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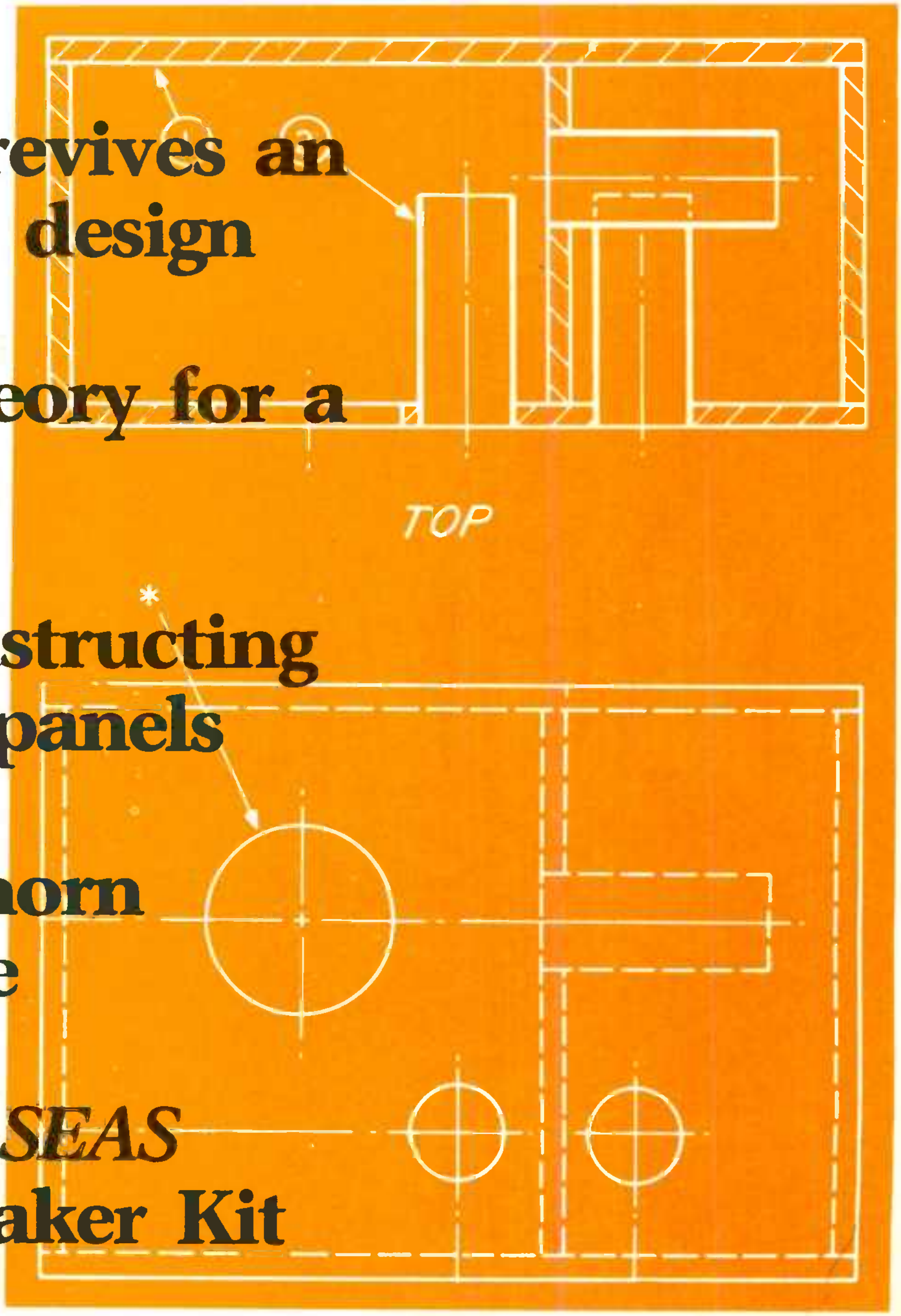
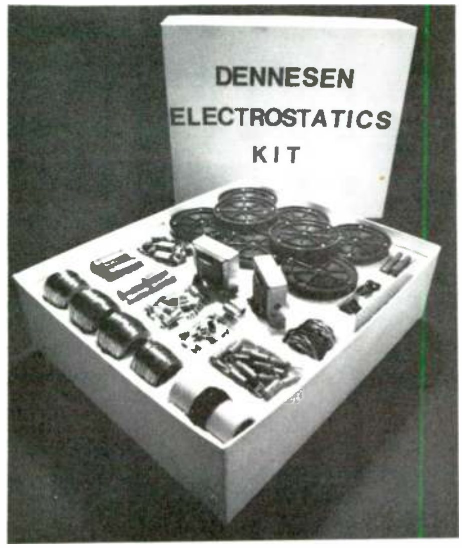
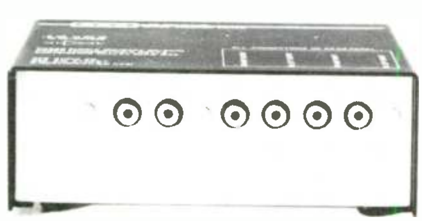


Good News



Dennesen is a new name on the horizon for audiophiles and offer some tantalizing prospects to speaker builders. Their Electrostatic speaker kit (pictured below) is a rather unusual looking collection of parts. We asked the company for more information and the photo is what we received. If your curiosity is aroused you may write to this shy company at Box 51, Beverly, MA 01915. We would advise you to wait patiently for some sort of full information on the kit, however. We are asking for a review sample just to satisfy our own curiosity.



Electronic crossovers are becoming steadily more popular and **Ace Audio** now offers one for subwoofer users that can be ordered as kit or ready-built and in a variety of crossover points. Their 6500-DSB comes with a standard 100Hz setting, 12dB per octave, Bessel configuration. It can be supplied on special order with other frequencies from 40 to 200Hz, and level controls are also available as an option. Full details are available from Ace at 532-5th St., East Northport, NY 11731.

Polypropylene is certainly making a name for itself in the capacitor world and now **KLH** is bringing out a 3-way speaker system, their KLH-150, with cones of this light, stiffer-than-paper, and acoustically dead material. KLH says that they got the idea of using polypropylene from the BBC who use such cones in their studio monitors. The KLH-150 is a vented system, 21"x10¼"x8½", 200mm woofer, 100mm midrange, 25mm soft dome tweeter, 20-75 watts rating and available in mirror image pairs. For more information write KLH at 145 University Ave., Westwood, MA 02090.

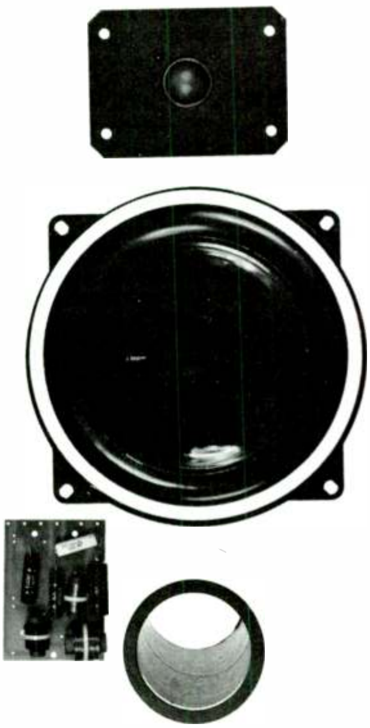
News releases we get from **Eventide Clockworks** (265 W. 54th St., NY, NY 10019) always include the words "the next step." From what I see of their offerings they fulfill the motto rather well. Their model JJ193 digital delay was used at the Winter Olympics which is available in 510ms, 1.022 second and 2.046 second versions. Their CD254 is a cheaper version with 254ms and adjustable for increments of 2ms steps by internal switches. Rack mounted, the units have LED level indicators. Although Eventide claim their units are the least expensive available, they don't tell us what the pricetag is. They will probably tell you if you write them about their offerings, however.

