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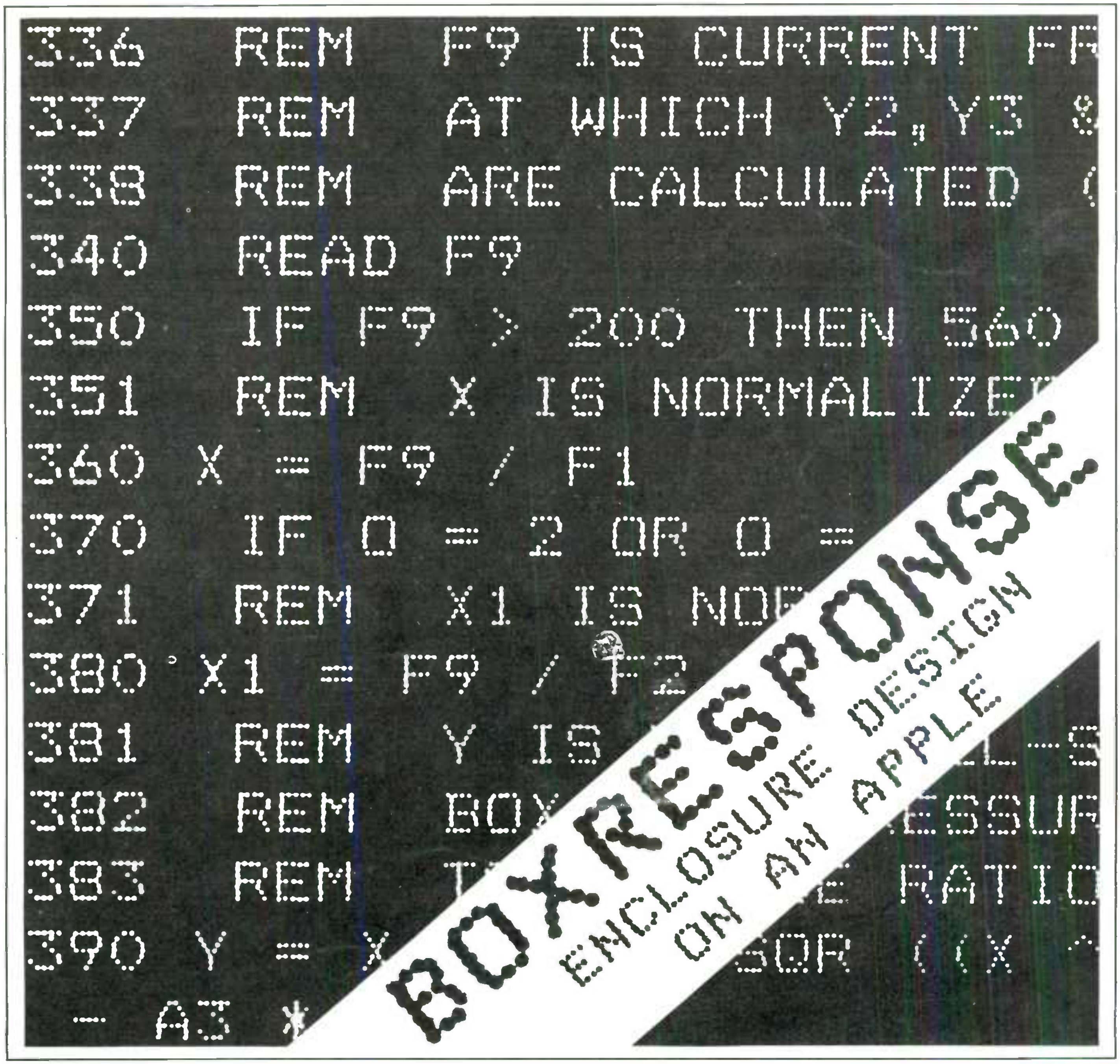
SPEAKER BUILDER



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BOXRESPONSE

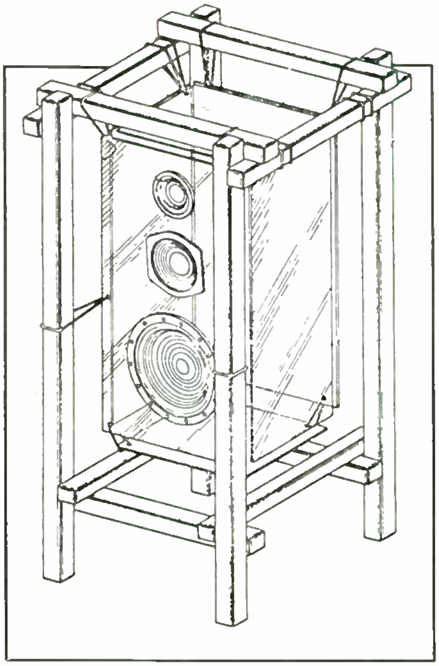
ENCLOSURE DESIGN
ON AN APPLE

Good News

L.A. WHITE JR. INC. has been issued a patent for a new loudspeaker enclosure that is reportedly free from resonance and backwave radiation from the driver. A free-standing frame supports front, back, side, top and bottom panels in such a way that the panels are free to move relative to each other.

Speaker drivers are mounted to the front panel so that frontwave radiation is allowed to project outward. Rearwave radiation is said, however, to be contained within the enclosure formed by the panels. As a result of impinging backwave energy, deflection of the panels reportedly dissipates the backwave without producing "ringing" or other resonant effects.

If you would like to know more about this enclosure, write to L.A. White Jr. Inc., 1920 Medi-Park Drive, Suite 1, Amarillo, TX 79106.



This is the time of year for new catalogs, three of which have come to our attention within the past few months. **AUDIO CONCEPTS** offers its catalog for $2. It includes information about the company's crossovers, enclosures, loudspeakers, drivers, acoustic foam, cabinets, capacitors, coils and accessories. Two special features are a section on biamplification and a list of sources (such as *SB*) for answers to general questions on loudspeaker design. Product descriptions are detailed, and most include photos. Audio Concepts offers a graduated discount from $3 to $20 (on a prepaid order of at least $500) with a coupon enclosed in the catalog. Write to Audio Concepts, PO Box 212, LaCrosse, WI 54602.

Another catalog comes from **PEERLESS AUDIO MANUFACTURING**. It showcases the company's Precision Loudspeaker Systems (PLS) program, which includes four suggested systems. Each system contains some combination of PLS woofer, tweeter and midrange (15 are available), along with a crossover and all its required terminals, terminal housing and sealing gaskets. The catalog provides a description of each system, a price list of the individually packaged components and specifications for the various drivers. For a copy of the catalog, contact Peerless Audio Manufacturing, 40 Jytek Drive, Leominster, MA 01453.

A third brochure features Alphasonik™ and Visonik® car stereo products. Among the newer items included are the Alphasonik EX-2 crossover and the BRS-1 rack. Other products on display are the company's full line of power amps, loudspeakers and drivers, along with its preamp/equalizer and amp/equalizer. Specifications, photos and/or drawings accompany each product description. The brochure is available from **VISONIK OF AMERICA**, 701 Heinz Ave., Berkeley, CA 94710.

A comfortable, efficient workbench that adds the aesthetic appeal of solid hardwood to its qualities is well nigh irresistible to the speaker builder. Put the price at rock bottom ($144 for a 70-by-50-by-33-inch unit), and the appeal is overwhelming.

EUROBENCH offers several workbenches and bench accessories that are attractive in appearance and price. You will want to know about their line of products if you do any serious woodworking. Write to them at 800 Main Street, PO Box 220, Dept. SB1, Woodbury, TN 37190.

In an effort to reduce resonance problems in speaker cabinets, **CELESTION** has borrowed a product from the aeronautics industry—honeycombed aluminum sandwiched between two layers of the same material. According to Celestion, this totally inert material produces no resonant frequencies, which makes for a perfectly dead cabinet.

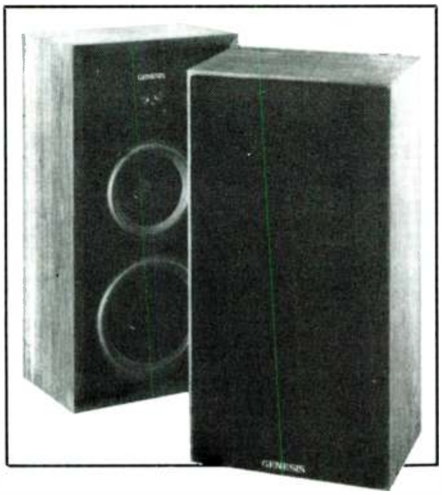
Celestion has combined this innovation with its laser-designed drivers in the SL600 loudspeaker, which measures 9 inches deep by about 14 inches high and 8 inches wide. For more details about the SL600, write to Celestion Industries, Kuniholm Drive, Box 521, Holliston, MA 01746.

As the newest addition to its Standard Series loudspeakers, **KEF ELECTRONICS** has introduced the Chorale III, a compact, two-way speaker of medium efficiency. The Chorale III's exceptionally small size makes it an ideal choice for bookshelf installations. The cabinet is finished in a durable simulated walnut veneer, while the speaker has a brown textile grille.

The Chorale III sells for $225 a pair and carries a five-year limited warranty. For details, write to KEF Electronics, 695 Oak Grove Ave., Menlo Park, CA 94025.

The Genesis 20 is an 8-inch, two-way speaker system with a 10-inch passive radiator. The vented enclosure design uses a Quasi third-order, low-frequency alignment and has a bass resonance of 34Hz. The 8-inch woofer uses a four-layer, high-temperature voice coil with a rubber impact bumper for durability under high-powered operation. The 1-inch inverted dome tweeter, which is individually response corrected, has a ferrofluid-damped suspension.

Overall frequency response is 34Hz to 20kHz, ±4dB, with a system sensitivity of 89dB at 1W per 1 meter. The speaker's walnut vinyl enclosure measures 27½ by 14 by 10½ inches.



Each speaker is packaged with its own frequency response performance graph on the carton and comes with a limited lifetime warranty. Suggested retail price starts at $200. For further information, contact **GENESIS PHYSICS CORPORATION**, Newington Park, Newington, NH 03801.

MENISCUS AUDIO SYSTEMS has announced a new product designed especially for the audiophile speaker builder, the Eclipse 1032 polypropylene woofer. Careful attention to nominal design parameters has resulted in a wide range of practical enclosure volumes suited to most alignments, including "transmission line" enclosures. Those wanting a vented box might find the enclosure size a bit large for this woofer, although a reduction in volume will yield a tolerable amount of ripple in response.

The cone body, manufactured of pure polypropylene, is coupled with a superior butyl rubber surround and controlled by an optimally matched fire-resistant spider. With the 2-inch, split-aluminum voice coil, the copper windings are set at 400°F, resulting in high thermal stability. The motor incorporates a 32-ounce barium ferrite magnet and the long-throw, two-layer voice coil.

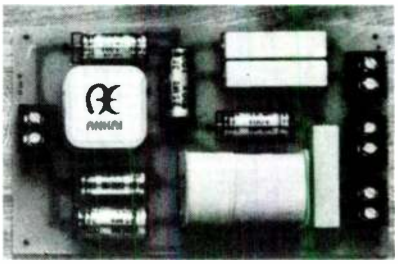
Manufactured with the amateur speaker builder in mind, the driver offers an excellent transient response and an impressive dynamic range. Single-quantity price is $31.95. For complete information on this and other Meniscus products, send $.25 and your name and address to Meniscus Audio Systems, Dept. SB-1, 3275 Gladiola, Wyoming, MI 49509.

In a new marketing twist, **ELECTRO-VOICE** is now offering plans for three of its computer-optimized vented enclosures and two of its horn enclosures. This allows builders who might want to attempt a more challenging project to obtain construction details about the cabinets.

Two of the three vented boxes complement two new low-frequency drivers intended for professional, high-quality sound reinforcement, playback and studio monitoring. The DL12X driver is suited to mid/bass applications in three or four-way systems or as a woofer in two-way systems requiring response to 70Hz and a small enclosure. The DL18X is designed for subwoofer use in three or four-way systems. Because of its large cone area, its high output is in the lowest octaves. The new units join the DL15X, which is appropriate for many fixed installations and concert sound applications.

The following plans for vented boxes are currently available: the TL806 (DL12X); the TL606 and TL606Q (DL15X); and the TL405 and TL505 (DL18X). Plans for two horn enclosures—the TL1225 mid/bass system (DL12X) and the TL4025 subwoofer (DL15X)—are also available.

For details, contact Electro-Voice, 600 Cecil St., Buchanan, MI 49107.



SPEAKER
BUILDER
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About This Issue

Having arduously studied his Thiele/Small theory, **Randy Parker** has come up with a four-enclosure system (p. 7) that is reasonably compact and incorporates an interesting pyramid shape as well. Those who are inspired by Parker's prototypes, but want a different approach might want to use Contributing Editor **Bob Bullock's** and programmer **Bob White's** Apple computer program (p. 13) for determining Thiele/Small alignments and box sizes. Those with other computers will no doubt be able to rewrite a few of the BASIC commands for Z-80-based and other machines.

If you need a resonance-free horn for a tweeter, you'll welcome **Scott S. Ellis'** article (p. 20) on casting with resins, which is a nice primer on the subject. Contributing Editor **G.R. Koonce** is back this time (p. 23) with a phase meter, an indispensable tool for the speaker builder.

This issue's "Tools, Tips, and Techniques" items come from **Scott Ellis, James Franc and Tom Clarke**, who write on converting iron-core chokes, large wire connectors and switched L-pads (p. 34). Details of **Paul Grandmont's** 12-foot, 23Hz transmission line system, using a full-sized lead template, are in "Craftsman's Corner" on page 35. Unfortunately, we have another break in our Carlberg odyssey, but we will run the concluding chapter as space allows.

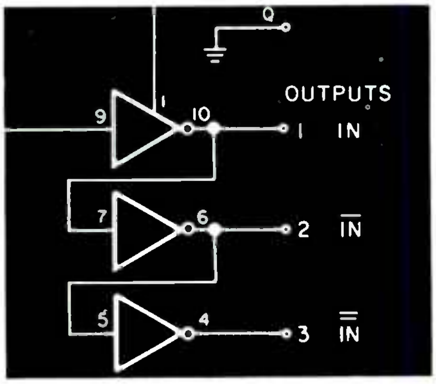
Next time, we will visit Buckinghamshire, England, and Ibiza Island off Spain's Mediterranean coast—all in the interest of the Jordan 50mm Module. Contributing Editor Bruce Edgar will interview E.J. "Ted" Jordan, while Harold Hirsch will build a pair of Jordan System 5s.

SPEAKER BUILDER

VOLUME 5 NUMBER 1 MARCH 1984

FEATURES

DEPARTMENTS



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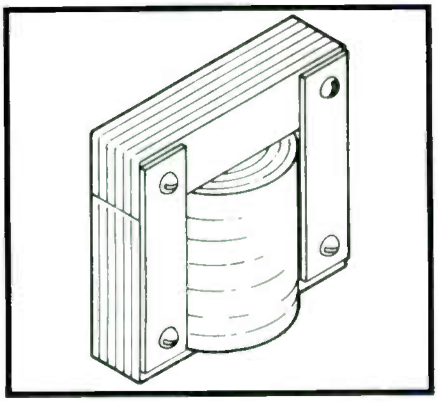

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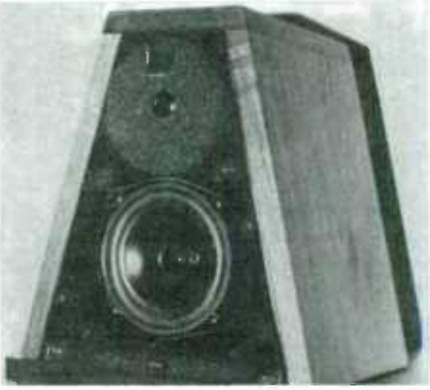

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Editorial

Fantasy and Technology

A recent article in *The New York Times Sunday Magazine* contends that a growing interest in a wide variety of fantasy and mysticism signals a pervasive disillusionment with technology. Author Kathleen Agena cites several examples—the 10-million copy sales of Frank Herbert's *Dune* novels, the 30-year sales figures for J.R.R. Tolkien's *Lord of the Rings* trilogy, the incredible success of George Lucas' films from *Star Wars* to *Return of the Jedi*, new fiction from Norman Mailer and John Irving, and numerous paintings, pieces of sculpture and musical works.

To those who say all this is mere escapism, Ms. Agena replies that she thinks it is far more than that. Supported by many sources, she argues that our common religious myths have all but disappeared, and no common belief system is evident in the West. Ms. Agena also sees a severe disillusionment with what she calls the expectations people have had of progress through technology and rationality.

These factors signify a return to mythology, as more and more people turn to mysticism in conventional religions and in the occult. This mode of thinking is dangerous, Ms. Agena says, because it is highly emotional and usually focused on a forceful, charismatic leader who uses some power from outside the visible world to achieve his ends. The end results of the mythologies of a Jimmy Jones or an Adolph Hitler are not, in the end, all that different.

Several weeks after reading this analysis, I read Anders Richardson's delightful article in *Fine Woodworking*, "A Blacksmith's Bleak View of Modern Tools." Richardson contends that 1905 is the watershed year for Americans who use hand tools. That was when drop forging was introduced by tool manufacturers as "...the improved, modern way to make hand-woodworking tools."

"It was modern, all right," he continues, "but far from an improvement." The advantage was, apparently, that the manufacturers could use alloy steel rather than "true, high-carbon tool steel." In addition, drop forging was faster, therefore cheaper. Tools made of high-carbon steel, Richardson says, "...outlive the men who made them and those who originally bought them."

Richardson goes on to tell you how to find an old saw blade, cut out a small strip of it, and by careful heating, cooling and tempering with a couple of gas torches, make a canoe knife that will outlast you and the lucky friend you leave it to in your will.

Modernity and technology have been sold as a means of human progress, but in many cases, technology's practical use is a series of small, incremental degradations of the products that are alleged to be "just as good as" before—but somehow are not.

The promises of technology have doubtless been oversold, and that is part of the disillusionment. But the deeper and more important root of our disappointment is the nearly universal use of engineering skill to cheapen the product. Watch out when they advertise the "new, improved" version of anything.

The reason why Anders Richardson and other craftsmen like him know better is their intimacy with the material about which they are talking. You must enter into hand-to-hand combat with Mother Nature to know the essential facts, and even then you can get fooled. She is a wily adversary, but a fair one: she plays strictly according to the rules, which are always rational, but not always logical. The only problem is that you must often find out what those rules are for yourself, and you can never be quite sure you know all of them.

Those who have made technology into some kind of mythological white knight who would cure society's ills and produce the good life for us all cannot have had a very close relationship with technology or with the physical world. The mythology of progress was and is, in my view, no more than a myth.

While technology is an unsatisfactory god, I contend that even as prostituted as it often is for reasons of greed and war mongering, it has given us a great deal that can be called the good life—and enormous improvement in our living conditions and longevity.

Technology is still underestimated as a source of deep human satisfaction. A great deal of genuine fear and apprehension is present in the population,

Continued on page 42

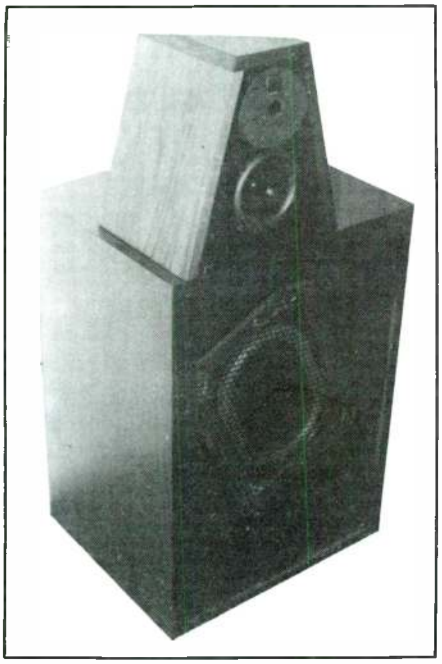
A THIELE-SMALL ALIGNED SATELLITE/WOOFER SYSTEM

BY RANDY PARKER

HAVING OWNED my handcrafted Webb transmission line speakers[1] for four years, I knew the KEF drivers (B139, B110, T27) were high-quality reproducers, but I wasn't totally satisfied with the low-end reach of the enclosure, especially considering the performance other designs were achieving with the B139. Therefore, I set about developing a speaker design that would give me better low-frequency performance and improve the performance in other areas of the system. To do this, I compiled a list of desirable design and construction techniques from the numerous contributions to *Audio Amateur, StereOpus, Speaker Builder* and other publications, and from input given by members of the Southeastern Michigan Woofer and Tweeter Marching Society (SMWTMS) audio construction club.

Then, using the Linkwitz three-cabinet system[2] as my primary model, I combined many of these ideas in a manner that suited my needs. This resulted in a four-cabinet, satellite/woofer design that includes optimized separate B139 bass enclosures for low-frequency performance, acoustically small satellite enclosures for the B110 midrange, and a T27 tweeter for improved dispersion and stereo imaging, improved crossover and greater room placement flexibility. My system does not have anything as sophisticated as the Linkwitz crossover/filter/delay network, but rather is a refinement of basic loudspeaker enclosure construction techniques.

WOOFER ENCLOSURE. For the bottom end, I had to decide between a larger transmission line system (Sanders' subwoofer described in *Speaker Builder*[3]) and a Thiele-Small aligned ported enclosure. Having made one transmission line system, I was not put off by construction complexity. The Thiele-Small alignments appealed to me because they offer smaller enclosure size and cost, less complex construction and more predictable results. Using David Weems' book *How to Design, Build, and Test Complete Speaker Systems*, 4th printing[4] (the first printing contains formula typographical errors), I designed the enclosures.



The measured design parameters for one of my B139's are as follows:

- free air resonance (f_s)—25.2Hz
- total Q (Q_T)—0.30;
- air volume equal to driver's mechanical compliance (V_{AS})—4.94ft³.

The formulas yielded an optimum enclosure volume (V_B) of 2.34 cubic feet, a 3dB down frequency (f_3) of 35.4Hz and a tuned enclosure resonance (f_B) of 31.3Hz.

Dave Clark of SMWTMS suggested I build the box with a larger net V_B of 3.4 cubic feet for deeper low-frequency response ($f_3 = 30.4$Hz) with relatively minor ripple (-1.01dB) and an f_B of 28.4Hz. I subsequently reduced the enclosure volume to 2.6 cubic feet by gluing sheets of ¾-inch-thick styrofoam insulation to the top and one side of the enclosure in place of fiberglass insulation, tuning f_B to 31Hz. (The styrofoam is intended to serve only as a volume reducer, not as damping material.) By cutting the styrofoam sheets to fit through the woofer opening and gluing them lightly, I made it easy to change the enclosure volume at a future date. For a more detailed explanation of these terms and relationships, see Robert Bullock's article in *SB*.[5]

I intentionally made the port longer than the Weems formula dimension. I tuned it by successively cutting the port and remeasuring the tuned response until I obtained the desired f_B. Even though the exact net internal dimensions are known (taking into account battens, braces, driver and port), the effect of the fiberglass sound insulation on apparent volume is difficult to predict. This is one reason why you cannot always calculate port dimensions exactly by formulas for a specific enclosure tuning frequency. My calculated f_B is not necessarily optimum, as I did not account for amplifier damping, hookup wire resistance and crossover resistance. I might recalculate optimum tuning in the future, since only f_B and/or enclosure volume require changes.

My next questions concerned what the box's physical dimensions should be and where I should locate the driver and port on the front baffle. Because I wanted the satellite enclosure to sit on top of the bass enclosure, the height of the enclosure needed to be tall enough to place the satellite at a seated listener's ear level. I chose external dimensions of 27 inches high, 16 inches deep and 19 inches wide. (See *Figs. 1* and *2.*) I based the relatively wide front baffle on Weems's recommendation that a wide front for a woofer enclosure will help form the bass wave and force it forward rather than allowing it to curl back around the box.

My choice of driver location on the baffle was based on Roy Allison's analysis of room boundary influence on loudspeaker power output and frequency response.[6] He says that certain ratios of distance to room boundaries will provide relatively smooth response curves in the mid-bass region. He recommends that the distance from the center of the woofer to the floor, and the distances around the two sides and top of the enclosure to the wall behind, should all be different. This provides bass reinforcement at a variety of frequencies for smoother response.

Because I also wanted the woofer close to the midrange driver for smooth transition between the two, I mounted the left woofer at the top right corner of the left channel enclosure and the right woofer at the top left corner of the right channel enclosure. This also produces mirror imaging. To further mix the distances from various locations on the driver to the enclosure boundaries, I also mounted the oval B139 at a 45-degree angle from vertical. This optimal mounting scheme provides smooth mid-bass in a variety of listening rooms as long as the enclosure is at least two feet from the side wall.

