z7. We would like to be put on your mailing list.

JOIN AN AUDIO CLUB



Expand your horizons. Improve your system. Learn about the latest equipment and techniques. Share viewpoints and experiences. Don't miss out on the fun and value of belonging to an audio society.

Typical activities include:

- **Guest Speakers.** Here's your chance to listen to and meet "superstars" of circuit design, prominent manufacturers, acoustical consultants, and recording engineers.
- **Tours.** Get a behind the scenes look at the equipment and talk with the people who operate it at local TV and radio stations, universities, research labs, recording studios, and factories.
- **Newsletters.** These publications are often of high technical quality and are full of worthwhile information even if you don't attend many meetings. Ads and reviews help you find the right equipment, the latest records, and the dealers who carry them.
- **Evaluation and Testing.** Frequently clubs sponsor clinics so you can bring in your equipment for checkups on test equipment most individuals don't own.
- **Group Buying.** This can be an effective way to obtain obscure items from abroad, including audiophile disks.

No club in your area?

Start one—with a **free classified ad** in *Audio Amateur* or *Speaker Builder*.

For more information, see the club listings in the Classified Ads of this issue.

Classified Advertising

SOUTHEASTERN MICHIGAN WOOFER AND TWEETER MARCHING SOCIETY (SMWTMS). Detroit area audio construction club. Meetings every two months featuring serious lectures, recording studio visits, design analyses, digital audio, AB listening tests, equipment clinics, annual picnic and audio fun. Club publication, *LC, The SMWTMS Network*, journals the club's activities and members' thoughts on audio. To join or subscribe call (313) 544-8453 or write SMWTMS, PO Box 1464, Berkley, MI 48072-0464.

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

AUDIOPHILES IN THE NEW JERSEY and Staten Island areas interested in forming a club please contact Joe at PO Box 1588, Staten Island, NY 10314, (212) 698-2280.

WANTED: Audiophiles in the Riverside-San Bernardino areas to form an audio club. Frank J. Manrique, 1219 Fulbright Ave., Redlands, CA 92373.

LONG ISLAND AUDIOPHILES: The Audio Syndrome is a Nassau/Suffolk county club dedicated to the pursuit of sonic excellence. Monthly meetings. Fred Masters, (516) 589-4260 or (516) 271-4408.

FOR SALE

Snell type A/11 speakers with Snell crossover for biamping. Speakers have been modified, \$1200 or best offer. Carl Bryson, 48 Harvey Rd., RFD 10, Manchester, NH 03103, (603) 434-4945.

Old drivers. EV: 12TRX-B, SP12-B (2), T-35, T-25, X-36, X-8, 15WK, 4Ω for K-horns; (2) University C-15-W, 8" mids; horn tweeters, 12" dual voice coil woofer; Western Electric 728-B; Altec 601 duplex, 802-8G (2), 811-B (2). Offers please. Paul B. Anderson, 230 First St. East, Sonoma, CA 95476, (707) 938-1728.

Electrocompaniet Ampliwire II, \$900; ARC D-350B, \$1800; MCP-2, \$800; Pyramid T-1 ribbon tweeters, \$900. David C. Shreve, 319 Concord, #7, El Segundo, CA 90245, (213) 322-4623.

Audio Research D76A amp, low hours on complete retube with Allegro Sound KT88s, 12 AX7Bs, etc., silver faceplate, \$725; Transcrip-tor Saturn turntable with Vestigal arm/Sonus Blue Gold cartridge, \$150; pair KEF B139s in 11 foot lines, \$300. You pick up. Michael Brinkman, (503) 324-7661 after 6 pm or weekends.

Audax 10" Bextrene woofers, \$40 pair; two Boak power amp regulators, positive and negative for Pass A-40, adaptable to other amps. Fully assembled and tested with four heatsinks, \$100 for both. Gary Galo, 49 Pierrepont Ave., #4, Potsdam, NY 13676, (315) 265-4268.