Next to the shower, the automobile is reputed to be the best environment for singing—or listening to music. Auto audio is getting pretty sophisticated these days and also rather expensive. One of the outfits deeply into highway hi-fi is **Visonik** who suggest you put the woofers in the back and their ferro-fluid treated midrange-tweeters in the front doors of your car. The door pair is a 5½"x3" assembly (DMT-1) and the woofer is either a 6" unit (W-620 G-8) or a 6"x9" (W-6920 G-8) to grace the rear of your vehicle's inner space. The woofers have a 100W rating—although the idea of driving anything at that level in a compact seems dangerous even with safety glass. The units are neatly packages for easy installation. More information is available from Visonik, 701 Heinz St., Berkeley, CA 94710.

Spherical enclosures for drivers are evidently ideal according to two of SB's authors, one of them referring back to Olson's work. A French company has finally done something about that interesting fact by offering five spherically housed speaker systems—one of them a semi-sphere to be sure, but a spheroid at least. Polydax is offering the Sonosphere units which range from 120mm to 200mm in size and from $75 to $250 per pair through **Nyco Sound Ltd.,** Box 169, Hanover, NH 03755. Nyco offers full information on the unusual units the largest of which has a frequency response the company says extends from 70Hz to 20kHz.

Spectrum Loudspeakers are a small company operating out of Toledo OH. Their first product is a special mounting ring for damping the diffraction of dome tweeters: one inch domes, to be exact. The rings are ¼" thick felt with a 2" diameter hole cut from the center of a 4" diameter circle. The fit the KEF t-27, Celestion HF2000, SEAS, Peerless and Audax tweeters. Any tweeter which has a recessed dome doesn't seem to improve with the ring, however. The felt is backed with an adhesive protected by a peel-off plastic film. Spectrum also have a new bookshelf speaker Model 108 they will send you details about if you write to them at Caller Box 2998, Toledo, OH 43606.

Bextrene drivers by Audax and a loudspeaker/crossover designer formerly with KEF by name of Malcolm Jones are the vital elements in four new speaker kit offerings from **The Speaker Works**, Box 303, Canaan, NH 03741. Two of the kits are floor-standing, two are bookshelf and they come as three-way or two-way versions. Speaker Works supply the driver/crossover packages with cabinet construction plans. The least expensive of the four is $65. For more information send $2 for The Speaker Works catalog of their complete lines of a very wide variety of kits.



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Advertisers: Adversary or Adjunct?

WITH THIS THIRD ISSUE *Speaker Builder's* circulation has moved above the 4,000 mark. Articles of exceptionally high quality are in our manuscript files and many more are in preparation. Advertising for this issue allows us to add an additional eight pages bringing the total to 48 this time. Your enthusiastic response to advertisers is producing some very pleased noises from those who are using our pages to sell their wares.

Many Americans seem to labor under the impression that advertising and advertisers are inherently dangerous to the integrity of editors and publishers. It is true that some few advertisers expect and even ask for an editorial mention in our pages—or a review of their product because they have contracted for ad space. But no editor must accede to such pressures unless he is dependent for his publication's existence on advertisers. Those audio publications whose ad rates run from eight to fourteen thousand dollars per page per insertion do have a serious problem now and then from an advertiser who doesn't like what is said about his product editorially.

We have that problem too, once in awhile. A valued advertiser of many years standing cancelled his advertising in obvious pique about a less than complimentary review of one of his products. But neither *Speaker Builder* nor our sister publication, *Audio Amateur* has the problem of depending on the advertiser for support. We depend on you—the reader—for our primary income to make *Speaker Builder* possible. We must be responsive to you and meet your needs if we are to make it. But the loss of one advertiser or two won't make a lot of difference to our success as a magazine.

However, I believe we cannot have a healthy and growing hobby without a growing amount of use of these pages by advertisers.

Our hobby of building loudspeakers is a very, very special one. It isn't for everyone. You, as a group of readers, are in possession of some unusual knowledge and know-how. And you are a brave, self-confident, adventurous lot. Although we live in what might be called a technological age—as a society we are widely afflicted by technological fright. The average person is paralyzed immediately by any talk of moderately complex technical matters. "It's all beyond me..." is the instant, unthinking response. But you are different. You are either eagerly curious about the possibilities of constructing your own special speaker system or you may be a person who has dug deeply into some aspect of speaker technology with gusto and are having a wonderful time with a great hobby.

And a special hobby means that our needs are special. There is little point in a great avocation, excellent designs, and a resourceful magazine if we cannot buy the special products we need to fulfill our dreams. Those special products are not usually going to come from giant corporations. Most of them are going to come from people who have dreams similar to ours and who often have turned hobbies into businesses. In talking with many of our advertisers I find a group of highly knowledgeable and enthusiastic people. Not all, of course. But the average is really startlingly high. They want to supply the best possible product and will get into whatever projects and ideas that your enthusiasm and patronage will support.

The vital element in the vendor who offers exciting products is his or her own commitment to real answers to problems. When a company loses that enthusiasm it either no longer understands, or cares, how the hobbyist feels or thinks. When that happens—the company is doomed to producing mediocrity for the masses or to dying.

The same thing happens to editors. Those who have lost the original fire of their understanding of the reader's feelings, do an increasingly pedestrian job of editing their publications.

Your interaction with the vendor, then, is a potential boon to this hobby of ours. It will not make a success of this magazine—but it will give us a better hobby. Your subscriptions make *SB* a success, the number of ad pages in it will increase it's size.

I think we may deduce one further fact from my thesis about the nature of the dedicated advertiser/manufacturer/vendor. There is a pretty good reason why you *don't* see some advertisers' wares in these pages. They are generally the giants who are interested only in the big bucks. The money men run them and determine merchandising policy. Your needs are too special and too demanding for them. Your needs are also too small and not lucrative enough. They are after the big studio installations, and the mass market herd who presumably respond to hype and graphics. And their R&D departments aren't all that concerned with real quality—only novelty. The Detroit syndrome calls for something new each year. Whether it is better is irrelevant.

So I believe a good hobby needs good manufacturers and vendors. We welcome their presence in these pages: news of their wares and ads offering them to you. We think you will do well to be responsive, critical, and where you can, a consumer. Your action ought to give us better products and thus a better hobby.

Enthusiasm and imagination—plus the invested energy to make dreams into reality will fuel this hobby of ours, nothing else. That sort of excitement will attract others to our ranks. Excellence breeds excellence. And doubtless from that enthusiasm and interaction will grow better products and supplies, useful tools and parts; a demand for the special hardware, drivers, cones, panels, horns, diaphragms, magnets, "matched pairs" of drivers, speaker testing programs for our computers, and a great deal else that we cannot yet imagine.

A magazine is an interactive community. Ideas stimulate fresh combinations of ideas. In this editor's view, the offerings of the vendor, the manufacturer, and the professional are all welcome as part of the mix. Those who don't play fair or who are merely greedy are in too small a pond to go undetected for long.

We hope you will continue your response to those whose wares appear in *SB*'s pages. Certainly *not* from a "support our advertisers" viewpoint. Respond to only that which honestly interests you. The last thing we want is some kind of phony, empty reaction to advertisers with the thought that thereby you are supporting *SB*. Not true.

In my view a good magazine has advertising almost as interesting as the text. And a magazine whose ads bore me will usually have content that bores me also.

Some will doubtless see this as a sophistry serving grubby ends. If this be self deception, make the most of it. No hobby on my horizon excels in any other way.

—EDWARD T. DELL, JR.

The Double-Chamber Speaker Enclosure

by R. N. Marsh

Revival of an experimental enclosure for getting usable 35Hz Bass from an 8-inch driver.

THIS ENCLOSURE WILL EXTEND the bass response of almost any good 8" or 10" driver to a usable 35Hz. With good, high-efficiency loudspeakers, the performance in the very low bass region is excellent. The enclosure design can make the basis of a multi-speaker system or be used for bass extension for small, high quality systems which are limited at low frequencies. This double-tuned enclosure is based upon an experimental design by George L. Augspurger and provides maximum flexibility in using a wide variety of drivers.