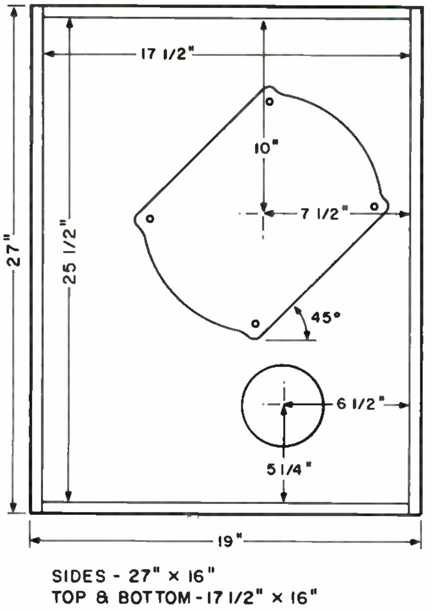


FIGURE 1: Front dimensions of the woofer enclosure. This shows the left enclosure driver placement; right driver placement is the mirror image.

I installed ports near the floor directly below the woofer. This improves boundary loading of port output, and one end of the diagonally mounted driver is still relatively close to the port for free breathing. The port itself is made of 4-inch (inside diameter) PVC sewer pipe, which is extremely rigid and easy to work. Sand the cut edges smooth and round them to minimize port air turbulence.[7] The tube is mounted to the baffle by press fitting it through a close tolerance hole and gluing it from the inside with silicone sealant by reaching through the woofer mounting hole. The silicone is cut easily with a razor blade to remove the port for re-tuning the enclosure.

The enclosure is constructed of ¾-inch, high-density particle board and glued with yellow (aliphatic resin) glue. It is screwed into ¾-inch-by-¾-inch oak battens at all joints with #8 1½-inch flat-head wood screws. I caulked the seams with white silicone sealant. I also braced the top, sides and back panels lengthwise with 5-inch-wide pieces of ¾-inch plywood (*Fig. 3*). Weems recommends lengthwise bracing, which divides the panels into two sections of minimum width. This raises the panel resonance to a higher frequency than that obtained with widthwise bracing and also increases structural rigidity. Tappan supports this experimentally and further suggests that "the brace should be placed slightly off center to cause the resonant frequencies of the two resulting panels to be slightly different."[8]

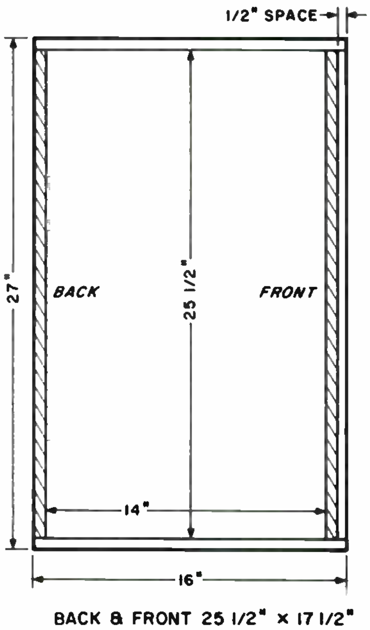


FIGURE 2: Side dimensions of the woofer enclosure.

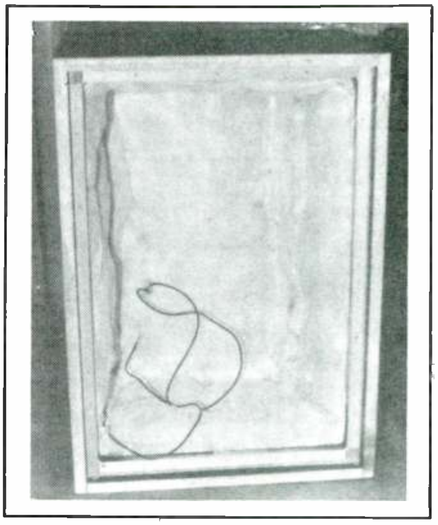


FIGURE 3: Woofer enclosure, without front panel. Fiberglass lining battened down with stapled cheesecloth prevents glass fibers from entering the driver gap.

The entire interior of the enclosure is coated with three coats of 3M Underseal, a rubberized car body

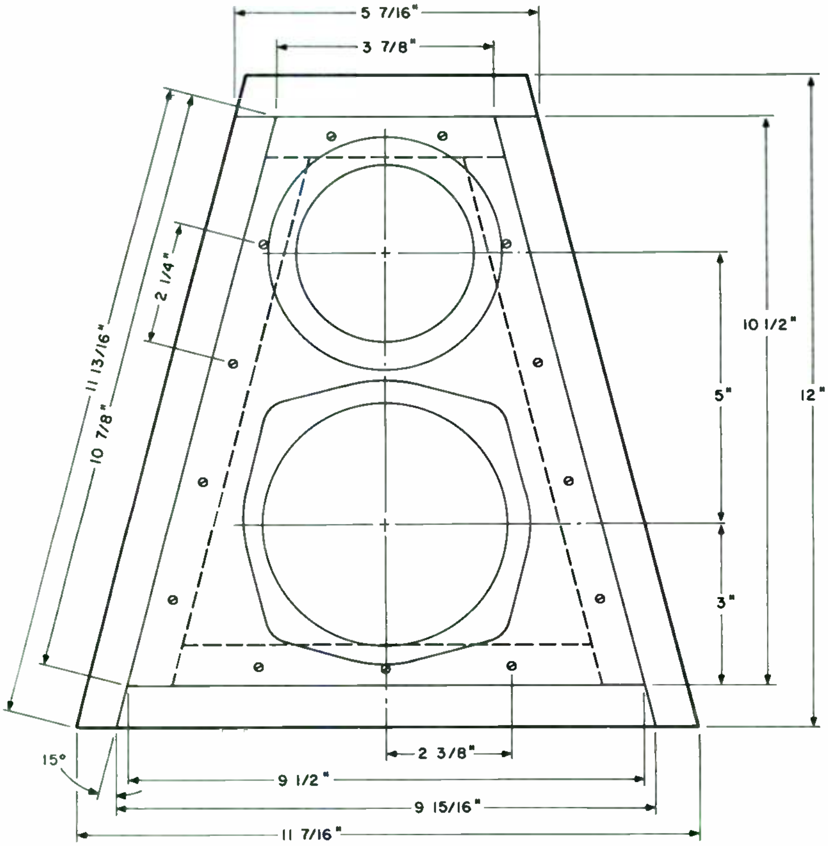


FIGURE 4: Front diagram and dimensions of the mid/tweeter enclosure.

undercoating (No. 08883), which supposedly is not as prone to affecting loudspeakers' rubber suspensions. The back, bottom and one side of the enclosure are lined with 1½ inches of fiberglass. I stapled the fiberglass to the enclosure and covered it with a single layer of cheesecloth to prevent stray fiberglass strands from winding up in the voice coil gap. I mounted gold-plated banana plug jacks in a recessed back panel and sealed them with silicone for connection to the outboard crossover. I covered the sides with walnut-grained formica and the tops with black-slate formica. The formica helps to damp these panels. I mounted the driver with rubber grommets on the screws to help isolate the basket from the baffle.

SATELLITES. The midrange and tweeter enclosures are small, with rounded corners and small external dimensions (especially width) to improve dispersion. I went a step farther to minimize cavity resonances by building the enclosure in the form of a truncated pyramid. I also prefer this shape aesthetically. The top and sides are solid ¾-inch, black walnut, finished with many coats of Tung oil. The front, back and bottom are ¾-inch, high-density particle board. Cutting the necessary angles was a challenge for my radial arm saw, especially considering the price of ¾-inch-thick solid walnut boards.

The internal construction is similar to the LS3/5A-type enclosure described by David Barnett in *Stere-Opus's* "Constructor's Corner."[9] The enclosure dimensions are 12 inches high, 11½ inches wide at the base and 9 inches deep (*Figs. 4* and *5*). I glued the enclosure and screwed it together using 1¼-inch flat-head wood screws. I screwed the walnut panels together through the battens from the inside so that no screw heads are visible. I predrilled all the screw holes in the solid walnut to avoid splitting it. (See *Fig. 6.*) I used ¾-inch battens at all joints, sealed with white silicone sealant, and applied several coats of Underseal to all internal surfaces, allowing it to dry thoroughly before installing the drivers. I lined five internal surfaces with 1-inch-thick polyurethane foam sheets and stuffed the cavity with well-teased, long-fiber wool.

Because I am using an outboard crossover in its own box, I made simple external connections to the back panel. I used a barrier terminal strip mounted on the back of the enclosure with holes drilled through the enclosure for the solder lugs. After I soldered the internal speaker leads to the lugs, I filled and covered the holes and back of the barrier strip with silicone sealant. I also installed a fuse holder on the back of the enclosure for a fuse in series with the tweeter. In case I decided to add the Celestion HF2000 super-tweeter left over from my Webbs, I used a six-terminal strip and left two unterminated wires connected to it inside the enclosure. So far, I have not needed it from a performance standpoint, but I would like to know if anyone has measured performance data that argues otherwise.

In accordance with the KEF instructions, I mounted the B110 and T27 in routed recesses and installed the B110 with soft rubber grommets on the mounting holes of the basket. I glued a ⅜-inch-thick felt "donut" to the entire tweeter mounting plate with a ⅞-inch cutout for the tweeter diaphragm (*Fig.*

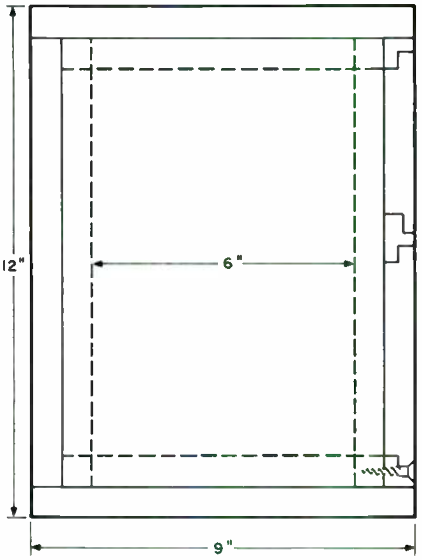


FIGURE 5: Side diagram and dimensions of the mid/tweeter enclosure.

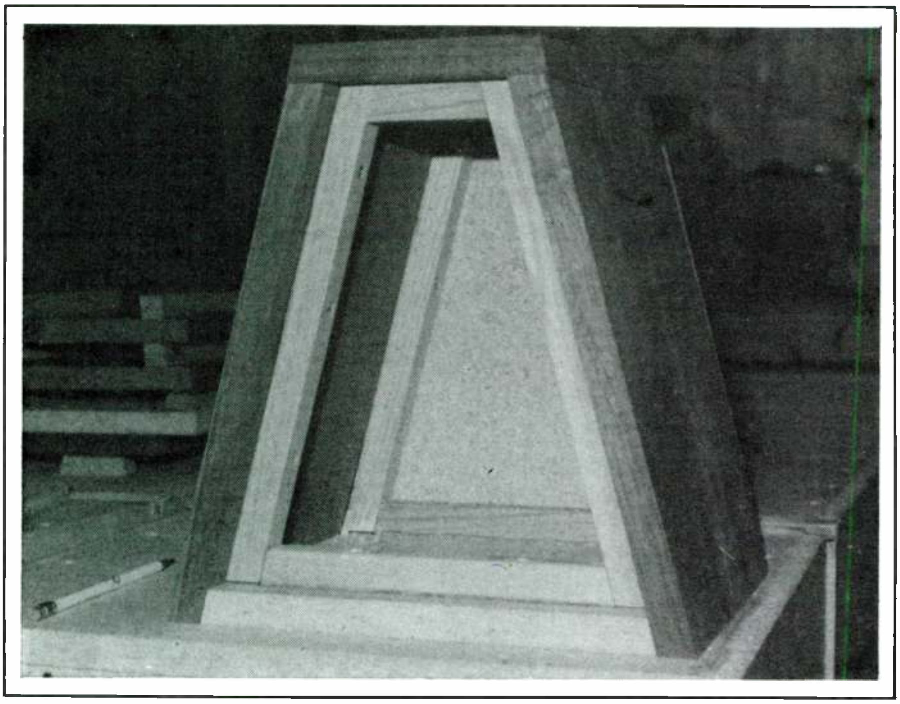


FIGURE 6: The mid/tweeter enclosure uses solid walnut hardwood and 1-inch-square battens.

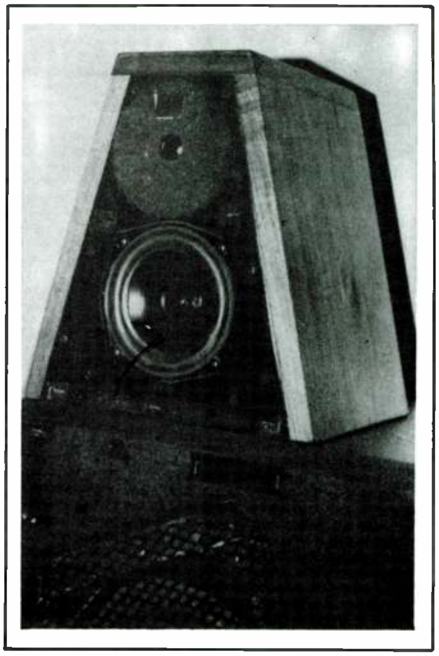


FIGURE 7: The smaller pyramidal enclosure, without the foam grille, sits atop the woofer. Note the thick felt anti-diffraction pad around the tweeter.

7). This significantly smooths the measured polar frequency response of the tweeter. The only sufficiently thick felt I could find locally was that used for snowmobile boot liners, which cost about $7 a pair. One pair of these large liners will cover eight tweeters.

CROSSOVER. The crossover frequencies are at 400Hz and 3,500Hz. I am not ready to take the plunge into biamping or triamping, so I stayed with the Webb passive crossover. After reading about the difficulty of building a crossover based on nominal component values and expecting it to perform as intended (not recognizing certain coils have "hidden" resistance or that Mylar capacitors might cause ringing where non-polarized electrolytics were intended[10]), I decided to order Badger Sound's Webb Super Power crossover.

I had used high-power, air-core inductors throughout my Webb system, with Mylar capacitors in the tweeter circuits. For this system, however, I decided to trust the engineering know-how represented in the Falcon network sold by Badger. That network uses iron-core inductors and non-polarized electrolytics. I assume the super-power version uses heavier gauge coil wire and provides a higher saturation power level and lower DC resistance. *StereOpus* reported that when comparing an iron-core choke in the Webb woofer circuit with an air core, inserting the air core subtly but audibly reduced the bass level. Apparently, this is because of the coil's resistance, so the iron core is a better choice.[11]

I improved the crossover by incorporating the additional components (also ordered from Badger) necessary to convert the T27 crossover to the KEF aB (acoustic Butterworth) network. This reportedly will remove edge and upper midrange coloration. I am also considering lowering the woofer crossover frequency from 400Hz to somewhere between 100 and 250Hz, but this would lower the power-handling capability of the system. Lowering the woofer crossover frequency might best be accomplished by biamping. I built each crossover into a small walnut box, which I placed on top of the woofer enclosure, and made all amplifier, woofer and satellite connections to the box. This design accommodates future crossover changes and gives maximum hookup flexibility.

PLACEMENT. Separating the woofer enclosure from the satellite enclosure permits optimizing the woofer for room loading and the mid/tweeter for directivity and dispersion. In practice, I place the satellites on top of the woofer enclosures directly over the B139s with the channels mirror imaged and the front edge of the satellite baffle flush with the front of the woofer baffle. The photo on page 7 shows the finished enclosures without the foam grilles. You can locate the woofer enclosures for best room response and the satellites for best stereo imaging.

I think positioning the satellites close to the woofers provides better stereo imaging with a 400Hz crossover frequency. A lower crossover frequency would make this less important. Also, the SMWTMS group conducted experiments in which the members were able to adjust the test setup for best time alignment within at least ±40 microseconds.[12] This corresponds to about ±½-inch forward or backward placement.

The satellite positioning flush with the front of the woofer baffle was confirmed by frequency response analysis with Dave Clark's White Model 140 ⅓-octave real-time analyzer. I believe the analyzer gave, with great precision, optimal driver positioning, as smooth frequency response was the criterion rather than "time aligning." The SMWTMS test indicated that varying time alignment disturbed frequency response, and the test subjects used frequency response when aligning the drivers' position. The analyzer confirmed good frequency response, but not necessarily time alignment.[13]

FINISHING TOUCHES. I mounted a black anodized decorative aluminum mesh grille over the woofers to protect them from my small daughter. The mesh is quite rigid and is mounted off the front baffle surface by several layers of adhesive foam strip to prevent the woofer cone from hitting it and damping the metal. I used flat black paint on all staples, screw heads, baffle boards and white PVC pipe. Custom Sound made the foam grilles, which feature beveled edges all around and are routed on the back to accommodate the felt around the tweeter and the metal grille over the woofer. To encourage vent air flow, I carved the back of the foam where it covers the port to ⅛-inch thickness.

I am very pleased with the results of this project. The midrange and treble response is smoother and more open, even without the super tweeter. The most striking improvement, however, is in the bass, where the response is deep and rock solid. I thought the reflex bass might not be as tight as the Webb transmission line, but it appears to be equally tight and has no mid-bass boom. It also appears to go deeper and is certainly tighter than the M&K "Cube" subwoofer I had used occasionally to supplement the Webbs.

The total project cost approximately $650. The drivers alone cost $386. I purchased the drivers in Detroit, but might have saved money by ordering from England. The best part of this project is having unique, high-performance loudspeakers that I can modify easily. The rest of my system includes a PAT-5-WJ-1A preamplifier, a modified Heath AA-1640 power amp (connected to the speakers with ten-gauge Saxton cable), a Delta-Graph octave equalizer, and a Phase Linear 1000 noise-reduction unit. Signal sources include a Thorens TD160 BC MKII turntable, a Grace 707 tonearm, a Shure V15 type IV cartridge, Teac 2300's tape deck and a Dynaco FM-5 tuner.

REFERENCES

1. Webb, B.J., "A Proven Transmission Line Loudspeaker," *The Audio Amateur* 1/75, pp. 3–9.

2. Linkwitz, Siegfried, "A Three-Enclosure Loudspeaker System with Active Delay and Crossover: Part I," *Speaker Builder* 2/80, pp. 12–18.

3. Sanders, Roger R., "An Electrostatic Speaker System: Part III," *Speaker Builder* 4/80, pp. 26–30.

4 Weems, David B., *How to Design, Build, and Test Complete Speaker Systems,* 1st edition, 4th printing (July 1980), Tab Books.

5. Bullock, Robert M. III, "Thiele, Small, and Vented Loudspeaker Design: Part I," *Speaker Builder* 4/80, pp. 7–13.

6. Allison, Roy, "The Speaker and the Listener," *Stereo Review*, August 1976 (Vol. 37, No. 2), pp. 56–61.

7. Bullock, op. cit., p. 13.

8. Tappan, Peter W., "Loudspeaker Enclosure Walls," presented October 10, 1961 at the 13th Annual Fall Convention of the AES.

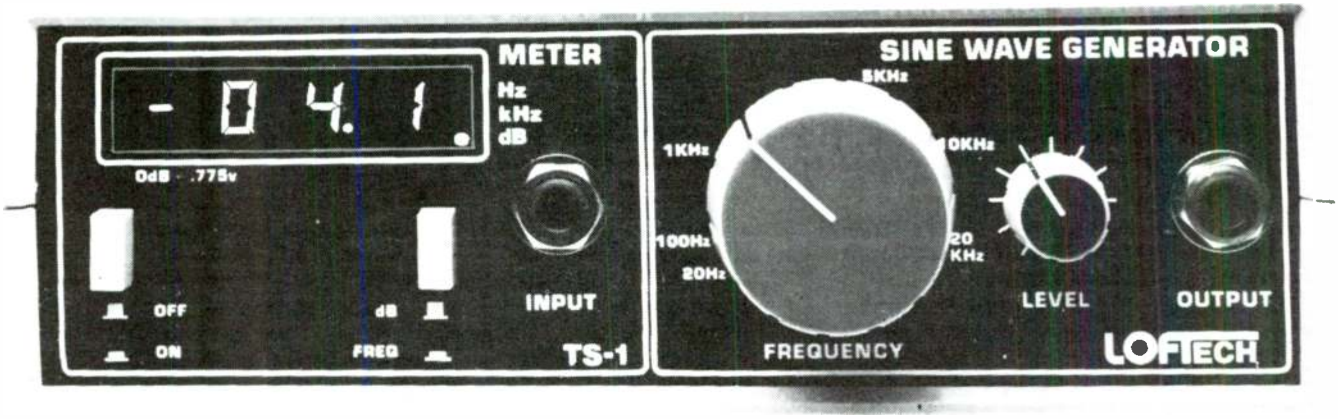
9. Barnett, David, "Constructor's Corner," *StereOpus* (Vol. 2, No. 5), pp. 40–42.

10. Hughes, Barry, "SB Mailbox," *Speaker Builder* 3/80, pp. 42-43.

11. Norton, Thomas J., "Constructor's Corner," *StereOpus* (Vol. 1, No. 4), p. 79.

12. Southeastern Michigan Woofer and Tweeter Marching Society, PO Box 1464, Berkley, MI 48072 (37th Meeting test results).

13. Greiner, R.A. and M. Allie, "Manipulating the Response of Multiway Loudspeaker Crossovers," presented at the 69th Convention of the AES, *Preprint No. 1761*.



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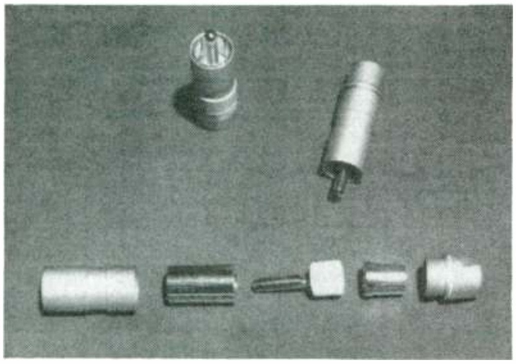

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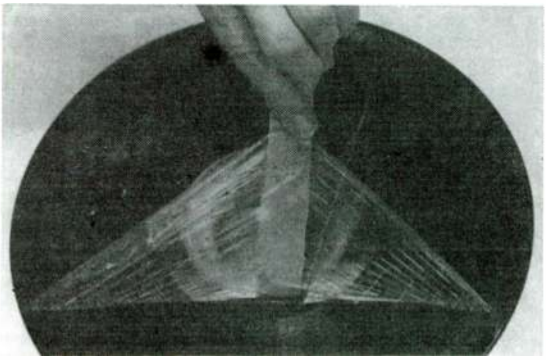

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BOXRESPONSE

AN APPLE PROGRAM FOR THE THIELE-SMALL MODELS

BY ROBERT M. BULLOCK and BOB WHITE

Editor's Note: Bob Bullock wrote this article, and Bob White is responsible for the final Apple BASIC version of the program presented here, as well as for the sample runs. Therefore, the "I" in the article is Bullock, and the "Bob" is White.

Computer programs based on the Thiele-Small models are an important part of our loudspeaker design and calibration work. In the design stage, the programs allow us to compare the performance of many projected systems without having to build any prototypes. They can also help us decide whether a given system needs further adjustment to obtain a targeted performance. I have written two programs, one for a minicomputer and one for a programmable calculator (*SB* 1/83, p. 15). The minicomputer program is more comprehensive because it provides data on power limitations and maximum as well as relative response. It also includes a vent design option and can handle filter-assisted alignments.

Bob uses a program that he adapted for the Apple from a BASIC code written by D.B. Keele[1] for design studies at JBL. It produces information in the same categories as my minicomputer program, but it is not written to handle filter-assisted systems.

BOXRESPONSE is the result of our collaborative efforts. It is essentially my minicomputer program with a few improvements. We decided against the Keele program mainly because it did not include equalized alignments, but also to avoid possible copyright problems. You should be able to modify it for use on any BASIC-programmable machine or to provide hard copy.