Two pairs transmission line speakers, one with 8" plastic Becker woofer, 4½" plastic GA1 mid, Philips dome tweeter, oak cabinet; one with 8" plastic SRC woofer, Audax dome mid, JVC ribbon, zebra wood cabinet; finest crossover parts, both very nice, \$600/pair. Allen Dixon, 217 Hamilton, Duncanville, TX 75116, (214) 296-2447.

Dynaco PAT-5 preamp, \$115; Transcrip-tor Saturn turntable (as seen in *A Clockwork Orange*) with Vestigal arm, best offer; Morel MW-160 6½" mid-woofer, \$60/pair; Dalesford D153 6½" mid-woofer, \$25. Jan Waalkes, (616) 874-8369.

Dahlquist speaker system—new DQ10s, factory mirror imaged, polypropylene caps, stands, DQ subwoofer and crossover, rewired throughout with Monster wire, all perfect, sounds superb. Also new Mitsubishi amp and preamp, cheap. Fred VanEman, 309 W. Albuquerque, Broken Arrow, OK 74011, (918) 455-0725.

KEF 105 II speakers, \$1590. Purchaser transports from Philadelphia. Call (215) 545-1160 or write 1610 Addison St., Philadelphia, PA 19146.

STAX/Acoustat: ELS81/8X, SRD7SB, SRM1/mkz. MK-121 biformer, info wanted for home construction. Will reimburse. Circuit diagram, etc. M.J. Campbell, 2011 107th Ave. SW, Calgary, Alberta, Canada T2W 1V6.

Pair CTS 12" woofers, 38 oz. magnet, \$20; pair KEF 139 woofers, \$80; pair Eminence 12" woofers, \$20. Also crossover parts cheap. Buyer pays shipping. All units used. David M. Landrie, 1714 E. 56th, Tacoma, WA 98404, (206) 472-9930.

Hafner 101k, two months, three-year warranty on parts, \$130; NAD 3020, integrated, 1½ years, under warranty, \$130; Jordan Modules, \$110/pair; Morel MDT-28, \$35/pair; Peerless PHT-25, \$13/pair; SEAS H107 tweeters, \$10/pair; Becker 8" polypropylene 908A327, \$32/pair; wooden speaker stands, new, \$15/pair; assorted crossover components; prices include shipping. Eric Pitschmann, 282 Torrey St., Rm. 108, Akron, OH 44304, (216) 762-8142.

SOTA DC head amp, \$95; pair KEF B139s, good working order with surround isolators, \$90; pair Dynaudio D28 domes, new, \$45; pair Variovents, \$6; long-fiber wool, \$10/lb. Russ Bleakley, PO Drawer H, Foresthill, CA 95631.

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Radio Shack hand-held sound pressure level meter, catalog #42-3019 (discontinued), or other inexpensive/used frequency response test equipment. Dan Greene, 805 Riverside Ave., Santa Cruz, CA 95060.



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Black Sumo Charlie, NAK 582. Russ Bleakley, PO Drawer H, Foresthill, CA 95631.

Collector wants to purchase or trade for Dynaco tube equipment (amps and preamps). Contact: Joseph P. Kmetz, 9861 Goodluck Rd., #10, Lanham, MD 20706.

Altec Lansing 15" speaker, 416A-16Ω; VTC audio transformers LS6, LS7, LS22, LS6L1, LS845; Altec Lansing output transformers, TM 119B, others. A.D. Fisher, 239 Georgina Ave., Santa Monica, CA 90402, (213) 395-0355 evenings, (213) 806-1351 days.

Contact with anyone in Ohio who has a Strathearn system built. Eric Pitschmann, Torrey Hall, Rm. 108, 282 Torrey St., Akron, OH 44304, (216) 524-6684.

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All these valuable back issues of *Audio Amateur* are still available

1970 "Price, Time and Value" surveys nine years of the fortunes of used equipment. An all silicon, complementary output, 20W per channel amplifier, fail-safe overload protected by Reg Williamson. A high efficiency bookshelf speaker by Peter J. Baxandall. How to update and improve your Dynaco PAT-4 preamp. A visit to the Heath Co.