Augspurger's article "A Double Chamber Speaker Enclosure" appeared in *Electronics World*, Dec. 1961, pp. 41-43, 72-73.

THEORY

The normal reflex enclosure is matched to the characteristics of a specific driver, since it is essentially a Helmholtz resonator tuned at or near the speaker's resonant frequency. At that frequency, the reflex (also called "ported") enclosure inverts the phase of the sound from the rear of the loudspeaker, adding it to that produced by the front of the cone. The enclosure also loads the loudspeaker acoustically, thus reducing cone movement and distortion.

Above and below this resonant frequency, the reflex enclosure unloads the driver. Consequently, if the enclosure resonant frequency is tuned too low for a given speaker, mid-bass response is weak and the driver can be overloaded in this range. If the enclosure resonant frequency is tuned too high, deep fundamental tones are lost and the speaker is easily overloaded by low-frequency signals.

The double-chamber enclosure is therefore tuned to two frequencies about an octave apart. The higher frequency gives acoustic loading in the mid-bass region, and the lower frequency maintains loading down to a suitable low-frequency limit.

DESIGN

In this design, the larger chamber (in which the driver is mounted) is tuned to 70Hz. Its volume is about 1.8 cubic feet. The smaller chamber is about one cubic foot. The two ducted ports tune the chamber. One port is in the partition between the two chambers and the others exhaust outside.

Below 70Hz, the first chamber starts to unload and the air moves freely through the port in the partition. As far as the speaker is then concerned, the partition ceases to exist. Near 35Hz

Fig. 1. View of the author's two driver prototype. RAM is the author's recording business name.

the combined volume of both chambers reacts with the two outside ports to establish the system's lower resonance point. By spreading the reflex action over a band of about two octaves, this double-tuned enclosure eliminates the need for closely matching a particular speaker's characteristics. This broad acoustic loading also increases efficiency while lowering distortion—a very worthwhile combination.

RESULTS

If we can succeed in producing response down to 35Hz from an 8 inch speaker, it doesn't mean much unless we have an honest 35Hz. If the output turns out to be mostly frequency doubling, audiophiles would not consider that useful; far better to restrict the bass range to a more orthodox limit. Fortunately, this system's low distortion is more impressive than its extended frequency response. Using a J.B. Lansing LE-8T driver with 15 watts continuous input (*very* loud), total harmonic distortion is less than 5% at any frequency above 30Hz. At 35Hz the THD is only 2%.

This speaker is flat within about 5dB total variation from 32 to 1000Hz, as measured outdoors radiating into a 180-degree solid angle. The speaker system's bass response in a room generally extends lower and is more efficient than its performance outdoors. I tried other drivers with little difference in the low frequency response cut-off. *Fig. 1* is a photo of a design using two 10 inch JBL musical instrument drivers (K110) I built for a bass guitarist friend. I kept the enclosure volume to the required size and only changed the dimensions to accomodate two speakers. The volume displaced by the drivers was taken into consideration. In this enclosure, the bass is crisp and firm. Bass is not particularly prominent until a really low fundamental comes along.

HOW TO BUILD ONE

The double-chamber enclosure's exact dimensions are not critical. The main chamber's volume should be 1.8 to 2.0 cubic feet and the smaller chamber should be between .9 and 1.0 cubic feet. The dimensions shown in *Fig. 2* are convenient and can be used for either a horizontal or vertical unit. The two outside ports can be located on any surface.

The enclosure must be very solidly built. I used ¾ inch particle board, Elmer's wood glue and screws every 4 to 6 inches for that "vault" look. The speakers are front mounted and sealed with Silastic® for an air-tight fit. I chose Formica® to cover the particle board but a wood veneer might be more at home in some environments.

The three port tubes are heavy cardboard mailing tubes of 2¾ inch I.D. and 7½ inch length. (6 square inches of cross-sectional area). I wrapped them with fibreglass tape to make a stiff, vibrationless port. Silastic (RTV Silicone rubber adhesive/sealant) applied between the cut holes and the tubes prevents leaks. I spray painted the inside of the tubes black and stapled them to the enclosure.

The inside of the enclosure was lined with two inches of fibreglass on all surfaces to help attenuate internal reflections. I used, for speaker connectors, banana jacks (one red, one black) counter-sunk flush with the enclosure surface and spaced ¾" apart at their centers.

SUMMARY

Possibly some of you weren't subscribers to *Electronics World* magazine in 1961 when this design concept was introduced, but the magazine was very much like *Wireless World*. I kept the issue on the experimental double-chamber speaker system knowing I'd put it to use some day. (I was 15 years old then.) At that time audiophiles were willing to accept an 8 inch or 10 inch driver in a bookshelf enclosure, but believed that when the cabinet grew to three or four cubic feet, they needed to install a 12 or 15 inch speaker despite opinions from experts (like G. Augspurger). So the design was never commercially developed. Today audiophiles are, I hope, more accepting of unusual designs, leaving the proof to the results. We also recognize the sonic benefits and performance of the smaller cones' quickness and responsiveness compared to the larger and more massive speaker cones. It's time, I believe, to revive this unusual, interesting and versatile design.

A husky speaker in the $15-$30 range can be expected to perform quite well down to about 40Hz in the double-chamber enclosure. But, you naturally won't be able to get powerful bass with low distortion afforded by better loudspeakers. □

FIG. 2

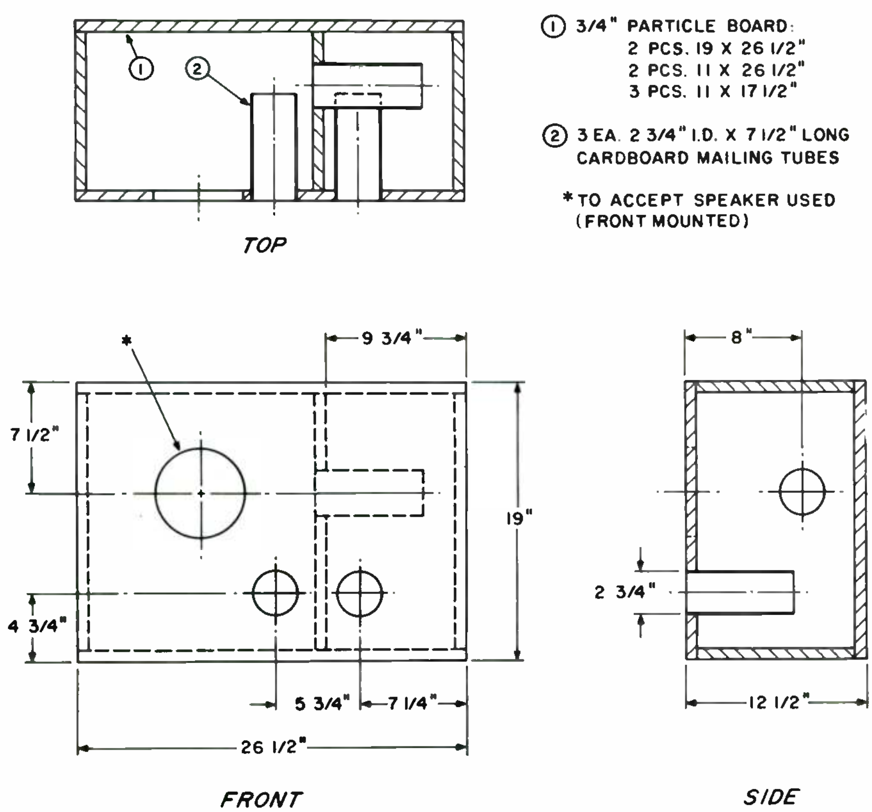


Fig. 1. View of the author's two driver prototype. RAM is the author's recording business name.