PROGRAM DESCRIPTION. BOXRESPONSE supplies model-based performance data for either closed or vented-box loudspeakers with or without the use of a first or second-order electrical high-pass filter as an active equalizer. The program requires driver, box and equalizer parameters, along with an order number to identify the system type. In all cases but one, the order number is the sum of the box order (closed = 2, vented = 4) and the equalizer order (0 = none, one and two). The excep-

```
1  HOME
2  PRINT " ************************************** ": VTAB 2
3  FOR I = 1 TO 18
4  PRINT " *"; SPC( 36);"* ";
5  NEXT : PRINT " ************************************** "
6  VTAB 5: HTAB 16: PRINT "BOXRESPONSE"
7  VTAB 9: HTAB 20: PRINT "BY"
8  VTAB 13: HTAB 10: PRINT "R. BULLOCK AND B. WHITE"
9  VTAB 17: HTAB 8: PRINT "FOR SPEAKERBUILDER MAGAZINE"
10  FOR PAUSE = 1 TO 5000: NEXT : HOME
11  PRINT "DO YOU WANT A PROGRAM SUMMARY (Y OR N)?"
12  INPUT Y$: IF Y$ = "N" THEN 30
13  PRINT "1. COMPUTES SMALL-SIGNAL"
14  PRINT "   RESPONSE (Y2).": PRINT
15  PRINT "2. MAXIMUM INFINITE BAFFLE"
16  PRINT "   RESPONSE OUTPUT (Y3).": PRINT
17  PRINT "3. MAXIMUM INPUT POWER (P1)"
18  PRINT "   AT SELECTED FREQUENCIES (F9)": PRINT
19  PRINT "    A. FOR CLOSED BOX (2)"
20  PRINT "    B. CLOSED BOX WITH 1ST."
21  PRINT "       ORDER EQUALIZATION (3)"
22  PRINT "    C. CLOSED BOX WITH 2ND."
23  PRINT "       ORDER EQUALIZATION (3.5)"
24  PRINT "    D. VENTED BOX (4)"
25  PRINT "    E. VENTED BOX WITH 1ST."
26  PRINT "       ORDER EQUALIZATION (5)"
27  PRINT "    F. VENTED BOX WITH 2ND."
28  PRINT "       ORDER EQUALIZATION (6)"
29  PRINT "TO CONTINUE PRESS ANY KEY": GET C$: HOME
30  INPUT "ENTER THE RESONANT FREQ. OF DRIVER (FS) ";F: PRINT
31  INPUT "ENTER ELECTRICAL Q OF DRIVER (QES)       ";Q1: PRINT
32  INPUT "ENTER MECHANICAL Q OF DRIVER (QMS)       ";Q2: PRINT
33  INPUT "ENTER THE EQUIV. VOLUME IN CU.FT.(VAS)   ";V: PRINT
34  INPUT "ENTER THE DRIVER D.C. RESISTANCE (RE)    ";R: PRINT
35  HOME : PRINT
36  INPUT "ENTER DRIVER POWER RATING IN WATTS (W)   ";P: PRINT
37  REM  DRIVER PEAK EXCURSION IN ONE DIRECTION ONLY
38  INPUT "ENTER PEAK EXCURSION IN INCHES (X MAX)   ";R1: PRINT
39  INPUT "ENTER DRIVER PISTON DIAMETER IN INCHES   ";R2: PRINT
40  REM  TOTAL DRIVER Q (QTS)
```

continued...

tion is a closed box with a second-order equalizer, which would have a natural order of 4. I used order number 3.5 to identify this configuration to distinguish it from a vented box with no equalizer.

The main output of the program is a table, each row of which contains performance data at one of the sample frequencies in the data statement in line 550. The data supplied here is for a woofer system, but the program can accommodate any frequency range and any number of samples by obvious modification of lines 350 and 550.

The second column contains the relative system response in decibels. In other words, if the second versus the first column is plotted, the result is the frequency response of the system under linear operating conditions. This data tells you how flat the response is and allows you to determine the system cutoff frequency. For fourth or sixth-order vented boxes, you will obtain the flattest response for a given driver by using the box/equalizer parameters tabulated in *SB* (4/80, p. 7; 2/81, p. 18; 3/81, p. 18; 1/82, p. 20).

The third column lists the maximum input power the system can handle at the sample frequency. Its value depends on two factors. First, the driver voice coil is able to absorb only so much power without burning up, so the input signal must be maintained at or below a thermal limit, which is usually the advertised power rating of the driver. Second, the maximum driver cone displacement must be limited because of driver geometry and the system's need to behave linearly. The linear operating range of a driver can be easily exceeded at low frequencies by input powers well within the thermal limit. Thus, column three lists the minimum thermal and displacement limited powers at the sample frequency.

If the entry in column three is equal to the driver power rating, then the system is thermally limited. Otherwise, it is displacement limited. The practical consequences of the latter condition are not easy to decide. For example, just because a system with a 100W driver thermal limit is displacement limited to 40W at 30Hz, that does not necessarily mean that

```
41  REM  IS CALCULATED AND
42  REM  DENOTED BY Q.
60 Q = Q1 * Q2 / (Q1 + Q2)
61  REM  DRIVER VOLTAGE RATING E
62  REM  IS CALCULATED FROM P
70 E =  SQR (P * R)
71  REM  K IS THE CONSTANT MULTIPLIER
72  REM  FOR THE VOLTAGE-IN INFINITE
73  REM  BAFFLE PRESSURE-OUT FUNCTION
80 K =  SQR (V * F ^ 3 / Q1 / R) / 753
81  REM  K1 IS THE CONSTANT MULTIPLIER
82  REM  FOR THE VOLTAGE-IN CONE
83  REM  DISPLACEMENT-OUT TRANSFER FUNCTION
90 K1 = .3535 *  SQR (V / F / Q1 / R) / R2 ^ 2
91  REM   FOR ORDER "O" SYSTEM IS
92  REM          2    CLOSED BOX
93  REM          3    CLOSED BOX+1ST ORD EQ.
94  REM         3.5   CLOSED BOX+2ND ORD EQ.
95  REM          4    VENTED BOX
96  REM          5    VENTED BOX+1ST ORD EQ.
97  REM          6    VENTED BOX+2ND ORD EQ.
100  HOME : HTAB 12: VTAB 10: INVERSE : PRINT "SYSTEM ORDER ?":
NORMAL
110  INPUT O: IF O < 2 OR O > 6 THEN 100
111  REM  BOX PARAMETERS ARE NOW
112  REM  ENTERED. FOR CLOSED BOX
113  REM  ENTER COMPLIANCE-BOX VOL.
114  REM  RATIO ALPHA (A). FOR VENTED BOX
115  REM  ENTER BOX LOSS QL (Q7),BOX
116  REM  TUNING RATIO (H) AND ALPHA (A)
117  REM  CONDITIONAL TEST FOR CLOSED BOX
120  IF O = 2 OR O = 3 OR O = 3.5 THEN 160: HOME
130  INPUT "ENTER BOX LEAKAGE LOSS QL (Q7)             ";Q7: PRINT
131  IF Q7 < 3 THEN  PRINT "MODEL IS INVALID FOR QL<3": GOTO 130
133  INPUT "ENTER BOX TUNING RATIO (H)                ";H: PRINT
135  INPUT "ENTER COMPLIANCE-BOX VOLUME RATIO(ALPHA)";A: PRINT
150  GOTO 190
160  INPUT "ENTER COMPLIANCE-BOX VOLUME RATIO(ALPHA)";A: PRINT
172  REM  IN STEP 180 VALUES FOR H
173  REM  AND Q7 ARE ENTERED WHICH
174  REM  FOOL THE PROGRAM INTO
176  REM  BELIEVING THAT THE CLOSED
177  REM  BOX IS ACTUALLY A VENTED BOX
178  REM  (H NEAR 0,Q7 NEAR INFINITE)
180 H = .0001:Q7 = 10000
181  REM  COEFFICIENTS A1,A2,A3 AND
182  REM  NORMALIZING FACTOR F1 FOR
183  REM  THE NORMALIZED BOX RESPONSE
184  REM  FUNCTION Y ARE DEFINED
190 H2 =  SQR (H)
200 A1 = H2 / Q7 + 1 / Q / H2
210 A2 = 1 / Q / Q7 + (A + 1 + H ^ 2) / H
220 A3 = H2 / Q + 1 / Q7 / H2
230 F1 = H2 * F
231  REM  UNEQUALIZED BOXES SKIP
232  REM  TO OUTUT CALCULATIONS
240  IF O = 2 OR O = 4 THEN 330
241  REM  EQUALIZER PARAMETERS
242  REM  ARE INPUT. FE IS EQUALIZER
243  REM  FREQUENCY. FE/FS IS INPUT
244  REM  FOR 1ST. ORDER EQUALIZER.
246  REM  FE/FS AND RECIPROCAL OF
247  REM  EQUALIZER "Q" (D) ARE INPUT
248  REM  FOR 2ND. ORDER EQUALIZER.
250  IF O = 3 OR O = 5 THEN 290
260  INPUT "ENTER EQ.FREQ.-DRIVER FS RATIO FE/FS     ";H3: PRINT
270  INPUT "ENTER EQUALIZER DAMPING COEFFICIENT       ";D: PRINT
280  GOTO 320
290  INPUT "ENTER EQ.FREQ.-DRIVER FS RATIO FE/FS     ";H3: PRINT
301  REM  VALUES OF FE/FS AND D
302  REM  ARE CALCULATED WHICH FOOL
303  REM  THE PROGRAM INTO BELIEVING
304  REM  THE 1ST. ORDER EQ. IS OF 2ND. ORDER
310 H3 = H3 / 10000:D = 10000
311  REM  F2 IS AN EQUALIZER FREQ.
312  REM  NORMALIZING FACTOR
320 F2 = H3 * F
```

```
321  REM  FINAL CALCULATIONS COMMENCE
325 Y5 = 0
330  PRINT "                     MAXIMUM   MAXIMUM  "
331  PRINT "                      POWER    INFINITE "
332  PRINT "           RELATIVE   INPUT     BAFFLE  "
333  PRINT "  FREQ.    RESPONSE    IN      RESPONSE "
334  PRINT "  IN HZ     IN (DB)   WATTS    IN (DB)  "
335  PRINT "  -----    --------   -------  -------- "
336  REM  F9 IS CURRENT FREQ.
337  REM  AT WHICH Y2,Y3 & P1
338  REM  ARE CALCULATED (PROGRAM OUTPUT)
340  READ F9
350  IF F9 > 200 THEN 560
351  REM  X IS NORMALIZED BOX FREQ.
360 X = F9 / F1
370  IF O = 2 OR O = 4 THEN 390
371  REM  X1 IS NORMALIZED EQ. FREQ.
380 X1 = F9 / F2
381  REM  Y IS THE SMALL-SIGNAL
382  REM  BOX ONLY PRESSURE
383  REM  TO VOLTAGE RATIO
390 Y = X ^ 4 /  SQR ((X ^ 4 - A2 * X ^ 2 + 1) ^ 2 + (A1 * X ^ 3
 - A3 * X) ^ 2)
400  IF O = 2 OR O = 4 THEN 420
401  REM  THIS SECOND Y IS THE
402  REM  BOX + EQ PRESSURE TO
403  REM  VOLTAGE RATIO
410 Y = Y * X1 ^ 2 /  SQR ((X1 ^ 2 - 1) ^ 2 + (D * X1) ^ 2)
411  REM  Y1 IS THE DRIVER CONE
413  REM  DISPLACEMENT TO VOLTAGE
414  REM  RATIO
420 Y1 = Y *  SQR ((X ^ 2 / H - 1) ^ 2 + (X / Q7) ^ 2 / H) / X ^
 4
421  REM  E1 IS THE MAXIMUM
422  REM  DISPLACEMENT LIMITED
423  REM  INPUT VOLTAGE
430 E1 = R1 / K1 / Y1 / 39.37
431  REM  LINES 440-450 DECIDE
432  REM  WHETHER SYSTEM IS
433  REM  DISPLACEMENT OR
434  REM  THERMALLY LIMITED
436  REM  AT FREQUENCY F9
440  IF E1 < E THEN E2 = E1
450  IF E <  = E1 THEN E2 = E
451  REM  Y2 IS THE SMALL-SIGNAL
452  REM  RESPONSE IN DB AT F9
453  REM  RELATIVE TO THE HIGH
454  REM  FREQ. REFERENCE LEVEL
460 Y2 = 20 *  LOG (Y) /  LOG (10)
461  REM  Y3 IS THE MAXIMUM LINEAR
462  REM  RESPONSE SPL IN DB AT
463  REM  1 METER AT FREQ. F9
464  REM  ASSUMING LOUDSPEAKER IS A
466  REM  PISTON IN AN INFINITE
467  REM  BAFFLE. DB IS REFERRED
468  REM  TO A THRESHOLD OF 2X10E-5
470 Y3 = 20 *  LOG (K * Y * E2 * 50000) /  LOG (10)
471  REM  P1 IS THE LINEARITY LIMITED
472  REM  INPUT POWER AT FREQ. F9
480 P1 = E2 ^ 2 / R
481  DEF  FN R(X) =  INT (X * 100 + .5) / 100
482 Y2R =  FN R(Y2)
483 Y3R =  FN R(Y3)
484 P1R =  FN R(P1)
490  PRINT  TAB( 4);F9; TAB( 12);Y2R; TAB( 23);P1R; TAB( 33);Y3R
500  IF O = 2 OR O = 3 OR O = 3.5 THEN 540
501  REM  Y4 IS VENT VOLUME
502  REM  VELOCITY AT F9
510 Y4 = K * H2 * E2 * Y / F / X ^ 3
511  REM  THE MAXIMUM VALUE OF
512  REM  Y4 UP TO CURRENT
513  REM  FREQUENCY IS KEPT AS Y5
520 :
530  IF Y5 < Y4 THEN Y5 = Y4
540  GOTO 340
550  DATA  5,10,15,20,25,30,35,40,50,60,80,100,150,200,210
560  RESTORE
```

continued...

the overall input power must be limited to 40W. This depends on the program source. If it contains only a few instances of 30Hz information above the 40W level and they are of short duration, then the nonlinear distortion caused by a higher overall drive level might be quite acceptable. On the other hand, if the program contains substantial 30Hz content, then it becomes important to observe the 40W limit.

The effect of exceeding a displacement limited input power is often evident in unequalized vented boxes. They are all displacement limited to a few watts at very low frequencies, which is exactly the range in which problems such as turntable rumble can produce "garbage" information at more than a few watts. The result is an apparent random cone displacement, which causes the audible bass content to be muddy. This is why I strongly recommend rumble filters.

The last column of the table indicates how loud the system can play at the sample frequency. More precisely, it is the sound pressure level (SPL) at 1 meter relative to 2×10^{-5} N/m^2 with the input power at the level in column three. The program calculates this assuming that the system is a piston in an infinite baffle radiating into half space. You might think that you should include a reverberant component, but I have found that the number calculated here is usually within one or two decibels of what would actually be measured at a normal listening distance from a stereo pair in a typical home listening environment.

For vented-box systems, the program includes an option for calculating vent air speeds and lengths for circular vent tubes. You supply the vent tube diameter in inches, and the program produces the vent length in inches and the maximum vent air speed as a fraction of the speed of sound (i.e., a Mach number). Bob and I have found that the vent length formula can be as much as 15 percent off, so we suggest you use it only as a rough guide. When fabricating a vent, cut it an inch or two longer than the computed length and tune it by measuring the system box-vent resonant frequency, trimming the tube as necessary.

As the program constructs the four-column table, it calculates the vent volume velocity at the input power in column three. It records the largest velocity found over all the sample frequencies and uses it to compute the vent air speed Mach number. Not everyone agrees about what the upper limit on this number should be to ensure a noiseless vent. Recommendations vary from 0.10 down to 0.02. I think you should shoot for something less than 0.05, although I have designed marginally acceptable vents with Mach numbers as high as 0.15.

```
570  INPUT "NEW BOX OR EQUALIZER (1=YES,0=NO)";O1: HOME
580 :
590  IF O1 = 1 THEN 100
600  INPUT "NEW DRIVER (1=YES,0=NO)";O2
610 :
620  IF O2 = 1 THEN 30
621  REM  PROGRAM ENDS FOR
622  REM  CLOSED BOXES
630  IF O = 2 OR O = 3 OR O = 3.5 THEN  END
631  REM  VENT OPTION STARTS
640  HOME : HTAB 8: VTAB 19: INVERSE : PRINT "VENT DESIGN (1=YES
,0=NO)": NORMAL : INPUT O3
650 :
660  IF O3 = 0 THEN  END
661  REM  VENT INSIDE DIAMETER
662  REM  IS INPUT IN INCHES
670  INPUT "ENTER VENT DIAMETER (INCHES)";D9
680  PRINT
681  REM  VENT WIND SPEED MACH
682  REM  NUMBER IS COMPUTED
690 M9 = 4.85 * Y5 / D9 ^ 2
691  REM  VENT LENGTH IS COMPUTED
700 L = 2124 * A * D9 ^ 2 / V / (H * F) ^ 2 - .732 * D9
701  DEF  FN Z(X) =  INT (X * 10000 + .5) / 10000
702 LR =  FN R(L)
703 M9R =  FN Z(M9)
704 Z =  SGN (LR)
705  IF Z =  - 1 THEN  PRINT "DIAMETER TOO SMALL,NEGATIVE PORT L
ENGTH": PRINT : GOTO 670
710  PRINT "VENT AIR SPEED MACH NO.          ";M9R
715  PRINT : PRINT : PRINT
720  PRINT "VENT TUBE LENGTH IN INCHES       ";LR
721  REM  WILL LOOP BACK FOR
722  REM  ANOTHER VENT DIAMETER
723  PRINT : PRINT : PRINT
730  INPUT "ANOTHER DIAMETER VENT (1=YES,0=NO) ";O4
740  PRINT
750  IF O4 = 1 THEN 670
760  END
```

PROGRAM INPUT. You must supply the program with driver, box and equalizer parameters. The required driver parameters are resonant frequency (f_S) in hertz; electrical and mechanical Q's (Q_{ES} and Q_{MS}); volume equivalent compliance (V_{AS}) in cubic feet; voice coil DC resistance (R_E); driver piston diameter in inches; maximum linear displacement limit in inches; and rated input power in watts. For preliminary design work where only total system Q (Q_{TS}) is known, you can safely set Q_{MS} equal to 3 and Q_{ES} equal to $Q_{TS}Q_{MS}/(Q_{MS}-Q_{TS})$. Once you have the drivers in hand, however, use the measured values.

The driver piston diameter is equal to the cone diameter plus two-thirds of the surround width.[2] Determination of the maximum linear displacement limit is discussed in an *AES Preprint* by M.R. Gander.[3] Three to six millimeters seems to be the rule for long-throw drivers of 5 inches or more nominal diameter.

The necessary box parameters are $\alpha = V_{AS}/V_B$ for a closed box or α, $h = f_B/f_S$ and Q_L for a vented box, where V_B is the net box volume in cubic feet, f_B is the box-vent resonant frequency and Q_L is the vented-box leakage loss. You can use a Q_L of 7 for preliminary design work, but should measure it for an actual system.

You can find the first-order equalizer by specifying the frequency (f_E) at which its response is to be -3dB. The program will ask you to supply f_E/f_S rather than f_E.

A second-order equalizer requires two numbers for its specification. The first is f_E, and the second is a dimensionless positive constant (D) so that the filter output at f_E is 1/D (i.e., its level is 20log(1/D) relative to the high-frequency reference). You must supply the program with f_E/f_S and D.

The most popular second-order filter is the Butterworth, which corresponds to a value of $D = \sqrt{2}$. As you can check, its level is -3dB at the chosen f_E. Any second-order, high-pass filter with a D smaller than $\sqrt{2}$ will have an output greater than the Butterworth at all frequencies well above f_E (i.e., in the filter passband). The output will eventually drop off and approach that of the Butterworth at high frequencies. The result is a response curve with a peak of $10\log(4/(4D^2-D^4))$dB at the following frequency (f_P):

$$f_P = \sqrt{2/(2-D^2)} \times f_E.$$

On the other hand, if D is larger than $\sqrt{2}$, the output will droop below that of the Butterworth at all frequencies in the passband. The three possibilities are shown graphically in *Fig. 1.* Receiver or preamp rumble filters are often first or second-order Butterworths.

The function of a rumble filter is to decrease the low-frequency power demands on a system, but equalizers also serve other purposes. For example, the class I, sixth-order alignments in *SB* 1/82 (pp. 20-24) allow a lower cutoff frequency than would be possible with the box alone, while still retaining a flat response. With this program, you can create your own equalized alignments, experimenting with different combinations of box and equalizer parameters. The second-order filter is best for this purpose.

I use Old Colony's 30Hz Garbage Filter Kit (KF-6) to build my equalizers, since it contains all the necessary parts except for a couple of resistors and a ±15V power supply. You can find complete wiring instructions and design formulas for second-order filters based on the kit in *SB* 1/82 (p. 24). This article uses f_A for f_E and A for D. Bob tells me that Speakerlab

(735 N. Northlake Way, Seattle, WA 98103) also sells an etched board and op amps for a first or second-order filter.

THE PROGRAM. As you can see from the listing, the program is liberally sprinkled with remark statements, which you can omit without affecting execution. They do, however, explain step-by-step what the program does. You can also change or eliminate any formatting instructions as long as you enter all the necessary system parameters. Be extremely careful about altering or deleting any statement with a number ending in zero: most of them are crucial computation or branching instructions. I have included several sample runs, which you can use for debugging. If you would rather not type in the program, the editor has indicated that Old Colony might be willing to offer the program on a floppy disk. Let them know if you are interested.

This program is valuable in design work, especially for preliminary studies involving decisions such as driver selection, box size and whether to equalize. Even after the system is constructed, you can use the program to decide whether you are within acceptable tolerance limits of your targeted design. This can greatly reduce the amount of fine tuning needed, as you might achieve an acceptable response even if the system parameters are not exactly on the mark.

The program can also help you develop a feeling for the potentialities and limitations of closed and vented boxes, how equalization affects performance, how parameter changes of various kinds alter behavior, and so on. Play around with different parameter combinations and observe the consequences. It can be as much fun as a computer game.

SAMPLE RUNS. I have included five sample runs of the program to familiarize you with its features. The first two runs are for closed boxes using the advertising specs of a Peerless TX-205F 8-inch polypropylene woofer. The remaining runs are for vented boxes using a Dalesford 12-inch, Bextrene-cone woofer. I took these parameters from my system, which can be converted to any of the three alignments by vent or equalizer changes.

Run 1. The alignment is a second-order Butterworth, which requires an α of 2.125 and has a -3dB frequency of 74.2Hz. Notice that this system is thermally limited at all frequencies, but does not reach the maximum reference SPL level of 106.7 until well above 100Hz. On the other hand, its roll-off is very slow, and it is still putting out a respectable 95.6dB at 40Hz.

Run 2. Using the driver from Run 1 with a second-order equalizer gives a lower -3dB point of 56.8Hz, although a much larger box is required. I leave it to you to decide whether system 1 or 2 is better. By the way, this second alignment is a fourth-order Butterworth.

Run 3. The alignment is a standard fourth-order quasi-Butterworth as listed in *SB* 3/81 (p. 21, *Table X*) for a Q_{TS} of 0.34, but with an oversized

```
ENTER THE RESONANT FREQ. OF DRIVER (FS) 42

ENTER ELECTRICAL Q OF DRIVER (QES)      .47

ENTER MECHANICAL Q OF DRIVER (QMS)      2.7

ENTER THE EQUIV. VOLUME IN CU.FT.(VAS)  1.7

ENTER THE DRIVER D.C. RESISTANCE (RE)   6


ENTER DRIVER POWER RATING IN WATTS (W)  40

ENTER PEAK EXCURSION IN INCHES (X MAX)  .25

ENTER DRIVER PISTON DIAMETER IN INCHES  7

              SYSTEM ORDER ?
?2
ENTER COMPLIANCE-BOX VOLUME RATIO(ALPHA)2.125

                         MAXIMUM    MAXIMUM
                          POWER     INFINITE
             RELATIVE     INPUT      BAFFLE
   FREQ.     RESPONSE      IN       RESPONSE
   IN HZ      IN (DB)     WATTS      IN (DB)
   -----     --------    -------    --------
    5         -46.87      40         59.88
    10        -34.83      40         71.92
    15        -27.79      40         78.96
    20        -22.81      40         83.94
    25        -18.96      40         87.78
    30        -15.85      40         90.89
    35        -13.27      40         93.47
    40        -11.09      40         95.65
    50        -7.68       40         99.07
    60        -5.24       40         101.51
    80        -2.4        40         104.34
    100       -1.15       40         105.6
    150       -.25        40         106.5
    200       -.08        40         106.67
```

SAMPLE RUN 1: Peerless 8-inch TX-205F, closed box.

```
ENTER THE RESONANT FREQ. OF DRIVER (FS) 42

ENTER ELECTRICAL Q OF DRIVER (QES)      .47

ENTER MECHANICAL Q OF DRIVER (QMS)      2.7

ENTER THE EQUIV. VOLUME IN CU.FT.(VAS)  1.7

ENTER THE DRIVER D.C. RESISTANCE (RE)   6


ENTER DRIVER POWER RATING IN WATTS (W)  40

ENTER PEAK EXCURSION IN INCHES (X MAX)  .25

ENTER DRIVER PISTON DIAMETER IN INCHES  7

              SYSTEM ORDER ?
?3.5
ENTER COMPLIANCE-BOX VOLUME RATIO(ALPHA).83058

ENTER EQ.FREQ.-DRIVER FS RATIO FE/FS    1.353

ENTER EQUALIZER DAMPING COEFFICIENT     .765

                         MAXIMUM    MAXIMUM
                          POWER     INFINITE
             RELATIVE     INPUT      BAFFLE
   FREQ.     RESPONSE      IN       RESPONSE
   IN HZ      IN (DB)     WATTS      IN (DB)
   -----     --------    -------    --------
    5         -84.45      40         22.3
    10        -60.36      40         46.38
    15        -46.27      40         60.47
    20        -36.28      40         70.47
    25        -28.53      40         78.21
    30        -22.21      40         84.53
    35        -16.92      40         89.82
    40        -12.44      40         94.3
    50        -5.77       40         100.98
    60        -2.16       40         104.59
    80        -.26        40         106.48
    100       -.04        40         106.7
    150       0           40         106.75
    200       0           40         106.75
```

SAMPLE RUN 2: Peerless 8-inch TX-205F, closed box, second-order equalizer.