1971 A superb, simple, high quality preamplifier by Reg Williamson. A 4+4 mike mixer, using four ICs in a compact chassis, with eight inputs and two-channel output. A four-channel decoder for adding a new dimension to listening; cost to build: \$12.50. Two four-channel encoders, one with microphone preamps, to put four signals on two tape tracks. Three voltage/current regulated power supplies for better power amp performance.

1972 A nine-octave graphic equalizer with slide pots by Reg Williamson. A 10 1/2" reel tape transport, a full-range electrostatic loudspeaker and a 900W tube amplifier for driving the electrostatic panels directly. A high quality op amp preamp, Heath AR15/AR1500 modifications. A new type A+B, low cost 35W amp, electronic crossovers for bi- and tri-amplifier operation. All about microphones, and tuning bass speakers for lowest distortion.

1973 Constructing five transmission line speakers, 8" to 24" drivers, peak reading meter, dynamic hiss filter, tonearm, disk washer, electrostatic amplifier II, customized Dyna MkII and Advent 101 Dolby. How to photograph sound, power doubling, mikes, Jung on op amps, Williamson on matching and phono equalization.

1974 A perfectionist's mod of the Dynaco PAS tube preamp, a mid/high range horn speaker, wall-mounted speaker system, IC preamp/console mixer by Dick Kunc, a family of regulated current limited power supplies, switch & jack panel for home audio, grounding fundamentals, low-level phono/tape preamp with adjustable response, IC checker, lab type $\pm 15V$ regulated supply. A series on op amps by Walt Jung. Kit reports: electret microphone, Class A headphone amp.

1975 Building the superb Webb transmission line, how to test speakers, a test bench set of filters, variable frequency equalizer, building and testing Ampzilla, power amp clipping indicator, a compact tower omni speaker, controls for two systems in three rooms. Visit to Audio Research Corp. Ultra low distortion oscillator, all about filters by Walt Jung, universal filter for either audio garbage or crossovers. Electrostatic speaker and schematics for Audio Research Corp.'s SP-3A-1 preamp, Heath's XO-1 and Marantz' electronic crossovers.

1976 Three mixers by Ed Gately, a vacuum system for cleaning disks, a 60W per channel amplifier for electrostatic speakers, a silent phono base, a perfectionist's tonearm, re-mods for Dyna's PAS preamp, Jung on active filters, a white noise generator/pink filter, tape deck setup by Craig Stark, modifying the Rabco SL-8E, a high efficiency speaker system for Altec's 604-8G, uses for the Signetics Compa-dor IC, modifying Heath's IM (tube) analyzer, simple mods for Dyna's Stereo 70 amplifier, a tall mike stand. Kit reports: Ace preamplifier, Heath's 200W/channel amplifier, Aries synthesizer, Heath's IO-4550 oscilloscope.

1977 Walt Jung's landmark series on slewing induced distortion, a wood/paper/epoxy horn, Reg Williamson's Super Quadpod, experiments with passive radiator speakers, a high efficiency electrostatic speaker with matching low-power direct-drive amplifier, modifying the AR turntable for other arms, Heil air motion speakers, a \$10 Yagi FM antenna, Ed Gately's 16-in/2-out micromixer, the speaker saver: complete system protection. Audio Research modifies the Dyna Stereo 70; the super output buffer, a 101dB precision attenuator.

1978 Modular equipment packaging, PAT-5 preamp mod, radio system for hospitals, supply regulation for Dyna's MkIII, B.J. Webb on phono interfacing and record cleaning, 24" common bass woofer, TV sound extractor, modifying the Formula 4 tonearm, phono disk storage cabinet, Jung on IC performance and noise control, Peter Walker's Quad factory, small horn enclosure, audio activated power switch, the Pass 40W class A amplifier, a thermal primer, capacitor tester, recording with crossed cardioids. Kit reports: Heath IC 1272 audio generator, Heath's IM5258 distortion analyzer, Hafler preamp, Dynaco's octave equalizer, West Side Electronics pink noise generator.