A Three-Enclosure Loudspeaker System with active delay and crossover: Part 2

by Siegfried Linkwitz

This speaker design project was started with the idea of mounting the boxes flush with the surrounding wall. Positioning the box in front of a wall causes a severe dip in amplitude response when the distance from the front of the box to the wall equals a quarter wavelength. For a typical 300mm enclosure depth the dip occurs around 250Hz, *Fig. 2.*[7]

If one imagines the walls near the speakers to be made of mirrors then one can easily visualize the images of the box in these mirrors. At frequencies where the radiation from the box is omnidirectional, we can think of each of these images as a separate sound source, whose output will add or subtract from the original source, depending upon how far the image source is removed in terms of wavelengths. For a half wavelength distance to the image source, corresponding to a quarter wavelength distance from the speaker to the mirror, the outputs from the real and the imagined source will cancel each other.

This description of virtual sound sources is valid provided that the speaker is radiating sound towards the walls and that the walls, floors and ceiling act as acoustically reflecting surfaces, i.e. mirrors. Mounting the boxes flush with the reflecting surface eliminates the virtual image behind the speaker and produces a smooth frequency response. The completed system with flush mounted boxes performed very satisfactory. In particular it gave good sense of depth perspective for some stereo material.

MOVING OUT

I discovered later that by moving the speakers out into the room and at least 0.5-1m away from walls and floor, I could obtain a significant improvement in sound perspective, see Photo. A in part 1. On appropriate program material it now became quite easy to pinpoint the location of individual instruments both laterally and in their distance behind the speaker plane. The whole sound stage moved into focus.

Furthermore, tape hiss and record surface noise became spatially separated from the musical material. The noise originated definitely at the speaker boxes while the musical instruments assumed their own space between and behind the boxes. In this sense the noise and ticks from a record surface are comparable to the coughing and shuffling of people at a live concert where one can concentrate on the performance and not be side-tracked by unrelated acoustical events.[8]

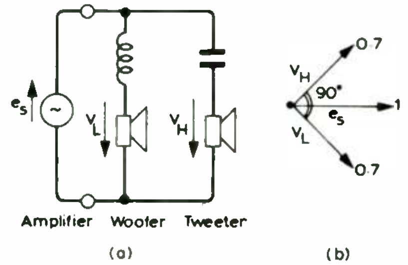


Fig. 7. Schematic network with 6dB per octave slopes and voltage phasor diagram at the crossover frequency.

It is not clear why the placement only a relatively short distance away from the walls should give such a marked improvement, particularly in light of the just-mentioned frequency response interferences from virtual images. It might be that the ear-brain combination performs a time domain analysis, and is able to allocate the wall reflections which occur 4 to 6ms later than the direct sound, to the characteristic of the listening room and not to the program material.

I mounted the speakers away from the walls by hanging them from the ceiling with a strong curtain cord. Electrical connections run from the back of the enclosure to the wall behind it and also serve to keep the speaker aiming forward. The small hanging units might be appropriately called satellites to the woofer box. The woofer itself is located halfway between the satellites, which are 2.5m apart.

The listening room is 5x8x4m (wxlxh), with the speakers in front of the narrow walls and the typical listening positions 5 to 6m away from the satellites.

CROSSOVER DESIGN

The simplest crossover network is the -6dB per octave slope filter of *Fig. 7.* Assuming idealized components, the current from the generator will split in such a way that the vector sum of the voltages across the low and high frequency driver terminals is equal to the source voltage at all frequencies $V_L + V_H = e_S$.

Correspondingly the vector sum of the sound pressures p_L and p_H generated by the drivers will be directly proportional to the generator voltage $p_L + p_H = ke_S$ and independent of frequency, provided that the distance from the listener to each of the drivers is identical. The B110 and T27 drivers though are a wavelength apart, which means that equidistance is obtained only for a plane in space, *Fig. 8*. For points outside this plane the sum of the two driver outputs will vary with frequency.

Furthermore, because the two drive voltages already have a 90° phase difference the summation will be different for symmetrical points above and below the plane of equidistance. In the crossover frequency region where both drivers contribute equally the system will radiate its maximum pressure at a 14° angle below the plane, *Fig. 9*. This simple dividing network has a wide range of overlap between the two drivers and therefore a tilted radiation pattern over at least two octaves.

A seemingly attractive feature of this network is its complete lack of phase distortion for points which are equidistant from H and L, *Fig. 8*. At these points perfect square-wave reproduction is achievable under free-field conditions or in an anechoic chamber. In a living room the increased radiation towards the floor and the reduced radiation upwards will produce a coloration in sound due to the frequency-selective change of the reverberant field. The ear is more sensitive to amplitude response than to phase shift. Therefore this filter and related designs with even greater than 90° phase difference between the drive signals and correspondingly greater off-axis intensity peaks are not used for the satellite system.[9]

SLOPE SCOPE

A 24dB per octave slope filter was chosen which has no off-axis peaks in the radiation pattern, *Fig. 9*.[10] The steep filter cut-off narrows the overlap region where the B110 and T27 interact. The T27 has its fundamental resonance at 1.4kHz and the highpass provides 27dB of attenuation at this frequency. At 5kHz where the B110 exhibits a cone resonance the filter has reduced the drive voltage by 18dB, *Fig. 10*. A 6 or even 12dB per octave filter would have insufficient attenuation to minimize exciting these resonances. The 18dB per octave filter was not considered because it tilts the polar pattern.

All these filters, with the exception of the 6dB per octave network, have a frequency-dependent phase shift and consequently some phase distortion. Only a network of linearly increasing phase shift with increasing frequency will have no phase distortion. The slope of the phase curve is constant in this case. Any deviation from the constant slope indicates that some amount of phase distortion is present. The question arises how much slope variation can be tolerated before it becomes audible and not merely visible on an oscilloscope.

The slope of the phase curve, usually referred to as envelope delay or group delay, has been plotted for typically used Butterworth crossover networks

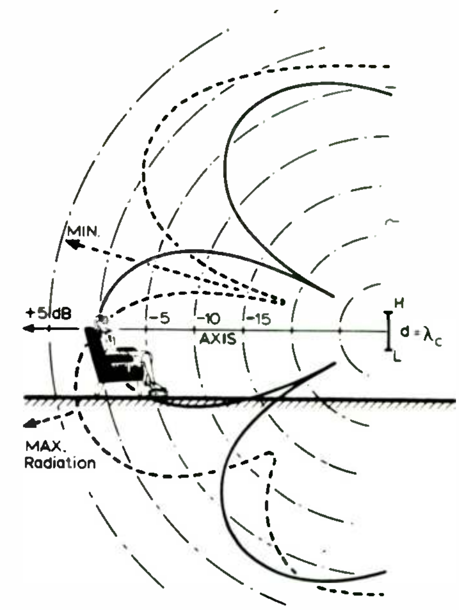


Fig. 9. Radiation of a 6dB per octave crossover network at the crossover frequency (3dB peak occurs below the plan of equidistance for non-coincident drivers) and the symmetrical pattern of a 24dB per octave crossover network at the crossover frequency (ref. 10).

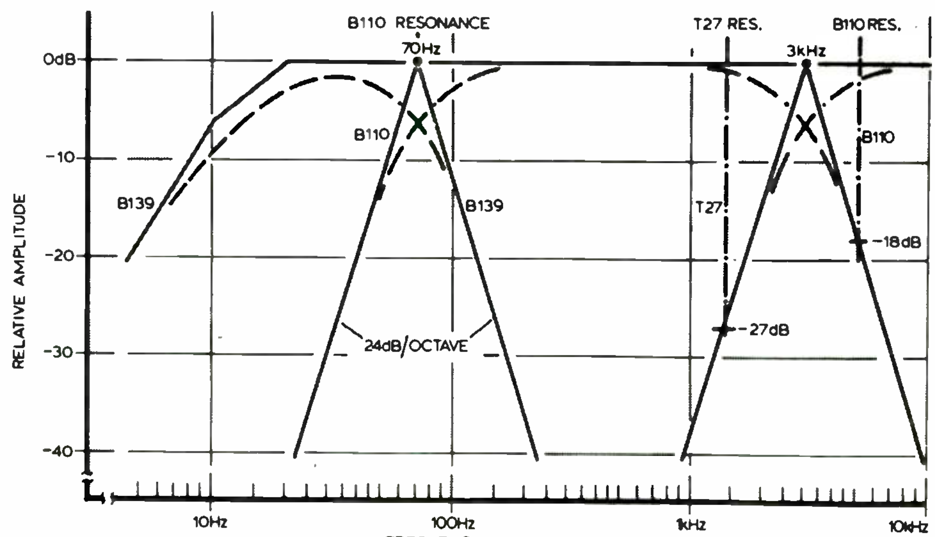


Fig. 10. Schematic response for crossover points and driver resonances.