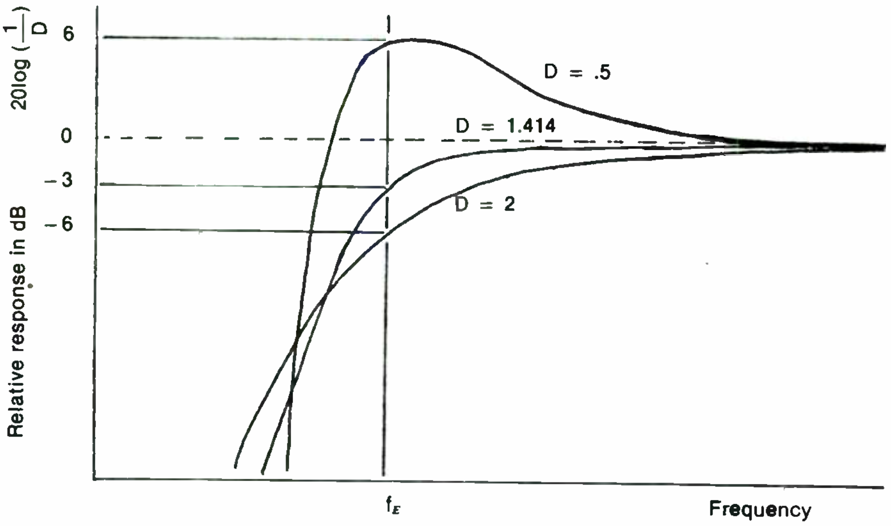

FIGURE 1: Second-order, high-pass filter response.

box. The first thing to notice is its poor power-handling ability at low frequencies, which is typical of unequalized vented boxes and is the reason a rumble filter is usually recommended. It is also worth pointing out that the relative response is ripple free, with a cutoff frequency slightly lower than the exact table alignments would have given. As you can see, you can obtain good performance without adhering strictly to tabulated alignments. The vent option indicates that a 4.24-inch vent diameter is satisfactory. Use two 3-inch tubes to get this diameter.

If you rerun this system with a second-order rumble filter defined by $f_E = 20$Hz, $D = \sqrt{2}$ (order = 6), you will find that the smallest input power is 56W at 15Hz, but it could probably be run safely at 100W in. The only penalty is a slight increase in f_3.

Run 4. This sixth-order, class I Chebyshev alignment is nominally based on *Table 3* in *SB* 1/82 (p. 21) for a Q_{TS} of 0.34, but with a larger box. This, together with errors in the equalizer parameters, results in a slight response peak at 25Hz, followed by a dip at 50Hz. These are too slight to be audible, though, and the alignment is quite satisfactory in spite of its deviation from parameter values.

If enough readers express an interest in the Bullock-White program, Old Colony will offer the program on a floppy disk. Estimated cost is $7. If you would be interested in purchasing the program, send a postcard to Old Colony, PO Box 243, Peterborough, NH 03458. Do *not* send payment. The disk will be available only if readers indicate sufficient interest.

The abrupt drop in infinite baffle output at 30Hz is not due to the ripple in the relative response, but to the fact that the system is displacement limited to 46W at 30Hz. Even if this system were limited overall to its minimum input power of 8.75W at 15Hz, it could still produce about 100dB at all frequencies above 20Hz.

Run 5. This is a sixth-order, class II quasi-Butterworth from *Tables 10* and *11* in *SB* 1/82 (p. 23) with a Q_{TS} of 0.34. Its most striking feature is that it is thermally limited at all frequencies. To accomplish this, the vent

Continued on page 42

```
ENTER THE RESONANT FREQ. OF DRIVER (FS) 23.6

ENTER ELECTRICAL Q OF DRIVER (QES)       .39

ENTER MECHANICAL Q OF DRIVER (QMS)       2.7

ENTER THE EQUIV. VOLUME IN CU.FT.(VAS)  8.4

ENTER THE DRIVER D.C. RESISTANCE (RE)   6.3


ENTER DRIVER POWER RATING IN WATTS (W)  100

ENTER PEAK EXCURSION IN INCHES (X MAX)  .25

ENTER DRIVER PISTON DIAMETER IN INCHES  10

                SYSTEM ORDER ?
?4
ENTER BOX LEAKAGE LOSS QL (D7)          9

ENTER BOX TUNING RATIO (H)              1.12

ENTER COMPLIANCE-BOX VOLUME RATIO(ALPHA)1.64

                      MAXIMUM   MAXIMUM
                      POWER     INFINITE
           RELATIVE   INPUT     BAFFLE
  FREQ.    RESPONSE   IN        RESPONSE
  IN HZ    IN (DB)    WATTS     IN (DB)
  -----    --------   -------   --------
   5       -56.32     4.2        40.88
   10      -33.21     6.64       65.98
   15      -20.15     13.38      82.07
   20      -11.22     41.67      95.95
   25      -5.23      100        105.73
   30      -2.15      100        108.81
   35      -1.01      100        109.95
   40      -.63       100        110.33
   50      -.42       100        110.54
   60      -.34       100        110.62
   80      -.23       100        110.73
   100     -.17       100        110.8
   150     -.08       100        110.88
   200     -.05       100        110.91
NEW BOX OR EQUALIZER (1=YES,0=NO)0
NEW DRIVER (1=YES,0=NO)0
          VENT DESIGN (1=YES,0=NO)
?1
ENTER VENT DIAMETER (INCHES)3

VENT AIR SPEED MACH NO.         .0932

VENT TUBE LENGTH IN INCHES      3.15

ANOTHER DIAMETER VENT (1=YES,0=NO) 1

ENTER VENT DIAMETER (INCHES)4.24

VENT AIR SPEED MACH NO.         .0467

VENT TUBE LENGTH IN INCHES      7.57
```

SAMPLE RUN 3: Dalesford 12-inch D300, fourth-order, vented box.

```
ENTER THE RESONANT FREQ. OF DRIVER (FS) 23.6

ENTER ELECTRICAL Q OF DRIVER (QES)       .39

ENTER MECHANICAL Q OF DRIVER (QMS)       2.7

ENTER THE EQUIV. VOLUME IN CU.FT.(VAS)  8.4

ENTER THE DRIVER D.C. RESISTANCE (RE)   6.3

ENTER DRIVER POWER RATING IN WATTS (W)  100

ENTER PEAK EXCURSION IN INCHES (X MAX)  .25

ENTER DRIVER PISTON DIAMETER IN INCHES  10

                SYSTEM ORDER ?
?6
ENTER BOX LEAKAGE LOSS QL (D7)          7

ENTER BOX TUNING RATIO (H)              .959

ENTER COMPLIANCE-BOX VOLUME RATIO(ALPHA)1.64

ENTER EQ.FREQ.-DRIVER FS RATIO FE/FS    .79

ENTER EQUALIZER DAMPING COEFFICIENT     .382

                      MAXIMUM   MAXIMUM
                      POWER     INFINITE
           RELATIVE   INPUT     BAFFLE
  FREQ.    RESPONSE   IN        RESPONSE
  IN HZ    IN (DB)    WATTS     IN (DB)
  -----    --------   -------   --------
   5       -75.63     100        35.34
   10      -38.03     42.36      69.2
   15      -14.05     8.75       86.33
   20      -.9        21.39      103.37
   25      .11        88.06      110.52
   30      .05        46.25      107.67
   35       .03       49.65      107.89
   40      -.09       63.54      108.9
   50      -.13       100        110.83
   60      -.13       100        110.84
   80      -.1        100        110.87
   100     -.07       100        110.89
   150     -.03       100        110.93
   200     -.02       100        110.94
NEW BOX OR EQUALIZER (1=YES,0=NO)0
NEW DRIVER (1=YES,0=NO)0
          VENT DESIGN (1=YES,0=NO)
?1
ENTER VENT DIAMETER (INCHES)3

VENT AIR SPEED MACH NO.         .1186

VENT TUBE LENGTH IN INCHES      5.09

ANOTHER DIAMETER VENT (1=YES,0=NO) 1

ENTER VENT DIAMETER (INCHES)4.24

VENT AIR SPEED MACH NO.         .0594

VENT TUBE LENGTH IN INCHES      11.45
```

SAMPLE RUN 4: Dalesford 12-inch D300, sixth-order, class I.

```
ENTER THE RESONANT FREQ. OF DRIVER (FS) 23.6

ENTER ELECTRICAL Q OF DRIVER (QES)       .39

ENTER MECHANICAL Q OF DRIVER (QMS)       2.7

ENTER THE EQUIV. VOLUME IN CU.FT.(VAS)  8.4

ENTER THE DRIVER D.C. RESISTANCE (RE)   6.3


ENTER DRIVER POWER RATING IN WATTS (W)  100

ENTER PEAK EXCURSION IN INCHES (X MAX)  .25

ENTER DRIVER PISTON DIAMETER IN INCHES  10

                SYSTEM ORDER ?
?6
ENTER BOX LEAKAGE LOSS QL (D7)          12

ENTER BOX TUNING RATIO (H)              1.42

ENTER COMPLIANCE-BOX VOLUME RATIO(ALPHA)1.64

ENTER EQ.FREQ.-DRIVER FS RATIO FE/FS    1.59

ENTER EQUALIZER DAMPING COEFFICIENT     1.6

                      MAXIMUM   MAXIMUM
                      POWER     INFINITE
           RELATIVE   INPUT     BAFFLE
  FREQ.    RESPONSE   IN        RESPONSE
  IN HZ    IN (DB)    WATTS     IN (DB)
  - ---    --------   -------   --------
   5       -95.77     100        15.2
   10      -61.28     100        49.69
   15      -41.85     100        69.11
   20      -28.31     100        82.65
   25      -17.83     100        93.13
   30      -9.46      100        101.5
   35      -3.64      100        107.32
   40      -1.06      100        109.9
   50      -.26       100        110.7
   60      -.24       100        110.73
   80      -.19       100        110.77
   100     -.14       100        110.82
   150     -.07       100        110.89
   200     -.04       100        110.92
NEW BOX OR EQUALIZER (1=YES,0=NO)0
NEW DRIVER (1=YES,0=NO)0
          VENT DESIGN (1=YES,0=NO)
?1
ENTER VENT DIAMETER (INCHES)3

VENT AIR SPEED MACH NO.         .0656

VENT TUBE LENGTH IN INCHES      1.13

ANOTHER DIAMETER VENT (1=YES,0=NO) 1

ENTER VENT DIAMETER (INCHES)4.24

VENT AIR SPEED MACH NO.         .0328

VENT TUBE LENGTH IN INCHES      3.53
```

SAMPLE RUN 5: Dalesford 12-inch D300, sixth-order, class II.

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CASTING WITH PLASTIC RESINS

BY SCOTT S. ELLIS

At one time or another, most audio hobbyists have wished that they had access to industrial machines or materials just for a day to test some idea or design that the home workshop cannot bring to life. Most of us have to be satisfied with what tools we can afford or devise. Occasionally, we might have the good fortune to obtain some industrial-grade materials, but for the most part, we are frustrated by our lack of access to high technology.

From time to time, however, some aspect of commercial technology trickles down to the hobby level. For the acoustic craftsman, one of the more significant of these commercial products is plastic resin casting.

WHAT IS PLASTIC RESIN? All of you have no doubt seen paperweights of clear, hard plastic with seashells, flowers or even tarantulas embedded in them. These are made of styrene resin, which is combined with a catalytic hardener such as epoxy. You can find the resin at many hobby shops under trade names such as "Diamond Cast" or "Castolite." It is also available from Tandy Crafts (Tandy Corp., One Tandy Center, Fort Worth, TX 76102) under the trade name "Clear Cast" and from Chemco (San Leandro, CA 94577) under the name "Mangelsen's Resin."

Items embedded in the resin are sealed against humidity, extremes of temperature, arcing and tampering. The resin may be clear, colored or opaque. Once cured, the resin, like most other plastics, may be machined with ordinary tools. Using either commercial or homemade molds, you can also use it to cast structural shapes.

I have used this resin for embedding circuit components, primarily electrolytic capacitors, and have recently begun to cast small horns as well. In addition, I have cast modular crossover assemblies that display mechanical and electrical stability and prevent removal of elements. The only components I have not cast are power resistors, as they need the free circulation of air to prevent overheating.

BEFORE YOU START. The resin comes in quarts or gallons, and the catalyst comes in half-ounce plastic bottles. Each bottle should be enough for two pints of resin mixture. I would encourage everyone, particularly beginners, to buy only the quart size of resin because it oxidizes quickly and must be used within two weeks after you open it. You can prevent oxidation by dropping glass marbles into the can each time you pour off some resin. The marbles occupy the airspace that would otherwise lead to oxidation. If you want to color your casting, you must use special resin dyes because water-based ones will not mix with the resin.

You must observe certain safety precautions when working with the resin. First, the resin is flammable, so you should not smoke around your bench. Second, although the resin itself is fairly innocuous to the skin, the catalyst is highly corrosive, so rubber gloves are imperative. Third, good ventilation is essential, as the mixture gives off a unique and penetrating odor guaranteed to make your experiment unwelcome indoors. (*It would be wise to wear an air filter and safety glasses for extended work of this kind. See* SB *1/83, p. 41.—Ed.*)

The usual precautions about keeping children and pets away apply here, as well as those about keeping all materials in their original containers. Also, like epoxy, the resin clings tenaciously to whatever it touches, so disposable mixing sticks and plastic or paper (but not foam) cups are in order.

Molds for the embedded objects come in a wide variety of shapes and sizes. Most commercial ones have their capacity in ounces marked on them. For small or multiple objects, you can use polyethylene ice cube trays. You can also use other molds such as novelty plastic candy boxes or plastic squeeze bottles. You can use some of these molds only once, so you should buy a mold for each casting you intend to make.

In any case, the mold should be made of soft plastic, such as polyethylene or vinyl. You should keep all molds very clean because any mark on the inside will show on the finished product.

CASTING THE OBJECT. Once you have set up your well-ventilated workbench, begin by casting an object of little worth, such as a pebble or shell, in a commercial mold. Experiment with your first few casts, and with practice you should be able to pick out suitable molds and projects more easily.

To prepare the plastic, mix the resin and catalyst thoroughly. Because they do not mix naturally, you must stir them together for a long time. The proportions of catalyst to resin are indicated on the can. Be sure to follow the directions carefully and to count the drops of catalyst one by one. A general rule of thumb is that small, shallow castings require more catalyst than large, deep ones. Too much catalyst is indicated by excessive (finger-burning) heat cracking of the cast and yellow discolorations. Too little results in prolonged curing times, even in good weather, and casts that remain sticky to the touch once out of the mold.

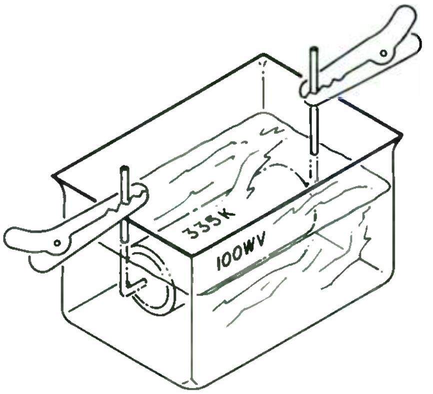

FIGURE 1: Alligator clips hold the object in the mold and protect the leads from the resin.

Objects to be embedded are processed in three phases:

1. Pour a small amount of the resin-catalyst mixture into the mold and allow it to set until it has the consistency of gelatin.
2. Make another batch of the mixture. Coat the item to be embedded with this fresh mixture and set it on top of the gel layer. Do not coat the leads from the circuit or device with resin. To protect them from the mixture, hold them perpendicular with clips or jigs during the curing process (*Fig. 1*).
3. Pour the remainder of the mixture on top of the object. Let the mold sit, undisturbed, until it cures.

Actual curing times depend on the freshness of the resin, the air temperature, the humidity and the use of coloring agents. For small castings in commercial molds, allow at least eight hours. I do not recommend using "promoters" or "accelerators" in the mixture. They can cause unpredictable effects and make the resin more volatile.

Remember to have all leads, jacks and plugs aligned properly before you pour the second layer. Also be sure that all jacks, relays and the like are totally enclosed, lest the resin render them inoperative.

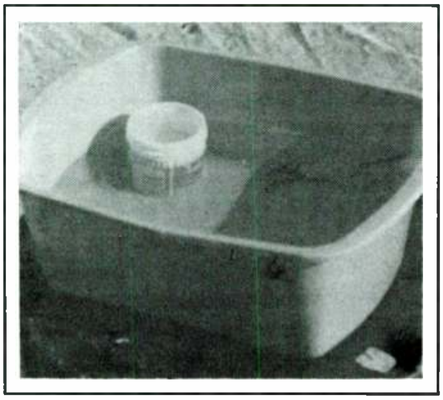

FIGURE 2: Set the mold in a pan of hot water to achieve a quick, uniform set.

Handling of large structural castings such as tweeter horns is somewhat different. Industrial users of resin put the mold in a water bath, which is controlled for optimum curing during all phases of the process. I adapted this for home use when I made a 9-ounce solid casting for a tweeter horn from an oval plastic squeeze bottle.

After pouring the mixture, I placed the mold in a plastic tub of hot (120–140°F) tap water, whose level was just below that of the lip of the mold (*Fig. 2*). I then covered the tub with aluminum foil (shiny side in) and rolled back the foil a little to allow air to circulate. After the resin had set to the point where the sides no longer "gave" from normal pressure (about 15 to 20 minutes), I removed the very warm mold, changed the bath to cold tap water and replaced the mold, removing the foil. I then let the mold sit for three hours to be sure the curing was complete.

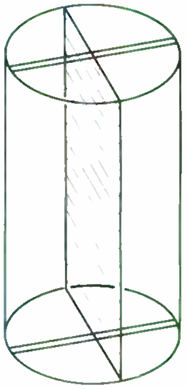

FIGURE 3: I sliced the oval cast with a bandsaw to produce four horn sides.

The casting came out perfectly, and the curing time was reduced from overnight to less than four hours. The hot water makes for a quick, uniform set, while the cold water dissipates the heat that the process gives off and prevents cracking. After allowing the surface to air dry overnight, I polished it with fine sandpaper to produce a finish like ground glass. I then sawed the oval cast (or "bole") into quarters, making two tweeter horns (*Fig. 3*).

I see no reason why you cannot make even larger castings. Custom-made polyethylene molds are quite expensive, however, and the finished casting is apt to be heavy for its size. Most large castings of this type, such as car bodies and boat hulls, are actually fiberglass-reinforced resin. Of course, for acoustic purposes, the walls of horn or enclosure casts must be at least ⅜ inch thick to prevent resonances. This is sometimes overlooked by commercial designers, who should know better.

Publications put out by various raw material manufacturers such as Monsanto and DuPont provide more information on structural castings. Most hobbyist magazines are mainly concerned with exotic objects such as birds' nests or rattlesnakes to embed.

As I said before, feel free to experiment. There are many uses for resin in acoustics and electronics, and the fun of casting is a reward in itself.

KITS
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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

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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'/C_2' components for 2 channels. Each $35.00

KL-3R: INVERSE RIAA. [1:80] Resistor/capacitor package complete. Contains stereo R_2'/C_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 (IG5818). 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, ±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, 4½" 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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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-C1A: 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$^{3}/_{8}$ x 9$^{1}/_{2}$"), precision resistors, polystyrene & polypropylene caps. Requires ±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

KK-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

KK-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 ±15V power supply @ 63 mils. Single channel. Each $49.00 Two channels. $95.00 Four channels. $180.00

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.

BUILD YOUR OWN PHASE METER

PART III IN A SERIES ON MODULAR TEST INSTRUMENTS

BY G. R. KOONCE
Contributing Editor

Last time, the author presented his wattmeter, which you can use to determine your unit's drive level. This time, he adds a direct-reading phase meter to his set of modular test instruments.

When I first started developing the test equipment covered in this series, I knew that I would need a phase meter (PM). I wanted a direct-reading meter with high potential accuracy, perhaps an error of ± a few degrees over the 20Hz to 20kHz band.

Direct-reading PMs usually compare the phase shift between the two signals' center-line crossings (i.e., at their 0V points). This approach removes any amplitude effects a signal would have on the phase measurement. The center-line crossings of both inputs can be located by hard limiters (clippers), which produce square-wave outputs whose transitions line up with the input center-line crossings over whatever input dynamic range you desire.

Luckily, the test equipment in my series uses analog meters read over about 10dB of dynamic range. For additional input dynamic range, you change an attenuator by 10dB to get back to the more accurate portion of the meter scale. If the clipper input were connected to the voltmeter board input (see Part I, *SB* 3/83, p. 12), the input range would be restricted to between 1V and 4V RMS (root mean square). For the clipper to maintain center-line crossings within an accuracy of 2 degrees for a 1V RMS signal, the voltage error must be less than:

$$\pm\sqrt{2}\times\sin 2\text{ degrees} = \pm 0.049\text{V}.$$

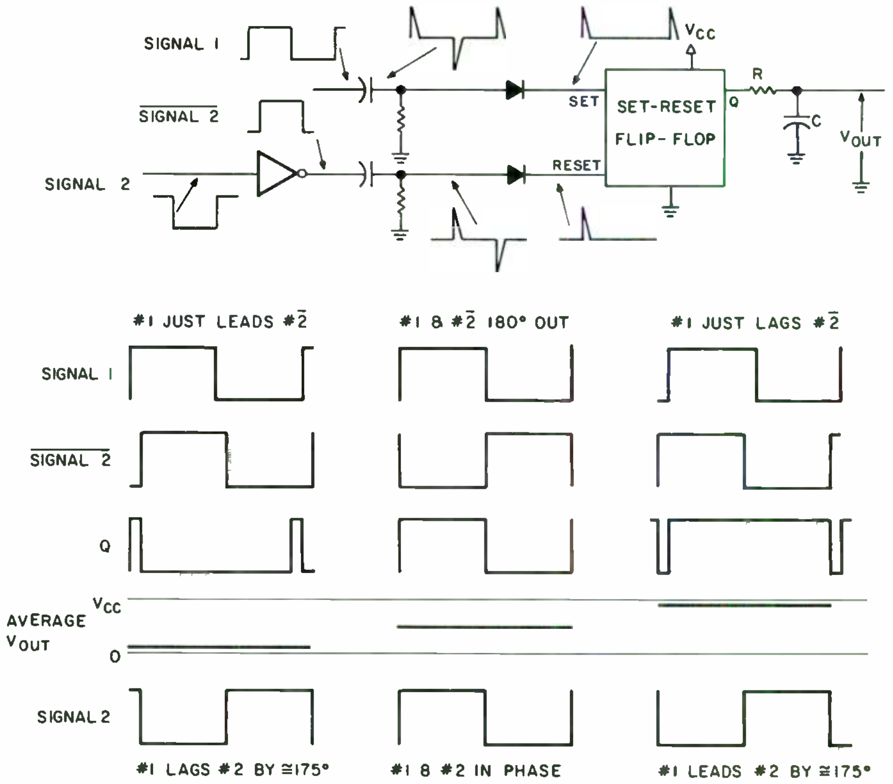


FIGURE III-1: Flip-Flop (FF) phase meter and waveforms.

It is possible to maintain this accuracy with a single-stage comparator, so converting the sine waves to square waves is not a major problem.

FLIP-FLOP vs. EXOR. *Figures III-1* and *III-2* show two common ways of converting the squared up input signals into a phase reading. *Figure III-1* shows the set-reset flip-flop (FF) approach, along with the waveforms involved. Signal 1 and inverted signal 2 ($\overline{\text{signal 2}}$) are differentiated to get edges. One edge of each is used to set and reset a FF. The FF output is averaged into a DC voltage.

Figure III-1 shows that V_{out} is zero for signal 1, lagging behind signal 2 (i.e., before the inverter) by 180 degrees. V_{out} is one-half scale when the signals are in phase, and it is full scale when signal 1 leads signal 2 by 180 degrees. This approach thus gives a full 360 degrees of phase coverage on the meter scale and has zero phase shift at center scale, which is a very convenient layout.

Figure III-2 shows the EXclusive

OR (EXOR) approach to reading phase. The truth table is shown for those who are not familiar with the EXOR function. *Figure III-2* shows that this approach gives an average V_{out} of 0V when the inputs are in phase and a V_{out} equal to full scale for 180 degrees of phase shift, either lead or lag. This approach expands the phase scale by two, with the meter going 0 to 180 degrees, but you lose the information about which input is leading (i.e., the sign of the phase shift).

It would appear at this point that the FF technique is by far the best one to use. I have been assuming perfectly symmetrical sinusoids, however, which are free of any outside interference. When you consider real-world conditions, the FF approach loses its edge. *Figure III-3* shows how a non-symmetrical test signal affects the two approaches. I have exaggerated the symmetry difference for clarity and in this case applied the same asymmetry to both waveforms.

This asymmetry has basically no effect on the EXOR approach, but introduces some error with the FF approach. *Figure III-4* shows the effects of noise and other interference on the test signal. If the interference occurs near the zero crossing, it causes the clipper to show multiple output transitions. Hysteresis on the clipper helps to curb this effect, but static hysteresis causes phase error with changes in the input signal level and thus must be kept moderate. (I will discuss use of hysteresis later in the article.)