1979 A space-age IC preamp; scientific evaluation of listening tests. Room testing oscillator, Advent mike preamp, three preamp construction projects, record manufacture, a primer on soldering, a variable frequency tube electronic crossover, a re-mod of Dynaco's PAT-5 preamp. A noise reduction system, Williamson's 40W power amp, an LED power meter, and an interview with Peter Baxandall. Kit reports: Integrex Dolby, Heath's audio load, IG1275 sweep generator and their technician's training course. Classic circuitry: a 1936 GE console, the Marantz 8B, Dynaco PAS-3 and Audio Research SP-6.

1980 Regulated power amp power supplies, a dynamic range and clipping indicator, a precise inverse RIAA network, an interview with Peter Baxandall Pt. II, a power supply regulator for op amp preamps, a timerless tone burst generator, filters outside the audio band, intensity stereo primer, upgrading FM tuners, choosing & installing an FM antenna, passively equalized phono preamp, soldering practice, Hafler DH-101 mod, an analog phase meter, an audio equipment rack, the AD7110 digital attenuator, capacitor dielectric absorption, tube RIAA equalization. Reviews: Hafler DH-200, SWPTC Tigersaurus 210A, Heath AP-1615 preamp, Logical Systems 318 Silencer, Heath AA-1600 power amp, Heath AD-1701 output indicator.

1981 Audio Research SP6 mods; revising preamp power regulators; home built heatsinks; Marantz 7C mods; Nelson Pass' MOSFET rebuild of HK's Citation 12; Williamson on record care: destaticizing and deep cleaning. An audio measuring system: A Swept Function Generator, Part 1; A Logarithmic Amplifier: Part 2. Modifying Dynaco's ST-150 amp and regulating its supplies; adding a tower for FM; microphoning, a heretic's view; super uses for Cramolin; de-ringing transformers; Jung and Marsh upgrade the Hafler DH-200 with clues for all amps, greening the ReVox A-77, evaluating Dolby-C.

1982 MC pre-preamp, two-tone IM measurements, double-blind testing and its alternatives, Heath IM-25 and IM-16 meter upgrades, phased array recording, adapting surplus meters to your needs, Bobbely 60W MOSFET amp, Rabco ST-4 tonearm upgrade, sophisticated preamp switching with minimum contacts, NiCad battery charger, sweep marker adder, Boak op amp electrostatic and dynamic headphone amps, DC servo loops for amps, Advent mike preamp update, double-blind testing, tangential tracking tonearm, building a plate reverb, selecting and evaluating interconnect cables, the last word on Dyna PAS tube preamp mods, distortion analyzer, stepped attenuator, tape deck testing and calibration device. Kit and Test Reports: VSM's stereo demodulator, Radio Shack's coincident mike, Fluke 8050A multimeter, Heath AA1800 amp, Phoenix CX decoder.

1983 A digital delay line, measuring power supply output impedance, upgrading Dynaco's FM-5 Tuner. A moving coil step-up transformer device, reworking the Hafler DH-500. A RMS AC voltmeter with dB converter, two tone burst generators, an overview of power supply design principles. Updating Dynaco's Stereo 400, a new 200W power amp design, a voltage variable resistor for oscillators, a ramp recording modem for tape alignment, a phono tip shape survey, new IC devices for audio, and a modular crossover system.

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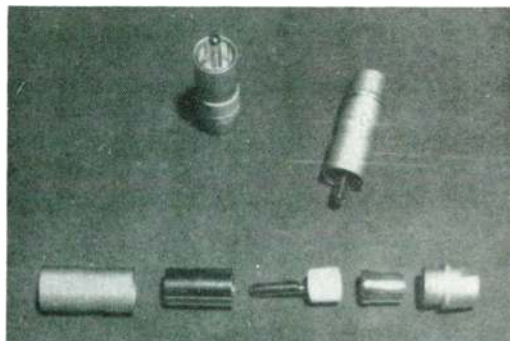
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it. After the shielded center wire is soldered to the center pin, the top may be screwed down to form a solid, strong compression junction between the crown and the skirt. This makes a virtually unbreakable connection, which is far more rugged and dependable than the conventional soldered joint. The Royce plugs will accept Mogami Neglex 2534 audio cables and others up to 0.230 inch in diameter. The Royce plugs come in color-coded pairs (red and white) only. Pair **\$9.50**. Two or more pairs **\$8.00** pair.

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