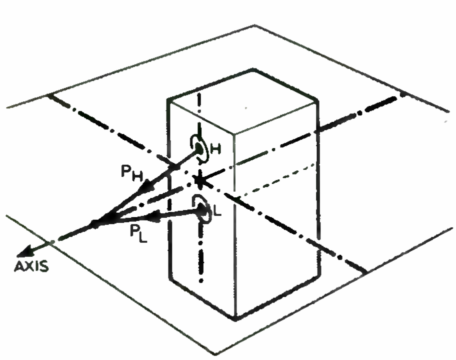


Fig. 8. Plane of points which are equidistant from the high frequency and low frequency drivers. The sum of the sound pressures is proportional to the sum of the electrical drive signals only in this plane.

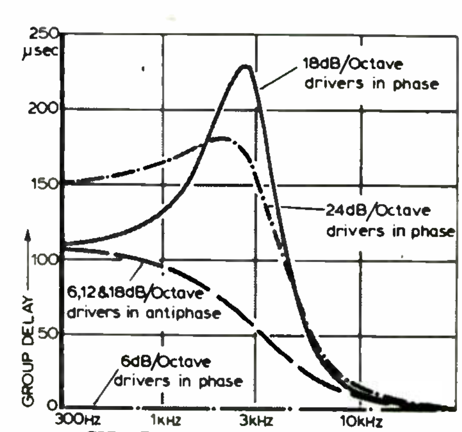


Fig. 11. Group delay frequency response of a speaker system due to a 3kHz crossover between midrange and tweeter with conventional first and third-order Butterworth networks, and with second and fourth-order cascaded Butterworth sections (ref. 10).

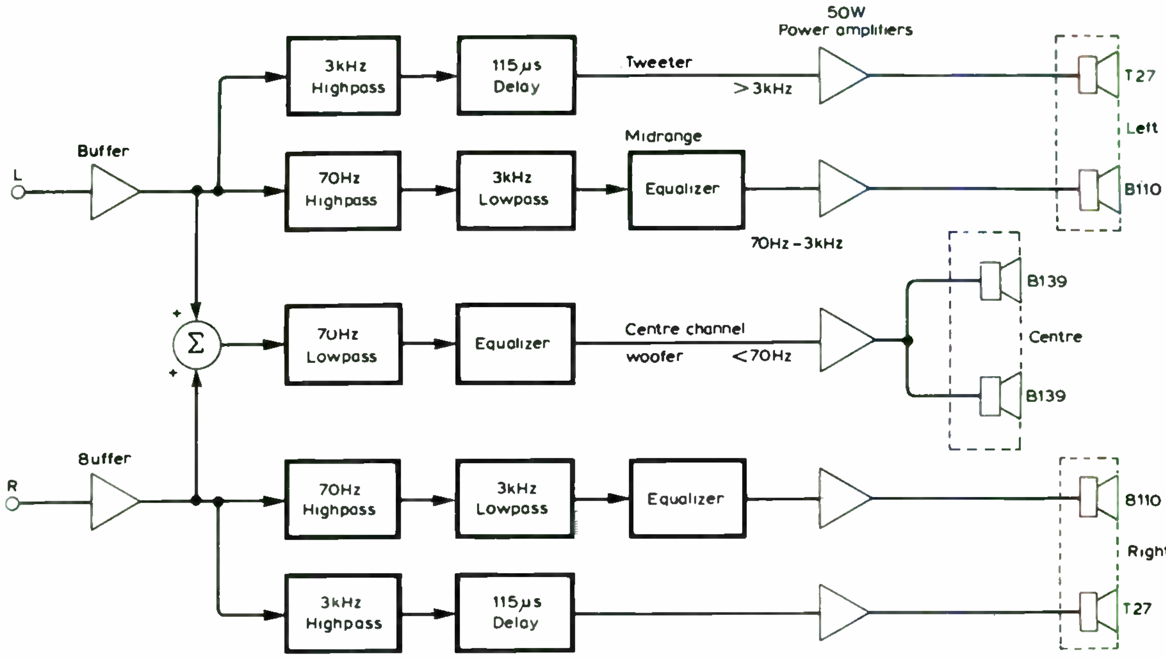


Fig. 12. System block diagram. Design formulas for each functional block are given to allow you to adapt the circuits of Fig. 13. The B110 is connected out of phase at its terminals relative to the T27 and B139 because of a 180° phase shift difference between the channels of Fig. 13.