In practice, it is likely that one or both inputs will come out of the clipper looking like signal 1 in *Fig. III-4*. In the EXOR approach, this causes slight errors. Its most troubling effect is that it prevents getting down to 0V when the two signals are in phase.

The effects on the FF approach are more dramatic. As the two waveforms approach the in-phase condition and the phase meter approaches center scale, things go awry and the meter jumps up near full scale. Consequently, the FF technique is useful only if you can guarantee sufficiently clean sinusoid inputs to the clipper.

When I looked at each approach's strengths and weaknesses, I noted the small amount of hardware in the EXOR circuit and decided to include them both. Thus, the PM board generates a V_{out} by both techniques, and a meter with both scale calibrations is switched to the desired V_{out}.

THE COMPARATOR. *Figures III-5, III-6* and *III-7* show the schematic, full-size circuit board positive and stuffing guide for the comparator, which is the clipper used with the PM. *Tables III-1* and *III-2* are the parts and parts size lists for the board. You need two of these boards, one for each input signal. The comparator is AC coupled to prevent DC offsets in

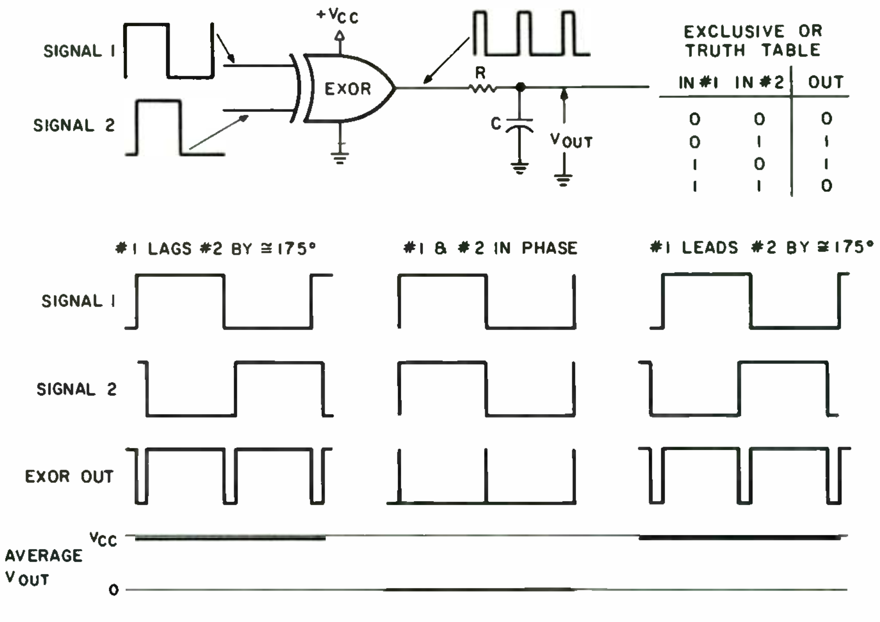


FIGURE III-2: EXclusive OR (EXOR) phase meter and waveforms.

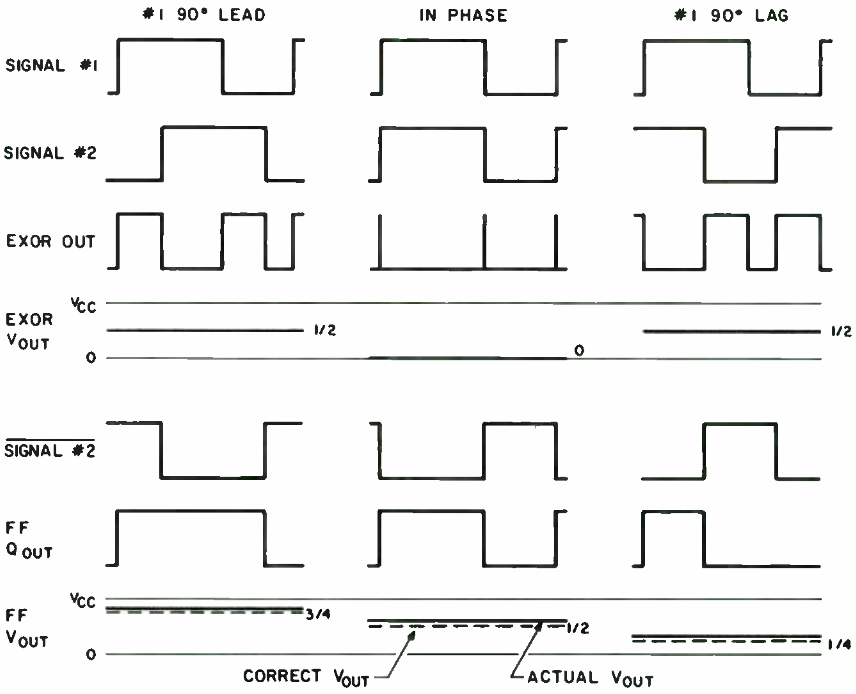


FIGURE III-3: Effects of asymmetrical waveform on phase meters. This is a special case. Asymmetry on only one input or other non-symmetrical combinations will cause error in the EXOR circuit.

the driving stage from affecting the zero crossings, and I have included protection diodes at the input.

Resistors R1 and R2 allow attenuation to be taken at the input. With the values shown for R1 and R2 in *Fig. III-5*, C1 causes a −3dB low-frequency breakpoint at ≅1.2Hz. Thus, at 20Hz, a phase shift of ≅3.4 degrees exists. If R1, R2 and C1 are the same on both comparators, the phase shifts tend to cancel each other. Resistor R7 provides pull-up on the open collector output of the 311 comparator to drive the CMOS 4049 inverting buffer. The +B power input is +12V and will come from the PM board.

Components R3, R4, R5 and C4 provide hysteresis (h) for the comparator to ensure fast, clean switching. Hysteresis is the term used for making the threshold of a comparator a function of the last transition's direction—i.e., giving it memory. *Figure III-8* clarifies this. As the input sinusoid rises from below 0V, it must rise to +h before the comparator output will go low. Once the comparator output goes low, the threshold moves to −h, so the input must drop past zero to −h before the comparator output will go high and move the threshold back to +h. If +h equals −h in amplitude, then the hysteresis is symmetrical about 0V. Assume that the comparator output moves a full 12V, which is fed back to the non-inverting comparator input multiplied by the following ratio:

$$\frac{R3}{R3+R4+R5} \cong \frac{R3}{R4+R5} \cong \frac{1}{2000}$$

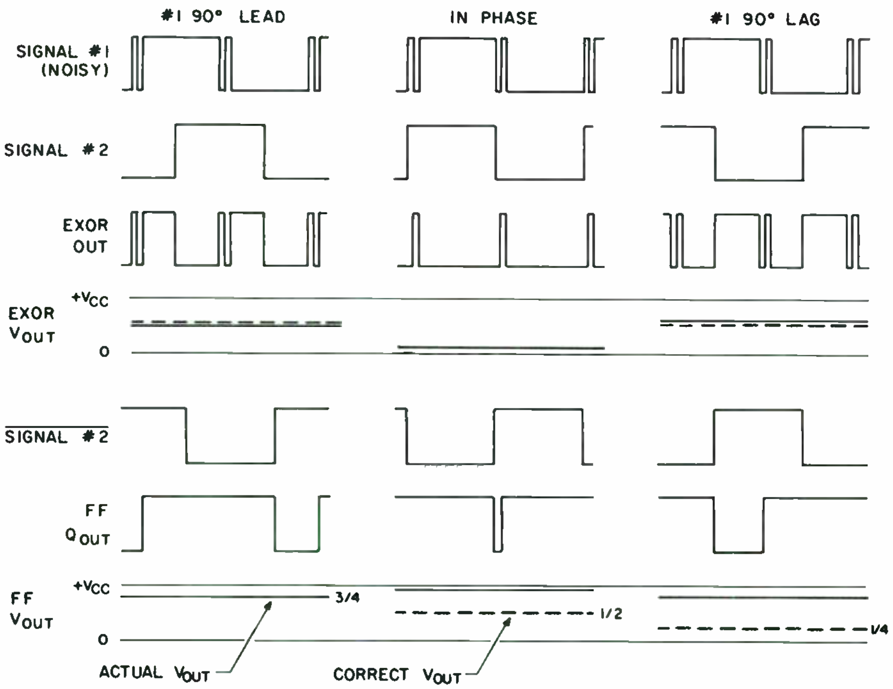


FIGURE III-4: Effects of "noisy" signal on phase meters. Noisy signal effects can result from noise, interference or distortion on the input sinusoid.

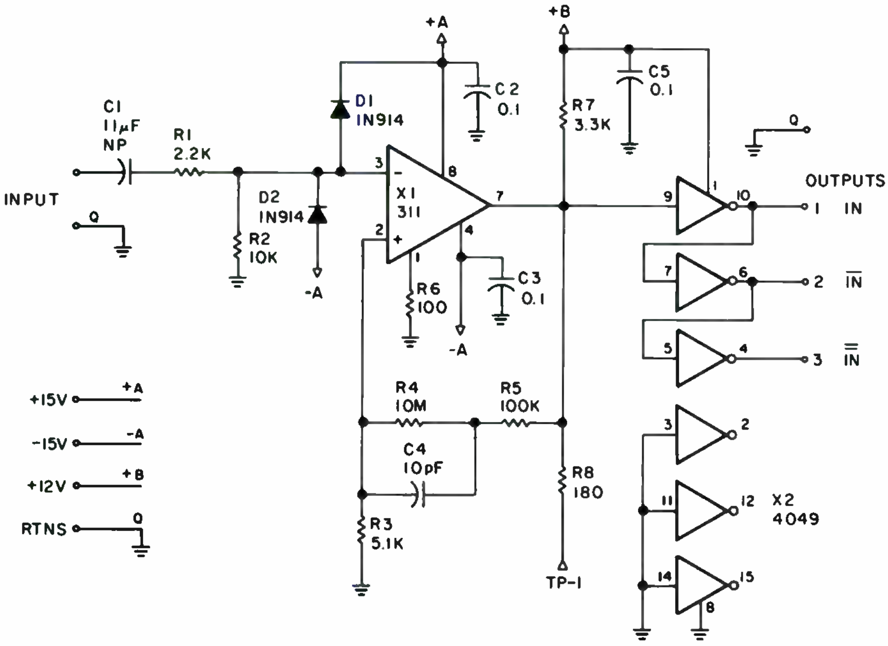


FIGURE III-5: Schematic diagram for the comparator (Board #248).

TABLE III-1

PARTS LIST FOR COMPARATOR (BOARD NO. 248)

R1	2.2k, ¼W (3mW normally)
R2	10k, ¼W (15mW)
R3	5.1k, ¼W (≅0)
R4	10M, ¼W (≅0)
R5	100k, ¼W (≅0)
R6	100Ω, ¼W (2mW)
R7	3.3k, ¼W (51mW)
R8	180Ω, ¼W (see **SB** 3/83, p. 12, for test buffers)
C1*	11μF, 15V non-polar tantalum (≅0V normal, 17V worst case); I used Kemet T111B116M015AS.
C2*, C3*, C5*	0.1μF, 25V disk ceramic (17V)
C4*	10pF dipped mica (17V)
D1, D2	1N914 (30V, ≅ 20mA)
X1	LM 311 comparator; mini-DIP case
X2	4049 CMOS Hex inverting buffer, 16-pin DIL

*See Parts Size List, Table III-2.

TABLE III-2

PARTS LIST FOR COMPARATOR

		Dimensions[1] (in inches)		
Component	Type	1	2	3
C1	A	0.2	1.0	1.2
C2, C3, C5	D	0.1	0.5	0.42
C4	D	0.18	0.46	0.26

[1] Refer to Fig. I-2 (SB 3/83, p. 14) for definitions.

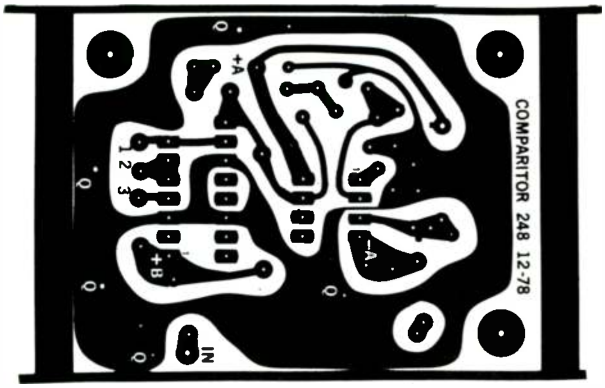


FIGURE III-6: Comparator circuit board (#248).

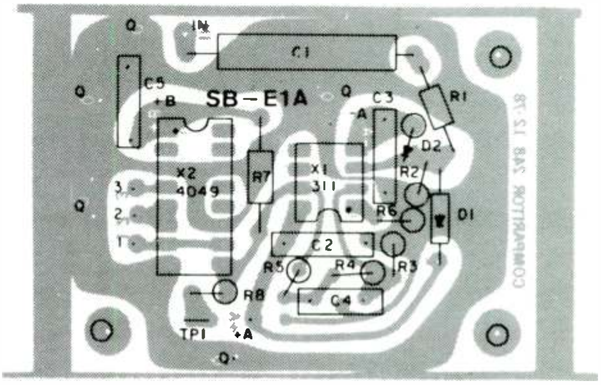


FIGURE III-7: Stuffing guide for the comparator board.

Thus, the non-inverting input changes about 6mV as the output changes on a steady-state basis, but C4 increases this 100 to 1 for short periods just after transitions to keep the comparator stable and to prevent high-frequency noise on the input from causing trouble. The 6mV DC hysteresis is so small that its lack of symmetry is of no consequence.

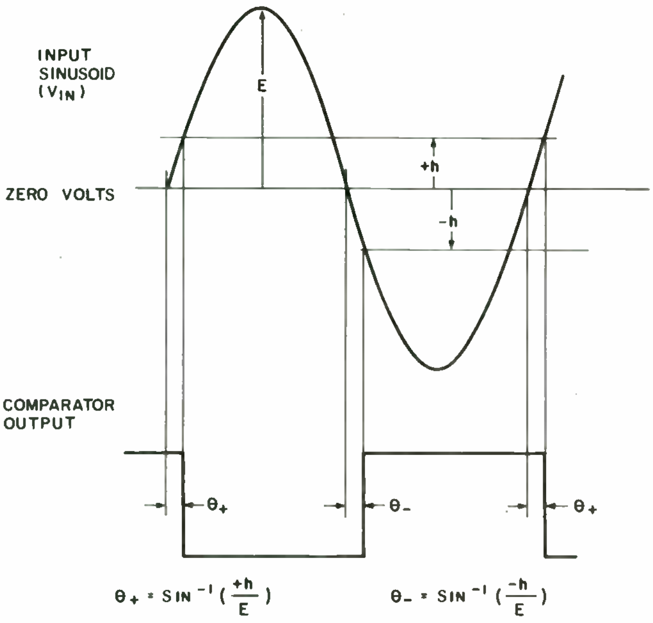


FIGURE III-8: Effects of hysteresis on the comparator.

TABLE III-3

EFFECT OF HYSTERESIS OF PHASE SHIFT*

Hysteresis Level +h & −h	Value of θ_+ & θ_- V_{in} = 1V RMS (E = 1.41V)	V_{in} = 4V RMS (E = 5.66V)	Change in Phase Shift as V_{in} Changes 3V
10mV	0.41°	0.10°	0.31°
20mV	0.81°	0.20°	0.61°
50mV	2.03°	0.51°	1.52°
100mV	4.05°	1.01°	3.04°
200mV	8.13°	2.03°	6.10°
500mV	20.70°	5.07°	15.63°

*See Fig. III-8 for definitions of terms.

TABLE III-4

PARTS LIST FOR PHASE METER BOARD (NO. 247)

R1, R2, R11, R12	10k, ¼W (29mW)
R3, R7, R10, R14, R18, R22	180Ω, ¼W (see Part I (SB 3/83, p. 12) for test point buffers)
R4, R6, R19, R21	33k, ¼W (9mW)
R5, R20	see text
R8	4.7k, ¼W (≅0)
R9	470Ω, ¼W (≅0)
R13	47k, ¼W (6mW)
R15	8.2k, ¼W (27mW)
R16	10k, ¼W (function of meter used—see text)
R17	330Ω, ¼W (function of meter used—see text)
R23-R26	220Ω, ½W (256mW max, 192mW typical)
C1*, C2*	100pF dipped mica (17V)
C3*, C6*	5.5μF, 15V tantalum-foil (14V forward)
C4*	40μF, 30V tantalum-wet anode (17V forward)[1]
C5*, C8*, C9*, C10*, C13*	0.1μF, 25V disk ceramic (17V)
C7*, C11*, C12*, C14*	10μF, 25V stand-up electrolytic (up to 17V)
D1-D3	1N914 diodes (if ≤ 40mA, $V_R \leq 17V$)
X1	4049 CMOS Hex inverting buffer, 16-pin DIL
X2	4030 CMOS Quad Exclusive OR, 14-pin DIL
X3	4011 CMOS Quad Two-Input NAND, 14-pin DIL
X4-X6	741 op amp, mini-DIP case
X7	78L12 +12V regulator, TO-92 case (see text on V_{out} requirement)
Q1	2N2222 or equivalent NPN (18V, 35mA, $\beta \geq 25$)
Q2	2N5139 or equivalent PNP (18V, 35mA, $\beta \geq 25$)
P1	2k multiturn trimpot, type A, B or C of Fig. I-1L (SB 3/83, p. 13)
P2	2k multiturn trimpot (function of meter used), size as P1

[1] Wet anode tantalum is a poor choice here, but has given no trouble.

*See Parts Size List, Table III-5.

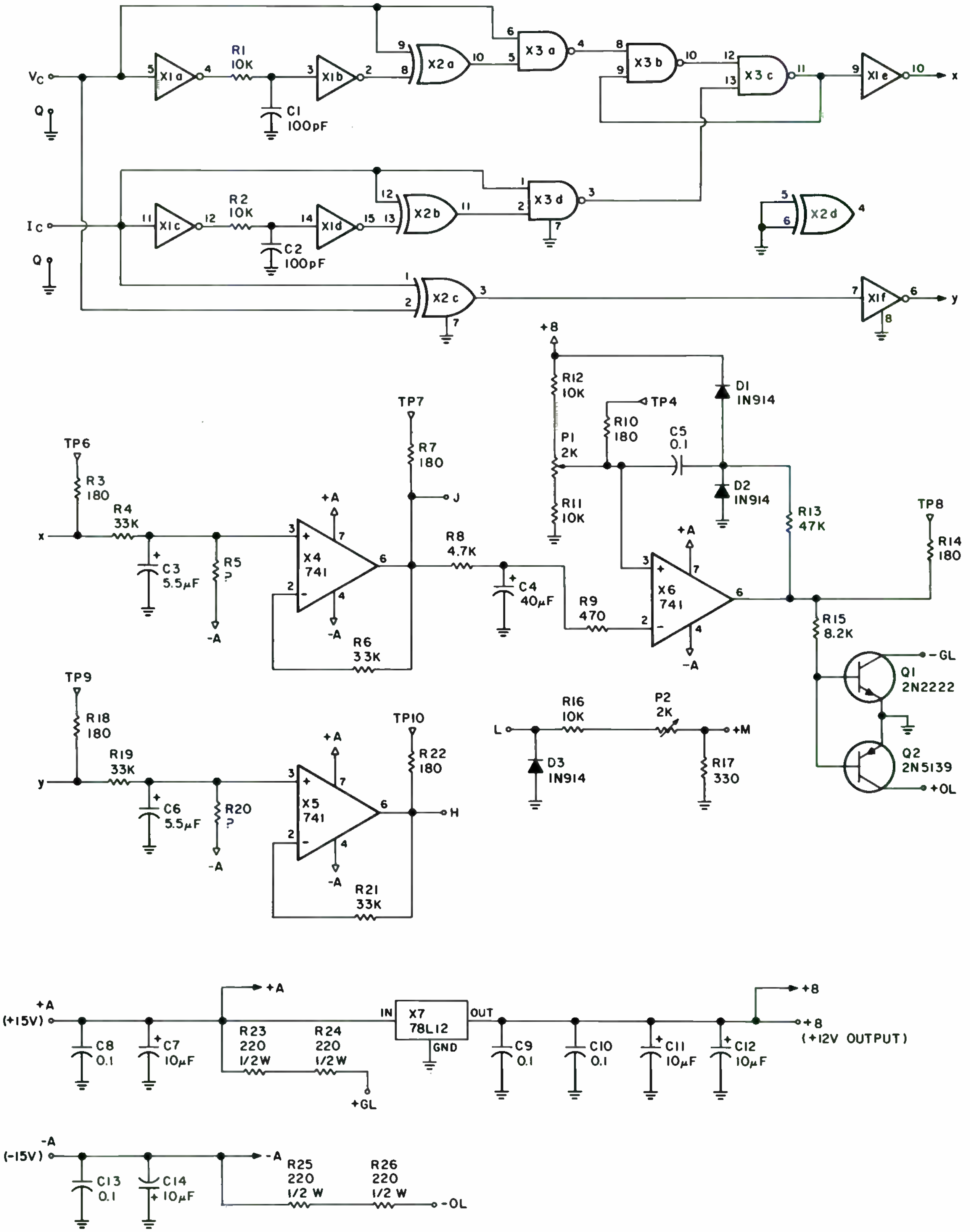


FIGURE III-9: Schematic diagram for the phase meter (Board #247).

The circuit in *Fig. III-5* works great on the bench, and if you want to build a PM for bench use over a reasonable input signal range, it is a good clipper. Performance of the entire PM with this clipper circuit is shown later. When the clipper was coupled to signals that had been through or associated with an acoustic-to-electrical transition, all the trash on the signals caused multiple output transitions at zero crossings, with the effects on the FF PM already discussed.

Note that in this series, I have increased the DC hysteresis on the comparators and made it more symmetrical. *Figure III-8* shows the effects of this. Assuming good input signal symmetry, if +h equals −h, the symmetry is preserved as θ_+ equals θ_-. Thus, a large amount of symmetrical DC hysteresis does not in itself cause a problem. What causes trouble is that θ_+ and θ_- change with the magnitude of the input signal. If the two AC signals coming to the comparators have different magnitudes, DC hysteresis will introduce phase error.

As I noted above, these input signals might move over about 12dB, so let's look at the phase error introduced by symmetrical hysteresis. *Table III-3* shows the values of θ_+ and θ_- for various h values with symmetrical hysteresis and input signals of 1V and 4V RMS, along with the phase change between these two values, which is the maximum error introduced. When h gets up near 100mV, you introduce phase errors near 3 degrees. This amount of hysteresis would ignore 200mV peak-to-peak (PTP) signals on an input of up to 11.3V PTP (4V RMS) or anything that is down over 35dB relative to the desired signal. Going to an h of 200mV will reject effects over 29dB down at the cost of 6 degrees potential phase error. You have to make a trade-off here. In general, if one or both signals are acoustically derived, you want h near the 100 to 200mV range, but even then certain conditions will cause trouble.

The comparator board has three outputs. Output 1 has the same phase as the input signal, output 2 is out of phase, and output 3 is back in phase but delayed slightly compared to output 1. This board has no calibration controls, so you can mount it where it is inaccessible.

Note that the comparator boards contain CMOS logic and should receive "static sensitive" handling during construction and connection to other boards. I am a bit sloppy here. I do use a transformer-isolated soldering iron, store CMOS in conductive foam or tubes, and try to keep one finger on the circuit board ground while soldering and such. Other than that, I treat the CMOS logic much the same as any other integrated circuit. I have not ruined one yet, but I always order spares just in case. Static charge can destroy even "protected" CMOS circuits, however, so you should exercise caution.

PHASE METER BOARD. *Figures III-9, III-10* and *III-11* show the

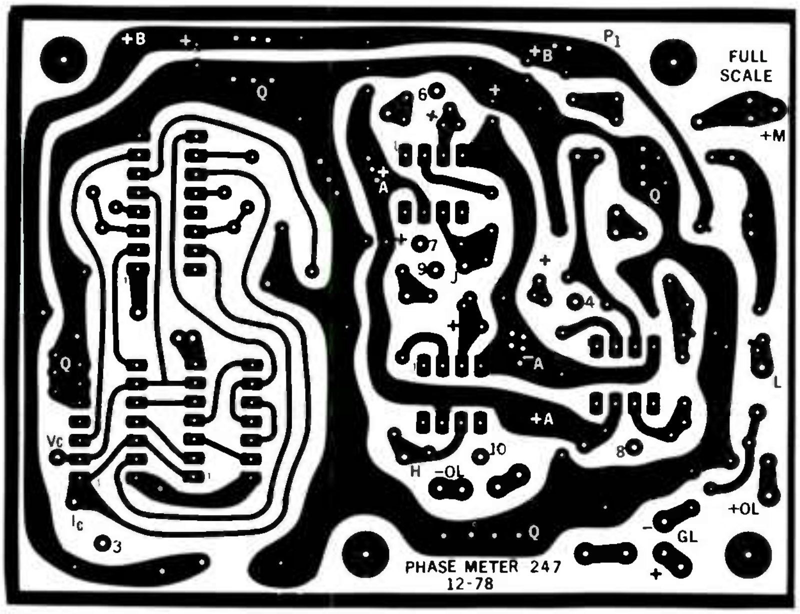


FIGURE III-10: Phase meter circuit board (#247).