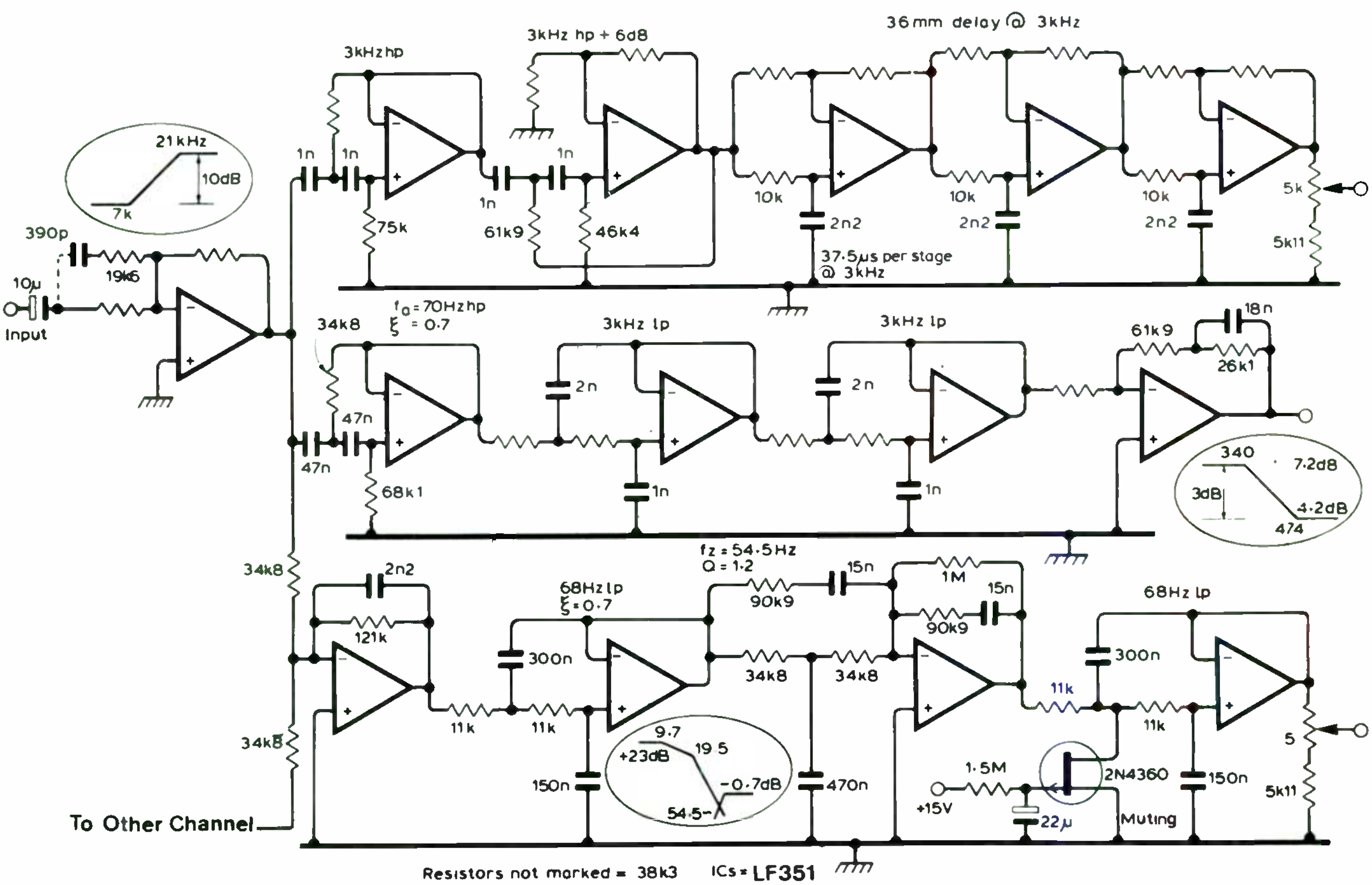


Fig. 13. Circuit diagram of crossover networks and equalizers incorporating delay compensation. Broken lines show optional h.f. boost components.

and the new network function, *Fig. 11.*[10] Merely changing the polarity to one of the drivers drastically changes the group delay for the summed driver outputs as in the case of the first and third-order Butterworth crossovers. Their on-axis amplitude response is unchanged, unless the drivers are separated some distance from each other. Then the polar pattern will tilt either up or down with the change in driver polarity.

To investigate the audibility of phase distortion an all-pass network was built which duplicates the group dealy of the new second and fourth-order crossover networks (12 and 24dB per octave curves in *Fig. 11*). Listening with headphones to stereo and mono program material, no audible difference could be detected with either one of the all-pass networks switched in or out. Therefore it seemed safe to use the fourth-order filter with its sharp cut-off behavior which minimizes the overlap between drivers.

CROSSOVER AND EQUALIZER CIRCUITS

The crossover networks and equalizers consist of a variety of active filter circuits. The overall block diagram of *Fig. 12* gives an indication of the system complexity. Design formulas are presented for each functional block so that the experienced constructor should be able to duplicate the circuits of *Fig. 13* or adapt the design to particular needs.

3kHz CROSSOVER NETWORKS

The fourth-order high- and low-pass filters are made up from cascaded second-order Butterworth sections, *Fig. 14*. The outputs V_H and V_L are in phase with each other at all frequencies and the voltage sum is equal to V_{IN}. At the crossover frequency f_o, therefore, the output from each filter will be $V_{IN}/2$ or 6dB down, which is different from the typical 3dB crossover point for filters where V_H and V_L are in phase quadrature.[10]

DELAY COMPENSATION

The B110 and T27 drivers do not radiate from the same acoustical plane even though they are mounted on the same baffle. The electrical signals arrive at each voice coil at the same time but because the T27 voice coil is located in front of the B110 voice coil the sound pressure wave generated by the T27 will be advanced relative to the B110. The 40mm driver off-set may seem insignificant unless it is related to the 144mm wavelength of a 3kHz tone where it corresponds to a 100° phase difference between the two driver outputs, i.e. $\Phi = 360° \frac{d}{\lambda}$.

The effect of driver off-set on the on-axis frequency response can be quite significant, particularly if both drivers contribute almost equally over a wide frequency range, *Fig. 15*. The frequency region of overlap is significantly narrower for higher-order filters because of their steeper cut-off.

The driver offset can be compensated for by adding electrical delay to the tweeter drive signal, or by mounting the tweeter in a different plane. Mechanically moving the tweeter back is feasible provided care is taken to avoid sharp cabinet edges and their associated scattering of sound. For electrical delay we use an all-pass network, *Fig. 16*. Its delay varies with frequency from τ=2RC at low frequen-

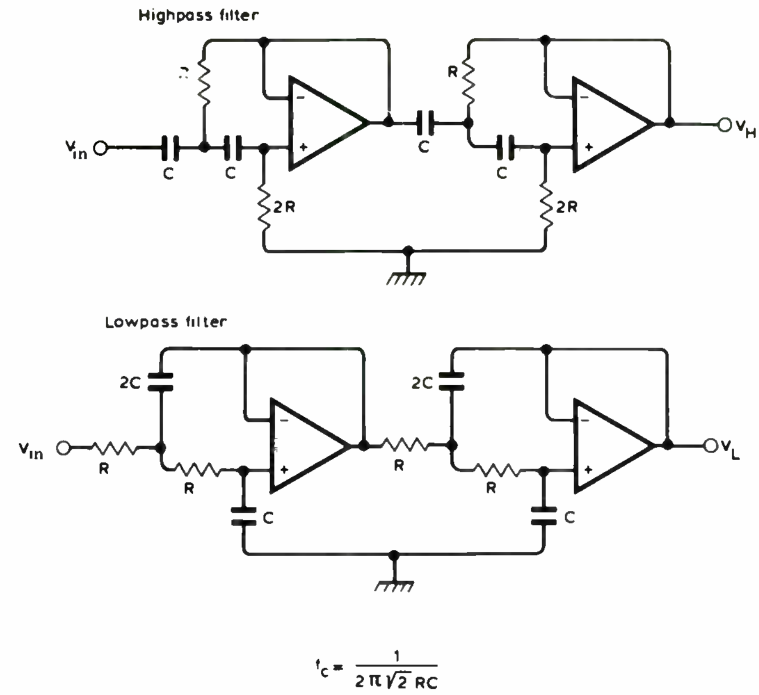


Fig. 14. Fourth-order 24dB per octave crossover filter sections are made up from cascaded second-order sections in both high and low-pass forms.

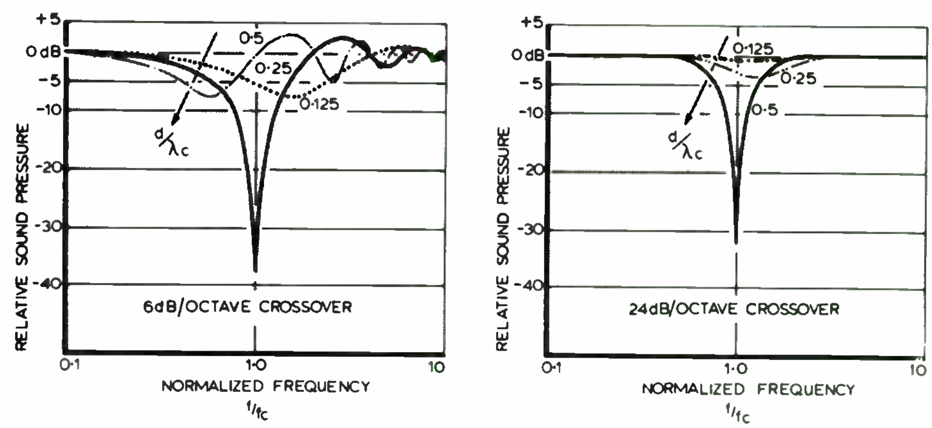


Fig. 15. On-axis response when the tweeter is positioned acoustically in front of the midrange by d/λ with 6dB per octave crossover, and 24dB per octave crossover.

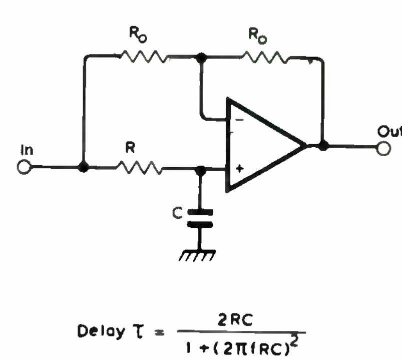


Fig. 16. Several all-pass phase shift networks are cascaded to obtain the required delay compensation.