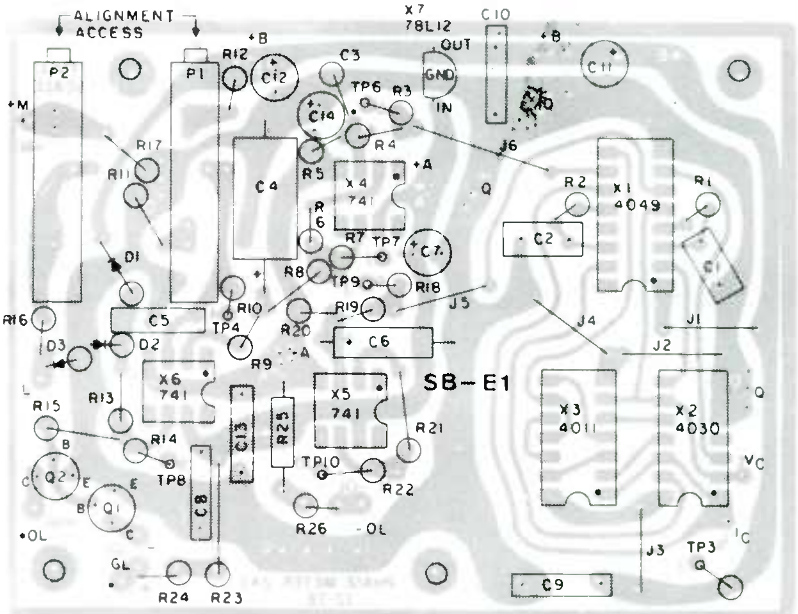


FIGURE III-11: Stuffing guide for the phase meter board.

schematic, full-size positive and stuffing guide for the PM board. *Tables III-4* and *III-5* are the parts and parts size lists. Basic operation of the logic section at the top of *Fig. III-9* is as follows. X1a and X1c through X2a and X2b are the differentiators putting out a pulse at each input edge. X3a and X3d act like diodes, passing the pulse that occurs on positive-going (rising) inputs. X3b and X3c implement the set-reset FF, and X1e is an output buffer. Unit X2c is the EXOR circuit followed by buffer X1f.

In the analog portion of *Fig. III-9*, R4 and C3 are the averager for the FF output, and X4 is a unity gain buffer. R19, C6 and X5 perform the same functions for the EXOR output. I used tantalum capacitors for C3, C4 and C6, but you could probably use aluminum electrolytics, although I have not tested them yet. R5 and R20 offset the averagers slightly toward negative if that is necessary. Breadboard tests have shown the offset to be positive, keeping the meter from getting to zero on the EXOR scale. I have provided adjustment for setting full scale, so R5 and R20 allow you to trim up zero if desired. The resistance used for R5 and R20 is usually greater than 10MΩ.

Point J is the FF V_{out}, while point H is the EXOR V_{out}. One of these points is switch connected to point L, the meter drive circuitry. Diode D3 prevents reverse meter drive during turn-on. No overdrive protection is needed, as meter full scale is set equal to the maximum expected V_{out}. Maximum possible V_{out} with an op amp failure is only 30 percent overload, not enough to hurt the meter.

Op amp X6 is used as a comparator. R8 and C4 further smooth FF V_{out} (point J), then X6 compares it with an adjustable threshold, while C5 provides AC hysteresis. P1 sets the threshold of X6 at FF V_{out} equal to zero-degree phase (about 6V). Therefore, if V_{out} goes above this voltage, X6 output goes low and Q2 comes on. Q2 lights an orange LED, and assuming about a 2V drop across this LED, it will pass about 28mA. When V_{out} drops below midscale, Q1 comes on and lights a green LED. Again, LED current will be about 28mA. The FF V_{out} signal drives these LEDs. If noisy input signals confuse the FF, these LEDs will read erroneously.

Voltage regulator X7 generates 12V for the CMOS on this circuit board and for the comparator boards. It is possible that with X7 output on the high side and the 7815 or 78L15 regulator supplying +15V to the PM board on the low side, the voltage necessary to make X7 operate will not be available. I select the +15V regulator driving the PM board to be above +15V and the regulator for X7 to be below +12V. You are all right if testing shows that +A (+15V) is at least 2V above +B (+12V).

The PM board also contains CMOS circuits, so you should consider it static sensitive. Review my comments about special treatment of these circuits in the comparator section of this article.

A COMPLETE PHASE METER. *Figure III-12* shows how two comparator boards and one PM board are

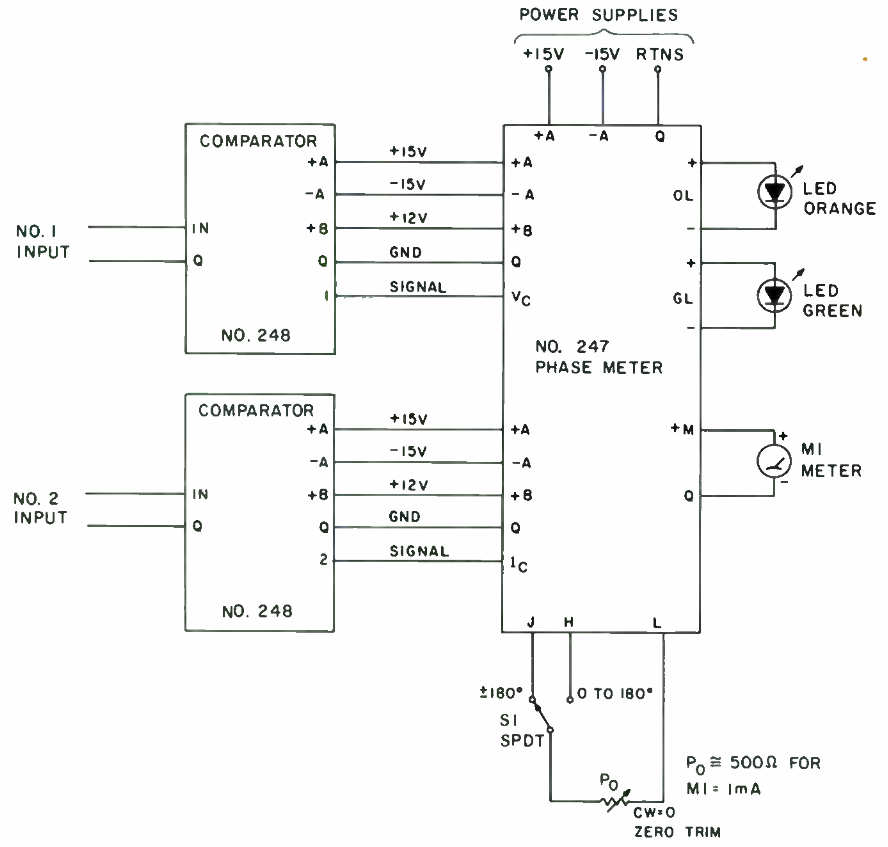


FIGURE III-12: Circuit board connections for the phase meter.

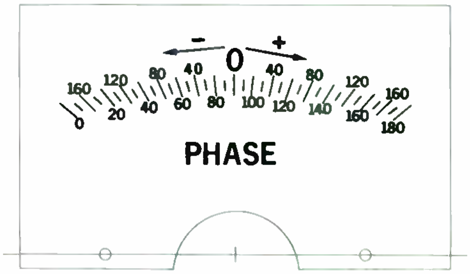


FIGURE III-13: Phase meter scale for the meters discussed in this article. Do not scale for use on other meters.

TABLE III-5

PARTS LIST FOR PHASE METER BOARD

Component	Type	Dimensions[1] (in inches) 1	2	3
C1, C2	D	0.18	0.4	0.25
C3*	B	0.16	—	0.25
C6*	A	0.16	0.6	0.7
C4	A	0.3	0.7	0.9
C5, C8, C9, C10, C13	D	0.1	0.5	0.42
C7, C11, C12, C14	C	0.25	—	0.1

[1] Refer to Fig. I-2 (SB 3/83, p. 14) for definitions.

*Same type cap

connected to form a PM unit. *Figure III-13* shows the scales I made for my meters. The top scale applies when switch S1 ties L to J (FF V_{out}). It starts at −180 for a V_{out} of zero and goes to +180 at full-scale V_{out}. If you study the schematic, you can verify the following input conditions for L tied to J: for a meter reading below center scale (negative phase) and with the green LED on, input 1 lags behind input 2; for a meter reading above center scale (positive scale) and with the orange LED on, input 1 leads input 2. Thus, if input 2 is the reference channel, the top scale reads the phase of input 1 relative to the reference.

The bottom meter scale is zero when V_{out} equals 0V and 180 at full-scale V_{out}. It is used for the EXOR PM when switch S1 connects L to H. When the input signals are clean enough that the FF mode is operating properly, the LEDs work with switch S1 in either position. The phase's sign can, therefore, be established, even when working on the bottom (0 to 180) PM scale.

Now let's look at the requirements for the meter M1. In both operating modes, it is driven from an op amp, and +B (≅12V) is full scale. I used 1mA meters with an internal resistance of ≅33Ω. The circuit would work with any meters up to about 10mA and 10V full scale. I have included R17 in *Fig. III-9* to give damping control on the meter movement. This keeps it from slapping the limit pins. My meters need R17, but many others do not, so I would start without it. In *Fig. III-12*, I_{FS} is the full-scale current (amps) and Rm the internal resistance (ohms) for your meter:

$$Rx + Rm = \frac{12}{I_{FS}}$$

where Rx is equal to (R16 + P2) in its calibrated position. Since the +12V (+B) is not too accurate, I would make P2 equal to about 0.3(Rx + Rm). Then R16 would equal (Rx − ½P2). If Rm is quite high, R16 could compute negative, in which case you would short it out.

The potentiometer (P0—actually rheostat) in *Fig. III-12* is a trim on the PM that you can mount on the instrument front panel. I used it on one piece of test gear, but it is not really needed and can be omitted. In practice, the PM has been quite stable. If your meter damping turns out to be poor, try adding resistor R17. If R17 starts to approach the meter resistance Rm, you might have to change R16 to allow full-scale calibration.

See Part I of this series (*SB* 3/83, p. 12) for a discussion of how I make my meter scales. For the top scale on the PM, 100 percent deflection spans 360 degrees of phase. Thus, each 10-degree increment represents 2.78 percent deflection on a meter that has a linear deflection with current. The bottom PM scale covers a total of 180 degrees, so each 10-degree increment represents 5.56 percent deflection. This lines up with the 20-degree lines of the top scale.

Note that some portions of the PM circuit board are optional. If you do not want the LEDs, delete all the components in stage X6 (back to R8). You might want to use only the FF PM approach, in which case you can delete the X5 stage. If you want only the EXOR approach, you can omit the X3, X4 and X6 stages. You are, however, using a very large circuit board for the function you are getting.

Calibration of the system in *Fig. III-12* is quite simple. Apply a 1kHz, 4V RMS sinusoid to both comparator inputs. With the switch in L to J position (±180-degree range) and P0 (if used) centered, adjust the full-scale pot (P2 in *Fig. III-9*) so that the meter reads zero on the top (−180 to +180) scale. Adjust the LED comparator threshold (P1 in *Fig. III-9*) until the comparator has trouble deciding which LED to turn on. If you drop the input frequency to about 20Hz, both LEDs will usually flash. Change the input back to 1kHz and switch S1 to L to H position (0-to-180-degree range). The meter should read very close to zero on the bottom (0 to 180)

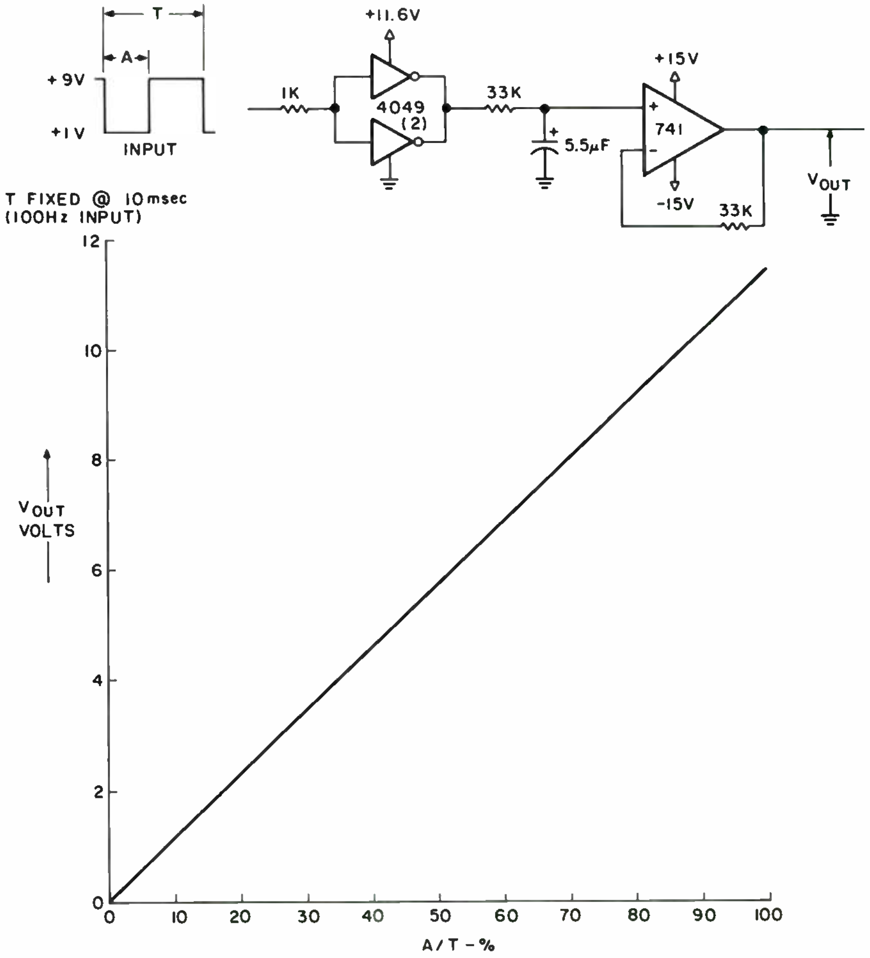


FIGURE III-14: Linearity run of the passive averager and buffer.

RECORDINGS INDEX *from* Old Colony

WHEN OUR COLLECTION OF RECORDINGS passed the 200 mark, my wife remarked to a friend that I was the only one who could find anything. When they passed the 400 mark, neither of us could. Our solution to the problem became the *Old Colony Recordings Index System.*

Of course, if each long-play disk contained only one piece of music, we would not need an index. That's how it was in the pre-1948 days of the 78s. We just arranged our heavy albums in order from Albeniz to Wieniawski. Today a single disk may contain both of these and eight others in between. The spine of the average 12″ package is a little over 3/16″ wide and 12½″ long. Even a list of composers on that spine is difficult—and the compositions are outright impossible.

The *Old Colony Recordings Index* allows you to put a serial number on each package's spine, which is the heart of the index's success. To aid you in making a simple, useful index of your recorded music, we offer the basic makings, which you are not likely to find locally. The system is simple, inexpensive and flexible.

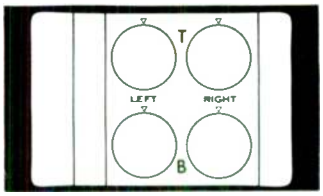
A number of users have found the system ideal for indexing slides. The stamp is used directly on the slide mount, with two letters and one numeral indicating the slide storage package and the remaining numerals the slide number in the set. A 3x5″ index file is set up by category: Flower gardens, Fountains, Uncle Fred, etc.

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 ½-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 (¾″) for a durable finish.

In addition to the starter kit, you will need to purchase the following locally: 3x5 file cards, 3x5 file guides (½-cut), a file box or drawer, an inked stamp pad (cloth, not foam, with permanent black ink), white glue and Scotch magic mending tape (¾″). 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.

The *Old Colony Recordings Index* makes it possible to index your recordings as you acquire them, regardless of size or content. The sooner you start indexing, the easier it will be to keep up with what you own. Radio stations, university libraries and hundreds of serious collectors are enthusiastic users of the Old Colony system.

ONE



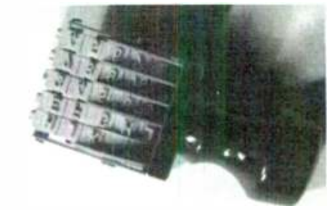
A pressure-sensitive label for the sleeve or box of the recording. It has a place for stamping a serial number in three places.

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.

TWO

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.

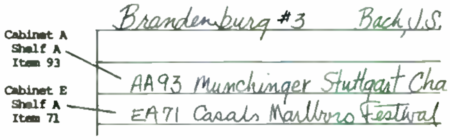
The first two bands of the stamp are the letters A to K (omitting I), and the last three are the numerals 0 to 9. These provide flexibility in coding. The two letters can designate cabinets and shelves; the numerals can designate consecutive serial numbers on those shelves.



THREE

A 3x5 (or larger) file with guides for each composer (and some performers) arranged alphabetically. Each card represents one work of that composer in your collection.

The name of the work is listed on the top line. The serial numbers of the disks and tapes where this work may be found are listed below, with the main performers noted as well.



Brandenburg #3 Bach, J.S.
AA93 Munchinger Stuttgart Cha
EA71 Casals Marlboro Festival

Old Colony Sound Lab • Post Office Box 243 • Peterborough, NH 03458 USA

Quantity	Item	Total Price
________	Old Colony Recordings Index starter kit at $9.95 each (250 labels, 250 composer names, adjustable rubber stamp and full instructions).	$__________
________	Labels at $1.50 per 100 (400, $5; 1,000, $12)	__________
________	Adjustable stamp(s) at $7.95 each	__________
	Total remittance	$__________

name ______________________________

address ______________________________

city ________________ state ________ zip ________

Please make check or money order payable to OLD COLONY SOUND LAB. No C.O.D.s. MasterCard and Visa acceptable. All orders postpaid in the USA. Add postage for 1 lb. for starter kit to foreign address. All remittances must be in US funds.

scale. Switch S1 back to the L to J position, then disconnect and ground input 2. The meter should read ≅ +180 on the top scale.

If it stays at zero, suspect crosstalk in keeping comparator 2 going even though its input is grounded. Drive input 2 and ground input 1. The meter should read near −180, and you should note the same crosstalk caution just given. With S1 in the L to H position (0-to-180-degree range) and good input symmetry, the meter should read about 90 degrees on the bottom scale with either input driven individually and the other grounded.

PHASE METER PERFORMANCE. This system consists of two comparators (*Fig. III-5* and *Table III-1*) and one PM board (*Fig. III-9* and *Table III-4*), which are connected as shown in *Fig. III-12.* I omitted R5 on the PM board used in these tests and chose a 33MΩ value for R20.

The DC current drains for the PM system are as follows:

	+15V	−15V
Full-up system, all options	15–55mA	8–40mA
No-sign LEDs or drive circuits	12–13mA	7–7.5mA

Design considerations made me use passive averagers for the FF and EXOR outputs. At first I questioned the linearity of this approach, but breadboard tests, shown in *Fig. III-14*, indicated good linearity. In this test, I used two parallel CMOS buffers to drive the averager, but results were the same with only one driver. One key consideration is that the averager be linear when driven by variable duty cycle square waves from a CMOS buffer.

Now, let's take a look at the sinusoidal input performance of a PM system. The system tested did not have the sign-indicating LEDs or the X6 stage circuitry to drive them. *Figure III-15* shows what the PM reads when you drive both inputs with 4V RMS at various frequencies. Remember, the 0-to-180-degree range does not yield a sign for the phase shift, so I have assumed positive for convenience in plotting. Under these conditions (also with 1V RMS to both inputs), the PM stays within ±3 degrees of zero from 5Hz to 300kHz.

Figure III-16 shows PM performance as both input signal levels are varied together. Results show phase (at 1kHz and 100kHz) staying within ±1 degree over the intended 1V to 4V input range. Below 1V input, performance deteriorates, with a 10-degree error indicated by about 0.1V RMS input, some 38dB below the 8V maximum input tested.

Figure III-17 shows PM performance with one input fixed and the other varied. With 1kHz inputs, less

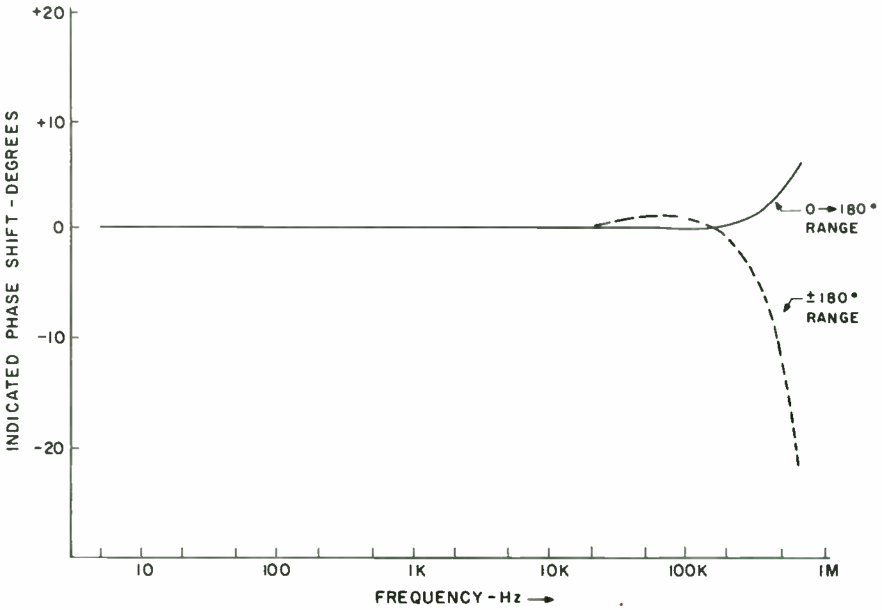


FIGURE III-15: Phase meter performance with frequency. Both inputs were driven together ($V_{in1} = V_{in2} = 4V$ RMS). The 0-to-180-degree range is shown going positive for convenience. The same test run at 1V RMS showed both ranges staying within ±3 degrees, 5Hz to 700kHz.

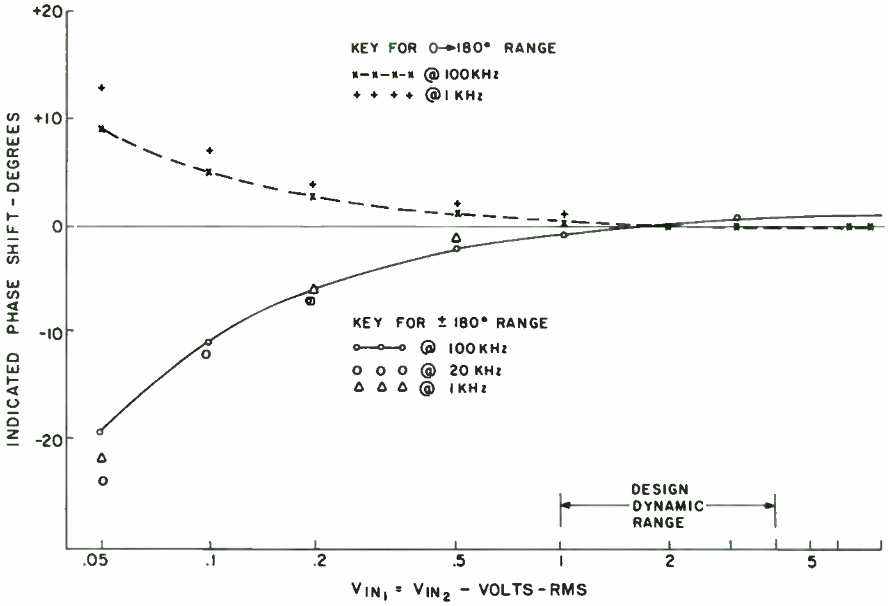


FIGURE III-16: Phase meter performance with input level. Both inputs were driven directly. The test frequency is as indicated. The 0-to-180-degree range is shown going positive for convenience.

Old Colony will be offering the boards for Mr. Koonce's phase meter. Send a postcard requesting cost information to Old Colony, PO Box 243, Peterborough, NH 03458.

than a 1-degree error is indicated over the 1V to 4V input range. Errors of 10 degrees do not occur until the input drops below 0.1V, the same as when both inputs are varied together. I tried to run this test at 100kHz to accentuate any phase error (*Fig. III-17*). This curve shows just how sensitive phase shift is in terms of the accuracies plotted on the performance figures. When I turned the test pot to its center point to give 2V input, it showed its maximum source resistance of 1.25kΩ. The test lead capacity and this resistance produced a 10-degree phase error. Assuming only one breakpoint, it would be located at about 550kHz, requiring something like 230pF.