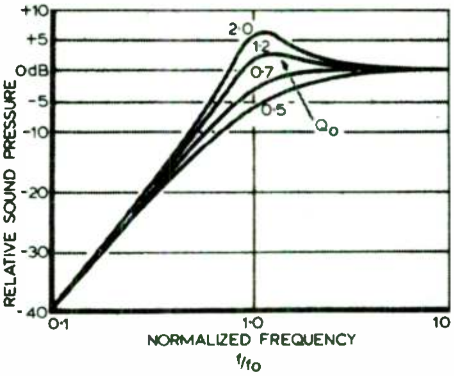


Fig. 17. Fall-off in response of a rigid piston in a closed box (ref. 11). Box resonance f_o and Q are determined as in Figs. 18 and 19.

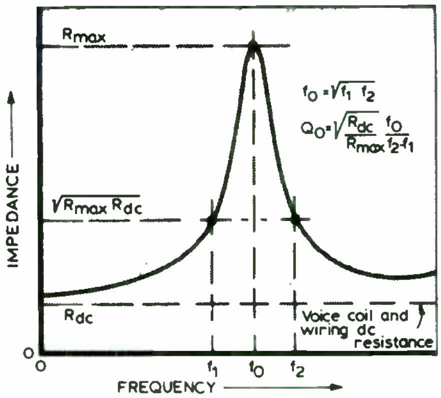


Fig. 18. Schematic response of the woofer driving point impedance measured as in Fig. 19 from which f_o and Q_o of Fig. 17 are derived (ref. 11).

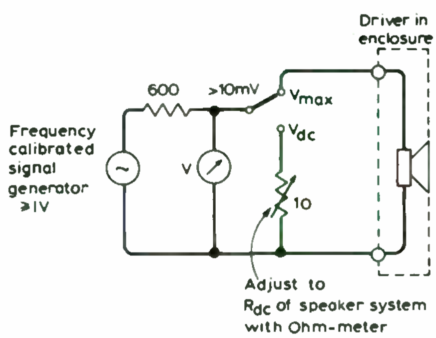


Fig. 19. Measurement setup for Fig. 18 to determine R_{DC}/R_{MAX} from V_{DC}/V_{MAX} and the frequencies f_1 and f_2 from

$$V = \sqrt{V_{MAX} \times V_{DC}}$$

cies, approaching zero delay at very high frequencies. To reduce the frequency dependency in the crossover region of around f_c the component values should be chosen such that RC $\ll 1/20f_c$. Several delay stages are cascaded to obtain the required total delay. This delay must be determined experimentally, but the spatial driver offset gives a reasonable starting point.

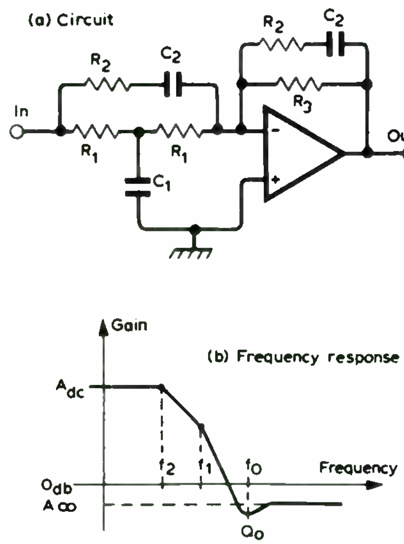
70Hz CROSSOVER NETWORK

The transition between the woofer and the satellite uses 24dB per octave slope filters similar to the 3kHz crossover. A transition frequency of 70Hz was chosen because the B110 output is 3dB down at this frequency due to the small internal volume of the satellite enclosures. The output continues falling off at a 12dB per octave rate below this frequency with approximately second-order Butterworth response shape. Therefore the driver in the closed box can be used as one half section of the required high-pass filter. The other half is implemented with an active second-order Butterworth filter section—the first stage in the center channel of *Fig. 13*. The low-pass filter for the B139 is again the two amplifier fourth-order network design—the second and fourth stages of the lower channel in *Fig. 13*.

WOOFER EQUALIZATION

The response of the woofer does not extend sufficiently far down in frequency. The fall-off in acoustic output will therefore be compensated with a properly increasing drive signal. Over the frequency range where the driver acts like a rigid piston its frequency response when mounted in a closed box[11] is

$$F_w = \frac{\left(\frac{f}{f_0}\right)^2}{\sqrt{\left[\left(\frac{f}{f_0}\right)^2 - 1\right]^2 + \left(\frac{1}{Q_0}\frac{f}{f_0}\right)^2}}$$



(c) Design formulas

$$f_0 = \frac{1}{2\pi R_1 \sqrt{C_1 C_2}}$$

$$Q_0 = \frac{1}{2\xi} = \frac{R_1}{2R_1 + R_2}\sqrt{\frac{C_1}{C_2}}$$

$$\frac{R_2}{R_1} = \frac{1}{Q_0}\sqrt{\frac{C_1}{C_2}} - 2 \qquad A_{dc} = \frac{R_3}{2R_1}$$

$$f_1 = \frac{1}{\pi R_1 C_1} \qquad A\infty = \frac{R_3}{R_2 + R_3} < 1$$

$$f_2 = \frac{1}{2\pi (R_2 + R_3) C_2} \qquad \frac{A_{dc}}{A\infty} = \frac{R_2 + R_3}{2R_1}$$

Fig. 20. Network extends the woofer low frequency response to f_1 by providing exact compensation for Q_o and f_o with schematic amplitude response, and design formulas.

This is a high-pass function with a corner frequency near the closed box resonance f_o and some peaking depending on Q_o, *Fig. 17*. The two parameters f_o and Q_o can be conveniently determined from the frequency response of the driving point impedance[11] of the speaker system, *Fig. 18*. If the system is driven from a generator with an internal impedance much larger than R_{max}, then the terminal voltage becomes proportional to the system impedance and Q_o, f_o can be determined from the voltage response as in *Fig. 19*.

For the two B139 woofers in their closed box the resonance occurs at 54Hz with a Q_o of 1.2. The response can now be compensated with a network which exactly complements the woofer roll-off and extends it to a lower cut-off frequency, *Fig. 20*. This design approach can be used to equalize other speaker systems if careful attention is given to the cone excursion capability and the power amplifier output voltage swing limitations. Both increase by a factor of four when the cut-off frequency is lowered by an octave.

For the playback of records much of the linear excursion range of the woofer is used to reproduce the large amplitudes of record rumble. This wastes driver linearity. Fortunately, the left and right-channel vertical rumble outputs from the pickup are out of phase and therefore cancel when the left and right channels are summed for a center channel woofer, as in this design. Separate left and right channel woofers can easily be tied together electrically to eliminate the unnecessary movement of air at subsonic frequencies from one speaker box to the other.[12]

The correct response of the woofer can be verified by placing a microphone about 1cm away from the cone to determine the near-field sound pressure which for a uniformly moving piston is proportional to the far-field sound pressure.[13]