Continued on page 43

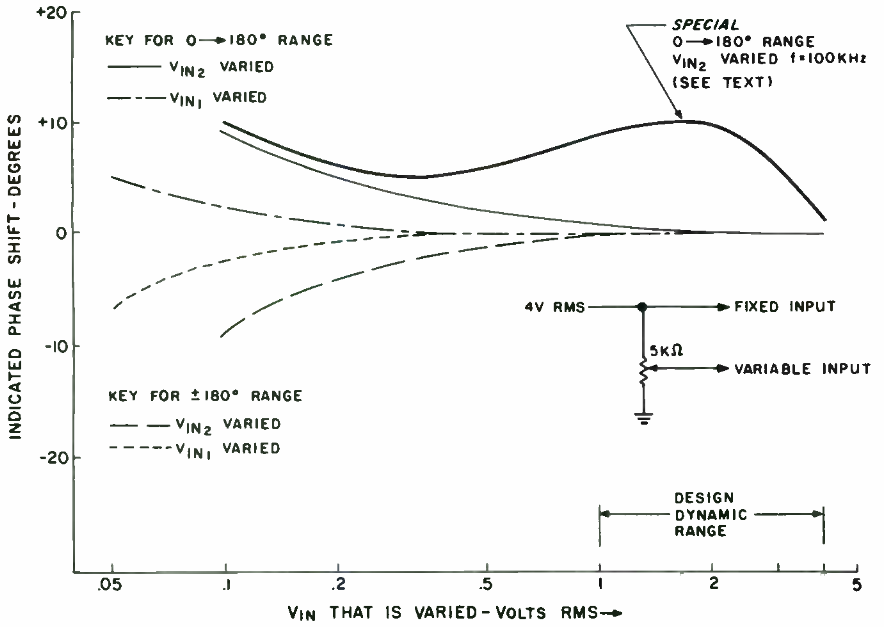


FIGURE III-17: Phase meter performance with one input level varied. Fixed input equals 4V RMS; frequency equals 1kHz, except for one special case. The 0-to-180-degree range is shown going positive for convenience.

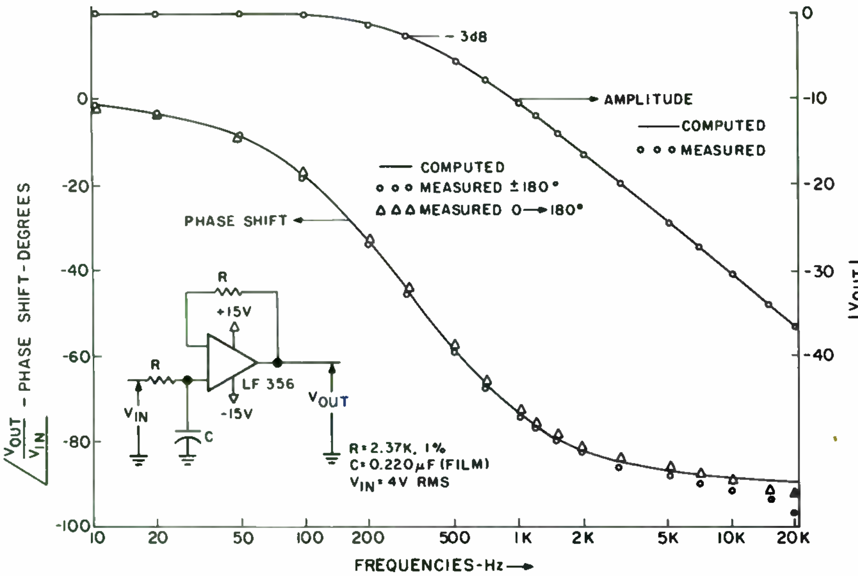


FIGURE III-18: Phase meter performance with the test circuit.

CIRCUIT BOARDS

Old Colony's Boards are made of top quality epoxy glass, 2 oz. copper, reflowed solder coated material for ease of constructing projects which have appeared in **Audio Amateur** and **Speaker Builder** magazines. The builder needs the original article (indicated by the date in brackets, i.e. 3:79 for articles in **Audio Amateur** and SB 4:80 for those in **Speaker Builder**) to construct the projects.

C-4: ELECTRONIC CROSSOVER (DG-13R) New 2 × 3½" board takes 8 pin DIPs, Ten eyelets for variable components. [2:72] Each **4.50**

D-1: HERMEYER ELECTROSTATIC AMPLIFIER II. [3:73] Two sided with shields and gold plated fingers. **Closeout.** Each **$5.00** Pair **$9.00**

F-1: BILATERAL CLIPPING INDICATOR. (CB-1) 2 × 2½" [3:75] Single channel. Each **$3.00** Pair **$5.00**

F-6: JUNG 30Hz FILTER/CROSSOVER (WJ-3) 3 × 3" [4:75] High pass or universal filter or crossover. Each **$5.50**

G-2: PETZOLD WHITE NOISE GENERATOR & PINK FILTER. (JP-1) 2½ × 3½" [3:76] Each **$5.00**

H-2: JUNG SPEAKER SAVER. (WJ-4) 3¼ × 5¼" [3:77] Each **$7.00**

H-3: HERMEYER ELECTROSTATIC AMP BOARDS. (ESA-3) Set of three boards with plug-in edges for one channel. [3:77] Set **$19.00**

J-6: SCHROEDER CAPACITOR CHECKER. (CT-10) [4:78] 3¼ × 6" Each **$7.25**

K-3: CRAWFORD WARBLER 3¼ × 3⅜ [1:79] Each **$6.00**

K-6: TUBE CROSSOVER. 2 × 4½" [3:79] Two needed per 2-way channel. Each **$4.25** Four **$13.00**

K-7: TUBE X-OVER POWER SUPPLY. 5 × 5⅝" [3:79] Each **$7.00**

K-12: MacARTHUR LED POWER METER. 5½ × 8¼" [4:79] Two sided, two channel. Each **$16.00**

L-2: WHITE LED OVERLOAD & PEAK METER. 3 × 6" [1:80] One channel. Each **$10.50**

L-6: MASTEL TONE BURST GENERATOR. 3½ × 6⅝" [2:80]. Each **$8.50**

L-9: MASTEL PHASE METER 6⅝ × 2⅝" [4/80] Each **$8.00**

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Tools, Tips & Techniques

Iron-Core Choke Conversion

Obtaining air-core coils for crossovers can be expensive. In addition, coils that have suitably low DC resistance can be quite large. Coils random-wound by hand might have a greater DC resistance than machine-wound coils, simply because the coupling between windings is not as uniform in the random windings.

I have found a source for machine-wound coils in the power-supply chokes that are made for high-current power supplies. (See *Fig. 1.*) When the iron core is removed, the remaining air-core coil might be suitable for audio use. To be suitable for conversion, the choke must have a rating greater than 2A and a DC resistance of 0.75Ω or less. These values are generally printed on the outer wrapper. The top set of "I" plates must also be separate from the side "E" plates, not interleaved with them.

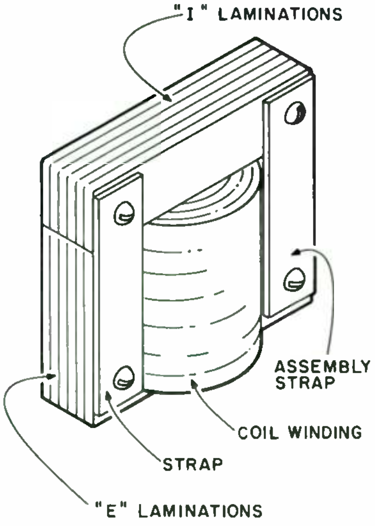

FIGURE 1: Typical iron-core choke construction.

These chokes usually have mounting brackets whose screws pass through the plates. Remove these. Clamp the closed side of the "E" plates in a vise. Pry up the "I" section with a screwdriver or slender crowbar. After you have broken the shellac between the "E" and "I" plates, the "I" section should come away easily. Most chokes have small wooden wedges between the coil and the core that must be removed. A small pair of locking needle-nosed pliers helps, or you may drive a thin-bladed knife into the wedges until they split and fall out. If you cannot withdraw the coil after the wedges come out, the laminations of the core and the side plates (a series of stacked E-shaped pieces) might have to be loosened one by one.

After the coil is free, measure it for its air-core value. Because of the variations in cores and windings, it is not possible to translate nominal iron-core values into air-core values. The first coil I disassembled was rated at 35mH; without its iron core, it measured at 1mH. If the value is too large, you may remove the windings, turn by turn, until you achieve the proper value.

Scott Ellis
Ocean Springs, MS 39564

Large Speaker Wire Connections

Those of you who, like myself, are proponents of large-diameter speaker wire might have experienced difficulty in making connections to speakers and amplifiers. The terminals on most units are just not big enough to accept wire much larger than 16 gauge.

I use 10-gauge wire and have had success with the following solution. Remove about ¾ inch of insulation from the ends of the wire. Twist the wire strands at each end to make a compact bundle. Heat the wire ends with a soldering iron and apply sufficient solder to bind the strands together in a rigid mass (rigid when the solder cools). You can then rotate the wire ends against a grinding wheel to reduce the diameter of about a ½-inch length (measured from the wire end) to a size that will fit your terminals.

The solder will eliminate stray strands of wire, make the ends rigid for grinding to a smaller diameter and minimize current loss at the transition in diameters. In addition to fitting terminals on your equipment, the reduced diameter will permit the installation of a variety of connectors, including spade lugs, ring terminals and banana plugs, for easier connection to speakers.

James T. Frane
Orinda, CA 94563

Easy L-Pad

This simple, inexpensive, three-position L-pad attenuator uses a slide switch and fixed resistors. The switch is a double-pole, three-throw, on-on-on type, which has two rows of four terminals. Each switch position connects one adjacent pair of terminals. Stackpole S51 or S91 (miniature) series switches, which are available from Allied, are suitable. Other brands and sources exist, but I have found this type of switch in grab bags from Radio Shack.

The attenuator is wired as shown in *Fig. 1.* In the upper (U) position, the crossover is connected directly to the speaker. In the middle (M) position, R3 is shorted and R2 is grounded so that R1 and R2 form an L-pad. In the lower (L) position, only R4 is grounded so that R1 and R3 in series with R4 form an L-pad. You can make all connections directly to the switch terminals. For best results, use 1 to 5W resistors, depending on

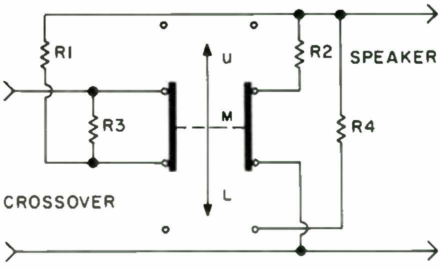

FIGURE 1: This three-position L-pad attenuator is simple and inexpensive.

Continued on page 42

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 10½" 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 ±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 Compandor 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 Quad-pod, 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, Borbely 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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Craftsman's Corner

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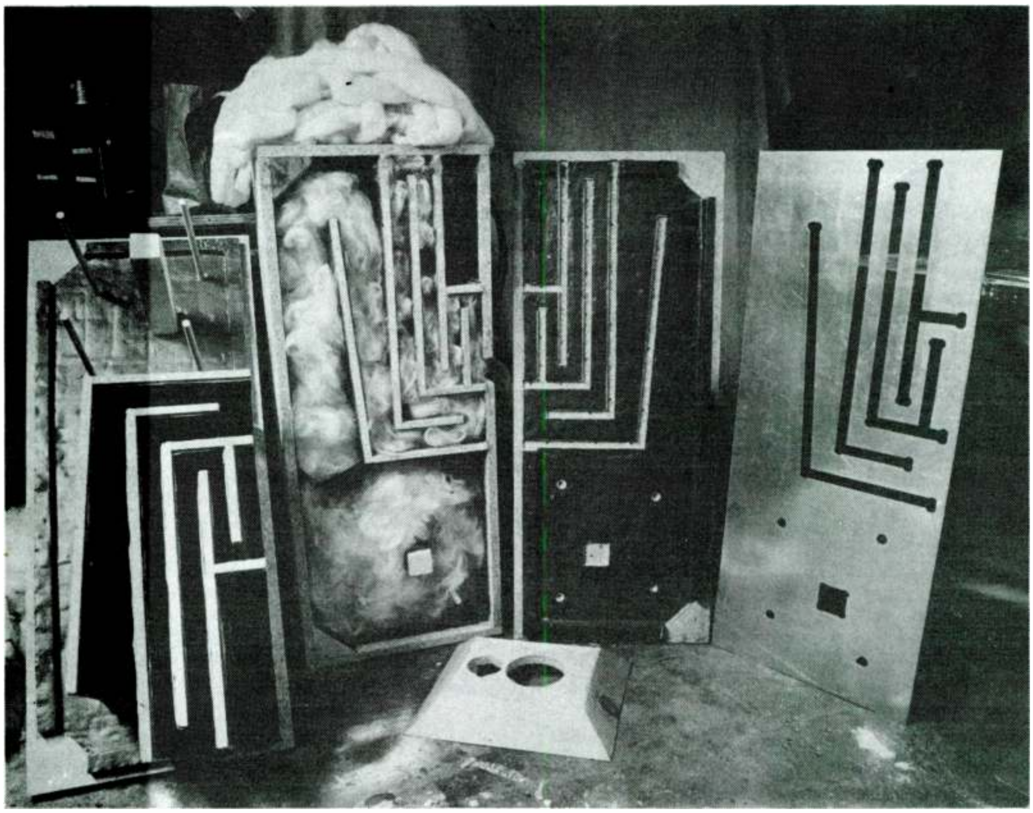


This photo, taken by Harold Holden, shows the transmission line in the making. The shiny lead sheet at the right functions as a template as well as effective resonance damping.

My loudspeaker is basically a lengthened Webb transmission line (*TAA* 1/75, p. 3). The line length is approximately 12 feet for 23Hz, ¼ wave fundamental resonance. Many of the tapering details, including the lower chamber, are identical to those in Webb's design. The midrange is in a sealed box, which I moved to the top and mounted in a low-diffraction truncated pyramid shape. The sides are 1⅛-inch high-density particle board, routed with the aid of an aluminum routing template (far right) to accept internal panels. I used long-fiber wool for the absorbent.

Martin Colloms discusses lead damping, a technique I used, in his book, *High Performance Loudspeakers* (Wiley & Sons). Lead sheeting is commercially available in 4-foot-wide rolls, 1/32-inch thick. It is called "acoustalead" and is used for soundproofing in industrial noise applications. It is normally mounted on a lightweight foam. I bonded ⅛-inch polyurethane to the lead with Scotch 467 high-performance adhesive, a thin double-stick tape available in 10-inch-wide rolls. I used the same adhesive to attach the two-layer damping to the cabinet interior. The lead comes with a coating that minimizes direct contact with the skin, so you need not take any special precautions other than thoroughly washing your hands.

This is a three-way system with sophisticated fourth-order electronic crossover and time delay networks (see Linkwitz, *Wireless World*, May–December 1978; *SB* 2/80, p. 12; 3/80, p. 9; 4/80, p. 14). The circuit uses op amps with discrete input transistors that are bridged to run Class A. I positioned the drive units acoustically close together (compared to the crossover frequencies) to yield a virtually hemispherical dispersion pattern.

These speakers are still not completed, so I'll reserve final comment on their success until I have a chance to perform extensive tests.

Paul Grandmont
Wrentham, MA 02093

SB Mailbox

CORRECTION: KOONCE VOLTMETER

*We have found an error in G.R. Koonce's "Build Your Own Voltmeter" (*SB *3/83, p. 12). The stuffing guides in* Figs. I-15a *and* I-15b *(p. 22) were printed with the wrong board patterns. The corrected stuffing guides appear to the right. Also note the change in the caption for* Fig. I-15b*: this stuffing guide is for the 7900* negative *regulator,* not *the positive, as it was originally labeled. We apologize for any inconvenience this might have caused.—Ed.*

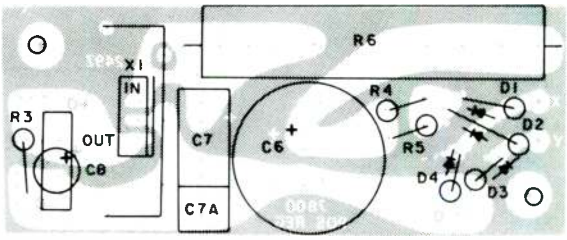


FIGURE I-15a: Stuffing guide for 7800 positive regulator. See Fig. I-17 for board pattern (No. 249Z).

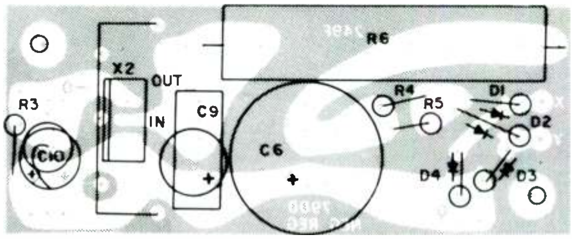


FIGURE I-15b: Stuffing guide for 7900 negative regulator. See Fig. I-17 for board pattern (No. 249F).

LINKWITZ DESIGN DEVELOPMENTS

I have constructed a system based on Siegfried Linkwitz's article on "A Three-Enclosure Loudspeaker System: Part III" (*SB* 4/80, p. 14). My design appeared as a "Designer's Corner" in *SB* 1/83 (p. 36). I have several questions, however, about this type of design.

First, what effect will the high-frequency roll-off of the midrange unit have? Consider the KEF B110, which I believe exhibits a roll-off above 6kHz, having a second-order roll-off. This is two octaves above a 1.5kHz crossover point, which might not be significant. With a higher crossover frequency, however, a shelving of the low-pass filter to the midrange might be desirable. Should the midrange have a true fourth-order acoustic response, and if so, what circuit topology should I use for the low-pass filter section? Also, how would I determine the driver's high-frequency characteristics at home, as the impedance curve in this instance is not relevant?

Second, both KEF and Meridian produce systems with two midrange units in a symmetrical vertical array—i.e., the KEF K1 monitor system and the Meridian midrange system. A higher-power satellite using such a driver layout could be designed, but wouldn't there be some trade-offs? For instance, such a design might produce a narrowing of the vertical radiation pattern's central lobe in the crossover region, as well as possible interference effects between the two midrange units. In the Meridian M10, both midranges are angled, one up and one down.

I must say that the small size of my satellites and the method of hanging them from the ceiling make them very attractive and practical. I should also say that my system handles compact disks very well, having adequate dynamic range in a domestic situation and superb transient performance.

On the subject of satellites, I intend to build ellipsoid-shaped enclosures and have experimented with various materials. Paper pulp (derived from newspapers) is one possibility, but the fibers must be broken down well. Also, you must add wallpaper starch glue and some plaster (Gypsum powder) to make a claylike mix. You would have to make molds of the enclosure in two halves, split down the major axis. Wall thickness should be approximately 20mm, thinned down around the B110 basket flange to avoid constriction of the chassis. Quite a bit of work is involved in such an enclosure, but reduced diffraction, standing waves and wall resonance are worth the effort.

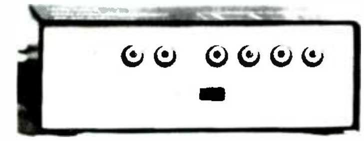
John Kasowicz
Melbourne, Australia

Mr. Linkwitz replies:

Mr. Kasowicz has raised a number of interesting questions, which I will answer based on my experience and whatever information I have.

First, the KEF B110 rolls off about 28dB between 6kHz and 12kHz. It also has a resonance at approximately 4.5kHz, with an associated response peak of a few decibels. This applies to the SP1003. The SP1057 is a little smoother, but not audibly different when crossed over at 1.5kHz.

The effect of this frequency response is a phase lag of about 20 degrees at 1.5kHz, which in turn produces an error of –0.13dB in the summation of midrange and tweeter sound pressures. This is insignificant com-



SB Mailbox

pared to other possible errors, so no special correction is necessary. At 3kHz, though, the phase shift is 45 to 60 degrees, which must be compensated for with appropriate phase lead from the crossover.

You could use the circuit in Fig. 25 *of my article (SB 4/80, p. 16) as a first-order approximation to the shelving needed for the midrange low-pass filter. This gets tricky, and I prefer the lower crossover frequency. Furthermore, at 1.5kHz the drivers are acoustically half as far apart as at 3kHz, and the radiation pattern is wider. The simplest and most revealing way I have found to determine the drivers' high-frequency response is to use the shaped tone-burst test (JAES (Volume 28, Number 4), April 1980, pp. 250–258).*

Second, the two-midrange-plus-tweeter array has some attractive features, but also some drawbacks. For example, you can build a respectable two-way system by equalizing the low end to 60Hz (−3dB) or build a high-power system where the satellites are crossed over to woofers at 150Hz. The trade-off, as Mr. Kasowicz points out, is a narrowing of the vertical radiation pattern's central lobe.

With two B110s at 9-inch intervals, the crossover should not be higher than 1.5kHz. Having the two midrange drivers arranged symmetrically on the front baffle emphasizes diffraction effects from the baffle edges, and the on-axis response might not be as smooth as the system described in my article. You can determine the optimum baffle proportions experimentally using the shaped tone-burst test.

The symmetrical midrange placement has the worst effect upon the tweeter frequency response in the 1.5 to 6kHz region, where the tweeter sees the adjacent cavities from the midrange cones. The symmetry emphasizes this effect. I cannot say how audible these measurable frequency response irregularities really are. I also do not know what effect the angling of the midrange units in the Meridian M10 has, but I suspect very little.

Despite these problems, I have used a symmetrical driver arrangement in my system for two and a half years. I built it because I wanted to test the audibility of different crossover networks without vertical shifts in the radiation pattern's central lobe. For this driver arrangement, the maximum radiation occurs on-axis even if the tweeter and midrange are not in phase. The crossovers are at 1.6kHz and either 24dB/octave, 18dB/octave or delay-derived. The system is, therefore, either a second-order all-pass or a first-order all-pass at 1.6kHz. For the delay-derived crossover, it shows no addi-

tional phase shift at 1.6kHz. The somewhat surprising result is that people cannot hear a difference between the networks on program material. Nonlinear phase shift in this region, if gradual, seems inaudible. This confirms earlier tests I have made.

Given that Mr. Kasowicz's system has adequate dynamic range for compact disks, he could expect some reduction in midrange nonlinearity at high levels by using two drivers and doing some extra work to find the optimum enclosure shape.

Finally, the main advantages of an ellipsoidal enclosure seem to be reduced diffraction effects and increased stiffness of the walls. I shied away from it because of construction difficulties and questionable aesthetics in an otherwise rectangular environment. You can obtain stiffness in a rectangular enclosure by using internal cross-bracing with ¾-inch-thick particle board panels. With ¾-inch-thick outside walls, braced so that there is no unbraced area larger than approximately 4 by 4 inches, panel resonances are pushed above 1.5kHz, which is outside the midrange excitation range.

Diffraction effects are not always as expected. For example, a point source on a sphere has a very irregular response off-axis. Using 45-degree-angled side panels and appropriate spacing of the midrange and tweeter from the panel edges can give a good on-axis and off-axis response. Because each driver has its own inherent directionality and sees the box only over its lower-frequency range, the resulting diffraction effects are best determined by measurement.

CROSSOVER CALL ANSWERED

I am writing in response to Bill Norris's "Passive Crossover Hunt" letter in *SB* 2/83 (p. 35). Having built custom vented 8, 10 and 12-inch subwoofer systems, two of which have hand-built crossovers, I would like to pass on the following information.

First, I am not sure what Mr. Norris wants to do, so I will offer a couple of alternatives. If he needs a dividing network *before* final amplification (i.e., between the preamp and amps), I would suggest the information that DeCoursey Lab (11828 Jefferson Blvd., Culver City, CA 90230) offers and go with an active crossover. This maintains better circuit integrity and omits passive unit insertion losses.

On the other hand, if he wants to divide *after* amplification via an internal passive crossover, the Polk LF14 should have the correct low-pass filter. The Polk spec sheet shows where the LF14 crosses over. All Mr. Norris need do for a −6dB/octave first-order network to his satellites is to use Polk's roll-off number to calculate (with the −6dB/octave formula) the needed capacitance to run in parallel between his SMG's positive terminal and respective amplifier lead. Considering most subwoofer impedance peaks, I prefer woofer roll-off between 80Hz (at −6dB/octave) and 125Hz (at −12dB/octave) for good bass response and imaging. Depending on the satellites' power rating and amplification, most systems can be crossed in at the first-order formula.

As for Mr. Norris's comment about the Polk drivers appearing to be the same as the full-range systems, don't bet on it. I have never seen the complete drivers, but I would assume that they incorporate some special electrical or physical damping of the drivers.

Finally, if Mr. Norris wants to modify or replace his crossovers, I would recommend SRC Audio parts or complete units, as they offer comparatively low DCR and high saturation. As for circuit topology, any of David B. Weems's publications (3238 Towerwood Ave., Dallas, TX 75234) would be helpful in passive crossover design.

Doug Cabaniss
Sullivan, IN 47882

IN DEFENSE OF McGEE, CDs

I love your magazine. Although half of it is over my head technically, I enjoy seeing what others are doing.

I was, however, dismayed to read some negative comments about McGee Electronics. People must remember that McGee is in business, and you get what you pay for. If I want a cheap tweeter, 99¢ is a great bargain. If I want the latest in ribbon tweeters, I think $40 is hard to beat, considering what some other companies are charging for the same item. McGee does handle Peerless, Electro-Voice and JBL, so what's the beef?

On another note, I was lucky enough to squirrel away enough Christmas money this year to add a new digital compact disk player to my system. Even playing disks made from popular analog masters is a joy. It offers everything LPs were supposed to provide, but without all the disappointments and disadvantages you usually encounter with them. The digitally mastered disks have an abundance of highs, lows and dynamics (found mostly in the classical selections), which does a lot to sweeten the sound of a speaker system.

Of course, compact disks are not in-

SB *Mailbox*

fallible: I have encountered acoustic feedback, which causes mistracking that sounds like the old stylus popping out of the groove. After moving the unit onto a more solid foundation and weighting the top with a cassette deck (being careful not to cover the unit's vent holes), I seem to have solved the problem. Incidentally, you can check a disk player for stability by tapping on the top or side while it is in operation.

Although I agree that we still have a long way to go in building and developing the "ideal" speaker (after all, that's why speaker building is such an intriguing hobby), I am proud that Philips and Sony have finally given us a format that allows us to produce music the way it was meant to be.

Clifford L. Dunning
Portsmouth, NH 03801

THE PERFECT FILTER?

I read with interest Nelson Pass's article on loudspeaker system crossovers (*SB* 2/82, p. 12). The electronic, or active, alternative seems the best way to go (as opposed to the passive, high-level alternative) for many reasons, not the least of which is its flexibility. Mr. Pass concluded by saying that even if the perfect electronic filter exists (as in the case of the asymmetrical or phase-coherent filter), there is no perfect acoustical response because the drivers themselves have a filter-type response that alters the electronic filter outputs.

I devised a form of electronic filter that can compensate for the acoustical response of the drivers. If you want any type of crossover filter to be effective in a two-way system, the woofer and tweeter responses must overlap. (See *Fig. 1.*) Theoretically, if you want a perfect acoustical response in the crossover region, you must compensate for the error of the woofer in the high frequencies (EW_h) and the error of the tweeter in the low frequencies (ET_ℓ). In this crossover region, the woofer is a low-pass filter response (WF_h), and the tweeter is a high-pass filter response (TF_ℓ), so you have:

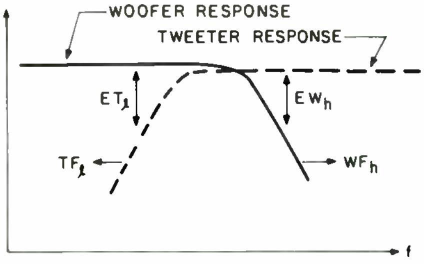


FIGURE 1: For an effective crossover filter, the woofer and tweeter responses must overlap.

$$ET_\ell = 1 - TF_\ell$$

$$EW_h = 1 - WF_h$$

This is true in amplitude as well as phase.

Because of the overlapping, the woofer can compensate for the tweeter error, and the tweeter can compensate for the woofer error. Here is the way to do it:

1. In the basic crossover, F is the high-pass response (e.g., 18dB/octave at 3,500Hz) that you want to give the tweeter. (See *Fig. 2.*) For this circuit's amplitude and phase,

$$T + W = 1.$$

2. In the real world, a tweeter has its own TF_ℓ response, for example, a 1kHz resonant frequency (*Fig. 1*). You can add a filter (TF_ℓ) to the basic circuit (TF_ℓ being a 12dB/octave, 1kHz high-pass filter) as in *Fig. 3*. Now, if the woofer is perfect (i.e., $EW_h = 0$, as in *Fig.2*),

$$T_{\text{acoustical}} + W_{\text{acoustical}} = 1$$

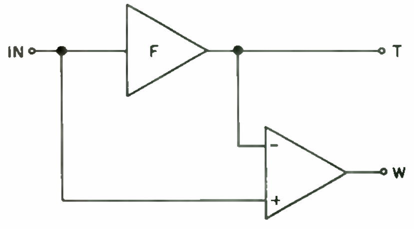


FIGURE 2: Basic crossover circuit.

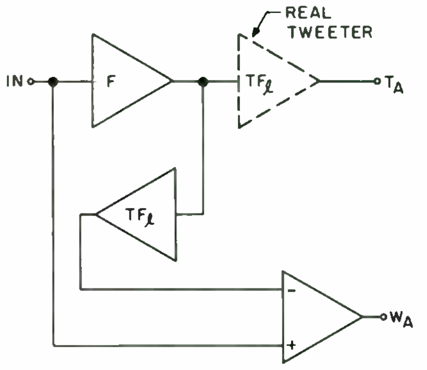


FIGURE 3: Crossover circuit with compensated tweeter.

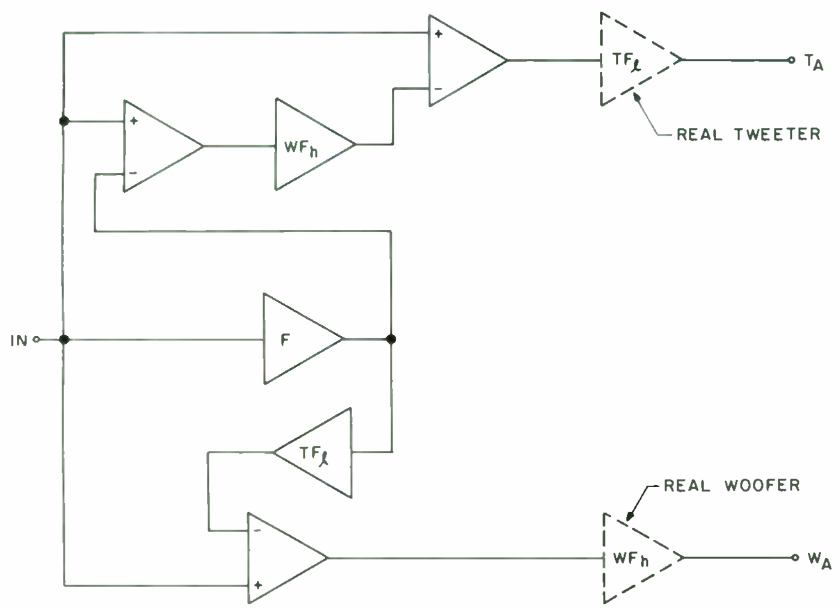


FIGURE 4: Crossover circuit with compensated tweeter and woofer.

so that the acoustical response is perfect.

3. You can add the woofer compensation the same way. In the high frequencies, the woofer can cut, for example, at 5kHz, so you add a filter (WF_h) to the circuit. As you can see in *Fig. 4*, the crossover circuit becomes a bit more complex. For this circuit,

$$T_{acoustical} + W_{acoustical} = 1$$

provided that there is an overlap in the drivers' own responses and that the crossover's own cut-off frequency is in this overlap. This method does not solve the problem of non-coincident drivers or changing response when off-axis, but it is a valuable step.

Serge Vermette
St. Angele de Laval, Quebec
Canada G0X 2H0

LOOKING AHEAD

I have been reading *SB* since its premier issue and would like to comment on its progress. One of *SB*'s strong points is its coverage of topics such as the Thiele-Small parameters and transmission lines. These articles have had a positive effect on my own designs. The bibliography section also renders a valuable service—i.e., collecting, collating and cataloging new articles in our field and related disciplines. In addition, the articles on active networks have been excellent and reflect author expertise.

Unfortunately, the articles dealing with speaker systems have not been so consistently good. I cannot believe that systems using cheap replacement drivers in cinder blocks and sewer pipes, systems using off-the-shelf crossovers, and designs that were obsolete 20 years ago are what we need in *SB*. Lachrymose tales of adolescent experimenting with cardboard enclosures should give way to more pertinent articles. We all know where we have been in acoustics; now we need to look forward to what we can accomplish in the future.

Scott Ellis
Ocean Springs, MS 39564

Reader Ellis singles out two speaker system articles (out of 14) in SB's first three years as being less than optimum. If he would read the "cinder block and sewer pipe" articles (2/81, p. 7; 3/81, p. 7) a bit more carefully, he would find they do not contain "cheap replacement drivers." Furthermore, both are well designed and each had a special intended use that seemed quite justified to us. His reference to "lachrymose tales" is an obvious allusion to Bob Carlberg's lighthearted odyssey, which is, we hope, humorous and entertaining.—Ed.

DELIGHTFUL DISCOVERY

Discovering your fine magazine last year was a delight. I am a senior citizen near-

SB Mailbox

ing 68. Ever since I was a teen-ager, I have messed with cabinets, modified the surround, experimented with an 18-inch bass driver, loaded the shelf with Wharfedale books and built a low, low frequency (2Hz?) hi-fi, using a clothes closet as an infinite baffle with three-way crossovers. On my own, I found out how to use a super low 8 or 10-inch enclosure and stuff it tightly with an old pillow or chunks of polyurethane (foam). This lowered the system resonance surprisingly. Now, hot diggity! Your 1983 issues recognize and discuss this effect.

I have the best of all worlds: 50 years a working musician, 50 years an electrical engineer, 50 years a "ham." Best regards!

Robert E. Mack
Orlando, FL 32810

PROSPECTIVE BUILDER

I enjoy *Speaker Builder* even though I have not built anything yet. Initially I subscribed to learn more about speakers so that I could make a more informed purchase. To this end, I recently purchased a set of Thiel 03a speakers, but I am still interested in building my own speakers.

I found your articles about the Linkwitz three-speaker system (2/80, p. 12; 3/80, p. 9; 4/80, p. 14) and Gary Galo's transmission line speaker (1/82, p. 7; 2/82, p. 24) quite interesting. I hope that

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Tools, Tips & Techniques

Continued from page 34

More attenuation produces more dissipation. I have had no trouble with 2W resistors on 0, 4 and 8dB three-position L-pads used on my midrange and tweeter with a 30W amplifier.

Table 1 gives resistor values suitable for 1 to 5dB steps and 8Ω impedance. I have rounded these values to the nearest standard value. You can obtain values for other impedances by scaling: times 2 for 16Ω, divide by 2 for 4Ω. You can find other attenuation values by using Glenn Phillips' formula (*SB* 2/83, p. 20). R1 and R2 are the L-pad resistance values for the medium attenuation position. R4 is the shunt resistance for the high attenuation position, and R3 is the high attenuation series resistance minus the value of R1.

TABLE 1

RESISTOR VALUES FOR 8Ω

Step	1dB	2dB	3dB	4dB	5dB
R1	0.68	1.5	2.2	2.7	3.3
R2	68	33	22	15	12
R3	0.68	1.5	1.8	2.2	2.2
R4	33	15	7.5	5.6	3.9

Thomas L. Clarke
Miami, FL 33143

(*Note: the switch used is a low-power device. It is inadvisable to use this type on amplifier powers higher than 25 to 30W.—Ed.*)

BOXRESPONSE

Continued from page 18

reinforces the driver output at a high frequency, and the filter substantially attenuates all frequencies below 30Hz. The penalty is an f_3 of about 35Hz, which is somewhat higher than that for systems 3 and 4. This system can be driven at the full 100W input power without fear of nonlinear cone displacement. It handles Telarc's *1812 Overture* quite impressively. Finally, note that a 3-inch vent is adequate here.

While writing this article, I was tempted to explore in detail the development of the program and the possible implications of the data it produces. The length would have been excessive, however, so I concentrated on what the program does and how to use it. I would welcome questions and suggestions from readers on program development or design implications, since they might reveal topics of widespread interest. (Remember to include a stamped, self-addressed envelope.)

REFERENCES

1. Keele, D.B. Jr., VBOXRES.BAS, Ver. 1.2, a computer program, 1979.
2. Elliot, B.J., "Accurate Methods for Determining the Low-Frequency Parameters of Electro-Mechanical Acoustic Transducers with BLI Excitation," *AES Preprint No. 1432 (K-5)*, presented at the 61st AES Convention, November 3-6, 1978.
3. Gander, M.R., "Moving-Coil Loudspeaker Topology as an Indicator of Linear Excursion Capability," *AES Preprint No. 1554 (A-4)*, presented at the 64th AES Convention, November 2-5, 1978.

Editorial

Continued from page 6

as is evident in the widespread fear of computers. One-third of the people whose work suddenly requires computer literacy experience this phobia. How ironic that IBM, in searching for a mythological symbol to advertise the PC, took a character from the early silent film *Modern Times* and turned him inside out. Charlie Chaplin, who was most terrified and overwhelmed by technology in the film, would never believe what he has become in the world of Big Blue.

In referring to this problem of computer phobia, *Psychology Today* recently reported that Boston's First National Bank has set up private computer instruction rooms for educating executives and is loaning them take-home machines. Commenting on the success of the program, John Martin, the bank's first vice president, says "...a little knowledge and interest will conquer their fears."

Our sentiments exactly.—E.T.D.

you will offer more articles on multi-amp speaker systems and subwoofers. I must admit to a certain amount of "math-phobia" about these articles, however. I am quite concerned that a "simple" math error could result in a considerable loss in time and money. I wish I could find an easier, more reassuring way of designing a system.

With *Speaker Builder's* guidance, I hope that I will be able to build a set of speakers that is not only better than the one I have now, but costs less than a similar mass-produced set would.

Eddy Henneman
Richfield, MN 55423

PHASE METER

Continued from page 33

Phase is very sensitive, and the tests indicate a high degree of accuracy.

So far, the tests have shown how well the PM holds zero when it should, but not how well it will measure other phase angles. Unfortunately, I do not own a good scope for making accurate phase measurements for comparison, so I decided to compare the PM performance with computed performance for a test circuit. *Figure III-18* shows the test circuit and its results.

The circuit is a passive, single-pole, low-pass section with a buffer. In the computations, I assumed that the LF 356 buffer was ideal. I measured the amplitude response to verify whether the circuit behaved as computed, and results indicated that it did. The PM results on both ranges are shown against the computer results. The error does not exceed $\cong 2$ degrees until about 7kHz, when V_{out} is down 36dB. Undoubtedly, the PM measures the test circuit properly throughout the audio frequency band of 20Hz to 20kHz.

Next time, Mr. Koonce will take a break from his test equipment construction series to discuss closed box alignment. Writing from the standpoint of a homebuilder, he will explain parameter trade-offs as a function of total system Q, while keeping the Thiele/Small driver parameters fixed.

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Mayware Formula IV with lightened headshell, damped arm tube, excellent, $70; Connoiseur BDI-K turntable in custom base, like new, $45; Heathkit IO-4540 oscilloscope, DC-5MHz, triggered sweep, with cables, manuals, 10X probe, like new, $150; 1 pair KEF B200 SP1014 mid-woofers, excellent, $75. Ronald A. Howanec, 518 14th St., Virginia Beach, VA 23451, (804) 491-2731.

Infinity IRS style EMIT tweeters, $17.50 each; replacement diaphragms for above tweeters, $8 each; reworked bipolar EMIT tweeters as above, $35 each; Sherwood SEL300 analog tuner with digital display and walnut cabinet, $275; Pioneer AD320 auto amplifier, $30. Michael Marks, 8206 Townsend St., Apt. #201, Fairfax, VA 22031, (703) 573-4912.

A complete set of speakers, crossovers and L-pads for a pair of Klipsch-type folded horn speakers (Speakerlab). These are new and in the original boxes. W-1508 15-inch woofers, HD-350 midrange drivers with exponential horns, HT 3500 tweeter with horns. All for $500. Call Joel Seidenberg, (201) 257-5189 evenings.

Peerless KJ20 PMR 2″ dome mids, $38/pair; PHT 19 tweeters, $19/pair; Audax MHD17-HR377SM 6½″ cone mids, $62/pair; MHD12P2SFSM 4½″ cone mids, $28/pair; HD13D37 1½″ dome mids, $42/pair. Steve Fritz, 5227 Calle Cristobal, Santa Barbara, CA 93111, (805) 964-0245, weekends only.

Ace Transient Perfect Crossover (new), $125; Gauss 15″ bass speaker, Qts = .35, Fe = 25Hz, Vas = 15.3 cu. ft.; 4″ voice coil and 400W RMS power handling (new), $280; drivers for AR-3a (complete set), used—make offer. Fred Janosky, RR 665 N. Wyoming St., Hazelton, PA 18201, (215) 374-0673 after 4:30pm.

Pair Acoustic Research AR 3AS, mint condition, asking $350. Please write or call Mike Johnson, 1149 N 850 W, Provo, UT 84601, (801) 373-7231.

Pair Dyna MK III PC1 blanks with new 6AN8's, $15; Dyna ST-70 PC3 blank with new 7199's, $20; six new GE1ZBY7A's for HK Citation 2, $20; Lambda rackmount HV supply with voltage and current meters, 350-550V DC @ 400mA, $125; Lambda rackmount HV supply with voltage and current meters, 350-550V DC @ 200mA, $100. Wayne Robertson, (617) 593-5937, 8-10pm EST.

Dual 522 belt drive, fully automatic single play, base and dust cover, with Stanton 681EE, near mint, $120, includes shipping. Rafael Lopez, 3340 NW 4th St., Miami, FL 33125.

Complete ESL amps, made by RTR for their DR-1, $1800; speaker, amps have 350Hz crossover for woofer, $95 each; Altec line amps, $20 (tubes); 9-16 power transformers, 60V-CT sec., $20 each; Ampex R/R 440-servo, make offer. Joe Stephens, 41285 Crest Dr., Hemet, CA 92344, (714) 658-9575.

Builder designed cabinets for KEF B-110's/T27's. Built by cabinet maker using ¾″ particle board. Rosewood formica, removable front baffle, speaker holes countersunk to KEF specs. T-nuts installed, banana plug terminals, ½″ corner braced throughout. Cabinets are 12″ x 8″ x 8″. $200? Walt Fleming, RFD #7, Norwich, CT 06360, (203) 889-1937.

Altec horns, 2 MR931-12 Mantaray horns without drivers, $50 for both. Includes shipping. Donald Sanford, 44 Cedar Glen, Port Angeles, WA 98362.

WANTED

Help! Does anyone have a schematic or other material for a Fisher model 500 monophonic tube receiver, circa 1955? Please don't confuse this with the 500C, stereo or transistor models. Send specifics and price to Lem Chastain, 7920 4th Ave., Apt. 3, Brooklyn, NY 11209, (212) 745-0131.

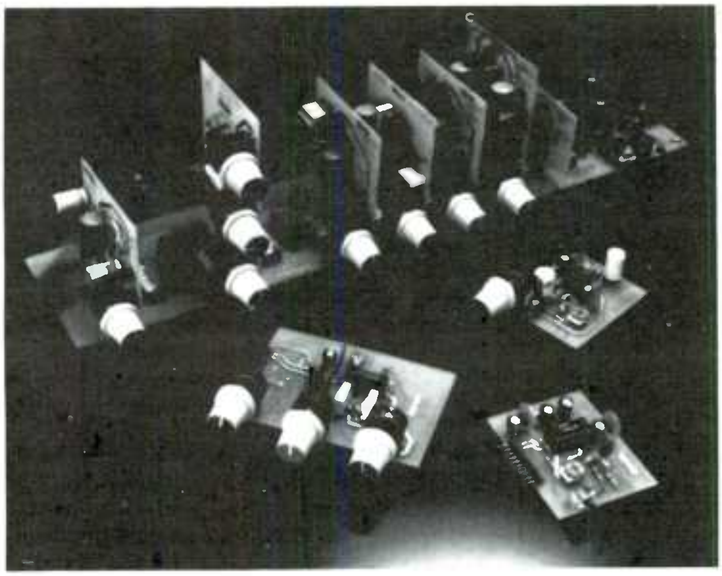
Technical information, reprint copies, design ideas, etc., on turntables (reprint copies of English originated table designs and reviews highly sought). Frank J. Manrique, 1219 Fulbright Ave., Redlands, CA 92373, (714) 793-9209.

Information and/or issues of *Listener's Review Finder*, *Hi-Fi and Video Dealer News* (British), *Stereonotes* (Canadian), *Leisure Time Electronics*, *Critical Record Review*, *Engineering Research*, *Records & Review* and *B-C Reel News #64*. G. Mileon, 14 Border St., Lynn, MA 01905.

Any older tonearm, must be in good working condition and very cheap. Also Sanyo preamp plus C55 with instruction manual. Specify condition and price. Rafael Lopez, 3340 NW 4th St., Miami, FL 33125.

Advertising Index

Plug In To Something Hot!



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G-Man --- Device used in conjunction with headphones for personal listening of musical instruments i.e. guitars, synthesizers, etc.

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Power Factor Controller --- Can save up to 50% of the energy costs for major electrical appliances.

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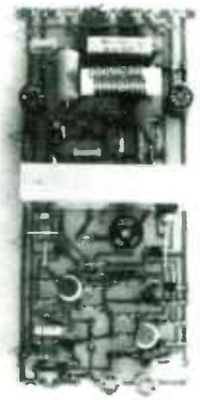
- Rise time 2 micro sec (with LP filter)
- Audio grade resistors and capacitors
- Designed by Erno Borbely

The soft clipping characteristics of tubes, combined with the clarity, precision and long term stability of solid state are the MOSFET's prime benefits. Fast rise time means excellent transient response, giving your system that sharp, well-defined sound you've always wanted. These high performance output devices also pass phase information easily, projecting a stereo image with striking breadth and depth. Top it all off with ultra-low distortion and you have a stellar performer.

The kit uses precision 1% metal film resistors and audio grade capacitors throughout. You will need to provide the case, chassis, line cord, and a small handwound "L" choke, but we supply the circuit boards, electronic parts, heat sinks, and power supply with transformer. For best results use OFHC wiring and Old Colony gold plated connectors.

Leave behind the harshness of bipolar transistor amps and enjoy your favorite music reproduced with exceptional purity. Build this 60W amplifier yourself and have the satisfaction of owning better-sounding audio equipment than you can buy off the shelf.



KP-6 MAKE AN OUTSTANDING MIKE PREAMP

for only $54.50

- Distortion less than 0.04%
- Output noise less than 60dB
- Flat frequency response 20Hz-20kHz (or can be tailored for your own needs)
- Fred Gloeckler's new revision of Advent's classic design

Now you can make clean recordings using this quiet, low-distortion mike preamp. Most tape decks have relatively cheap, noisy mike preamps because few people ever use them, so it's a good place for manufacturers to cut costs. If you've never used your mike inputs, or if you've never made a live recording, you're missing half the fun of owning a tape recorder. And if you've been discouraged by the poor sound quality you get with mikes compared to line level inputs, this outstanding mike preamp is just what you need to enjoy the full benefits of owning a tape deck.

Why bother with live recording? Besides, I don't know any musicians worth recording, you say. The fact is, you will gain a much deeper insight into your system by doing some live recording. To experiment with mike placement and to solve some of the problems of hall acoustics will provide you with a level of understanding which will increase your enjoyment of your system and record collection many times over. And many young musicians in local schools and churches are eager and willing to let you record them, just for the fun of hearing themselves on tape.

The kit includes audio grade capacitors and resistors, circuit board, and input transformers. You provide the case, chassis, appropriate input/output connectors, and power supply (which could be two 9V batteries, or if you have an Advent 201, use its built-in 18V output).

Construct this updated version of Advent's mike preamp and not only save money, but enjoy the full potential of your tape deck, while learning about recorded sound. You will hear your system with new ears after a few recording sessions.

LOW LOSS SUPER CABLES

- Neglex #2534 Cable 60¢/foot
- Mogami Neglex 2534 audio grade cable
- Use Neglex 8mm gold connectors (Old Colony phono plugs are not large enough for Neglex cable)
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- Super flexible—drawn and annealed by Mogami
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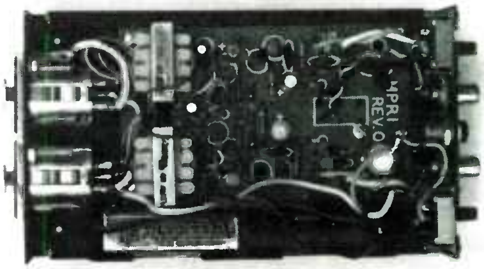
- Two twisted pairs, plus spiral electrostatic shield
- Low capacitance between conductors
- Improved imaging, less fog, better highs



KH-8 MORREY SUPER BUFFER

only $14 (two channels)

- Inexpensive system upgrade
- Removes hidden distortion
- Isolates your tape monitor circuits

What kind of load does your preamp really see? Even with its power off, some of your tape deck's input circuitry can present a distortion-producing load. This distortion, along with tuner signals, often leaks through the tape monitor switch. The Morrey Super Buffer cleans up your system and improves its sound quality by isolating your tape monitor circuit or other impedance matching problems from the rest of your system.

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	KH-8 Morrey Super Buffer $14.00 each	
	ft. Mogami Neglex #2534 Black cable 60¢/ft*	
	ft. Mogami Neglex #2534 Blue cable 60¢/ft*	
	Neglex 7550B Gold Over Brass 8mm Phono Plugs $3.25 each*	
	Total	

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