SYSTEM EQUALIZATION

As active networks are already used

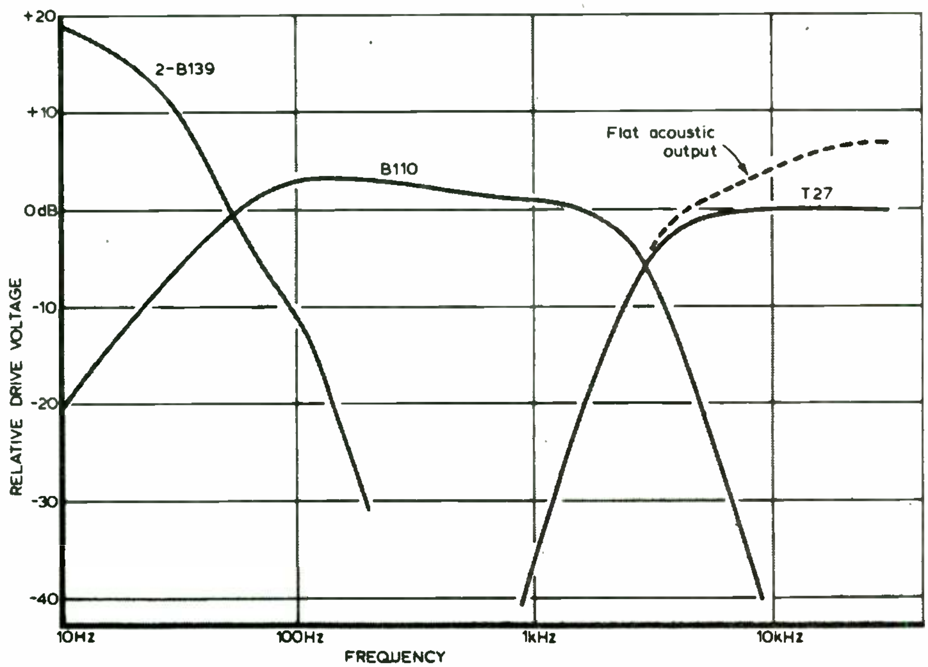


Fig. 21. Measured voltages at the driver terminals of the complete system. A flat response does not seem to give natural-sounding reproduction.

for the crossover filters it seems attractive to also use them to equalize the complete speaker system for a flat amplitude response at the preferred listening location. A microphone at that position will pick up the direct sound coming from the speakers and a large number of reflections from various objects and the walls of the room. The microphone cannot distinguish between the different sources. The microphone output voltage which corresponds to the direct sound from the speakers will be masked by the voltage due to the reverberant sound field. The ear-brain combination seems to be taking its clues for locating the details of the stereo image from the direct sound even when the reverberant sound energy is much larger than the direct sound. This might explain why attempts to equalize for a flat response at the listening location gave unsatisfactory results.

The response at one meter from the speaker measured in the room appears to be a better starting point for equalization. But even for this location a completely flat response does not seem to give the most natural-sounding reproduction. Some form of shelving or sloping response seems necessary.[14]

In this design a 3dB low-frequency boost is applied to the B110 signal to obtain flat acoustic output over its range (last stage in the center channel of *Fig. 13*). The T27 is allowed to follow its own gradual roll-off, but if a flat high-end response seems desirable then the simple network shown with broken lines at the input stage will give the necessary high-frequency boost.

HUE FIDELITY

An analogy might help to describe the subjective impression of a properly designed and equalized system by comparing it to the color photograph of a familiar scene. A fair sound system might correspond to an out-of-focus picture, possibly with the wrong reds and blue or an overall color tint. Comparing two such systems to each other is like looking at two blurry pictures of reality. Where one might prefer one over the other because of its color balance, there is no question of either being a realistic reproduction.

A high accuracy sound system corresponds to a photograph which is focussed and without unnatural emphasis on any color. When a high standard of reproduction is being approached it becomes possible to hear clearly areas of slight imperfection like in a picture which is not exactly focussed or has just a slight color tint. For the high-frequency equalization of the speakers this means that too much output shifts the sound image out of focus. The image depth becomes blurred because the high frequency overtones seem to be less distant than the virtual sources which generated them.

The chosen speaker equalization appears to match the greatest variety of program material. A properly functioning treble control in the preamplifier is needed though to correct for differences in recordings. The final response of the drive voltages for the three speaker units, *Fig. 21*, could have been generated or approximated with passive networks. The practical implementation might prove to be difficult and no attempt has been made to design a passive crossover/equalizer. The design flexibility of active networks far outweighs the possible cost saving of passive networks when only a single system is being built.

CONCLUSION

I hope some of the design techniques and ideas expressed here will stimulate a more rational design of loudspeaker systems. Certainly the drivers will be continuously improved for reduced resonances but enclosure design, materials, and shapes will need much more study and development.[15] Nevertheless it is possible to design a highly satisfactory system even with today's standard components. □

Part 3 will detail additional refinements and optional improvements in this system. —Ed

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A Corner Mid-Range Horn

by Bruce C. Edgar

PROBLEM

Your church's fellowship hall needs an improved PA system. The old system consisted of a large number of 8" ceiling mounted speakers on a 25 volt line. The congregation complains of poor coverage and high distortion. After numerous auditions in full and empty conditions, I concluded that the sound absorption of 300 people (typical meeting size) forced the sound operator to overdrive the system to reach a reasonable sound level. Two solutions are open to us: Buy a new power amplifier or build a more efficient speaker system.

SOLUTION

The expertise of an audio amateur is often called upon in situations such as this one which are outside the familiar living room environment. Sometimes the new problems give the stimulus to unusual solutions. In this case, I suggested that I could build a corner mid-range horn system for a fraction of the cost of a new amplifier.

HORN DESIGN

The primary objective of a PA system is good speech reproduction, which eliminates any requirement for a response below 100Hz. (This means no deep bass!) On the treble end, speech formats can go up to 4kHz. These bandwidth requirements can be handled by one horn of proper construction. Corner placement of the horn at the ceiling reduces mouth size requirements and gives good dispersion.

A literature search turned up two good designs for freestanding mid range horns by Crabbe[1] and Babani[2]. Crabbe designed a plywood and plaster straight horn with a 200Hz cutoff for a KEF B139 speaker coupled directly to the throat. Babani used a 6" x 9" oval speaker in a mid range 300Hz horn built up with particle board strips. However, I felt that a gentle rolloff of the response down to 100Hz would give better reproduction of a male voice without too much objectionable bass boom.

Dinsdale[3] gives a very useful summary chart for exponential horn design parameters. After trying several combinations of flare rates, throat and mouth sizes, and drivers, I decided that the best compromise was a 10" lead guitar speaker in a 120Hz folded exponential horn. Dinsdale recommends a 16.5 sq. in. throat area for a 10" driver which I translated into a 2" x 8¼" slot. Although the optimum mouth area for a 120Hz corner horn is 125 sq. in., the folding of the horn worked out better with a length of 30" and a mouth size of 250 sq. in. The larger mouth size is also good for wall placement.

In deciding the actual folded configurations, I drew on previous successful designs for guidance. The throat configuration of *Fig. 1* is an adaptation of Klipsch's[4] famous corner horn design (see Klipsch's *Fig. 4*). Sanial[5] suggests that dividing the path into two separate channels gives a better folded configuration. Thus the 2" wide throat slot couples into two 1" wide vertically flaring channels in *Fig. 1*. The length of this throat assembly is determined by the speaker size. Then the throat assembly couples into sections that flare in the horizontal plane as shown in *Fig. 2*.

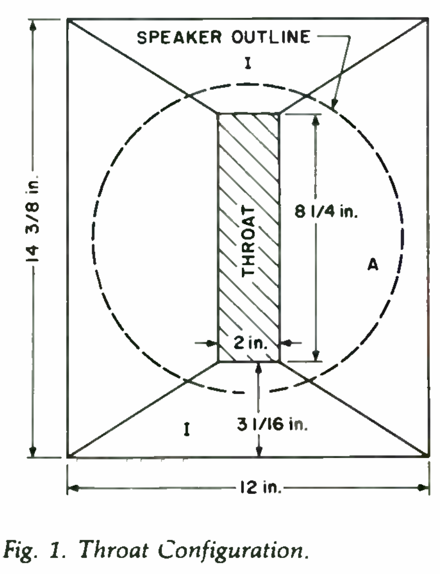


Fig. 1. Throat Configuration.

The constant vertical dimensions of 14⅜" is fixed by the exponential expansion at 6" away from the throat. The rest of the horn configuration is determined by reconciling the requirements of the outer 24" length of the horn with two folds and the mouth size. The resultant configuration of *Fig. 2* is very similar to the Ambassador Horn designed by Briggs[6], although he leaves the throat design to the reader's imagination.

The driver is a 10" lead guitar speaker sold by Radio Shack (#40-1004). It has a 90Hz resonance frequency, a stiff suspension, and a metal dust cover. The stiff suspension is required for the high throat pressures found in horns. An acoustic suspension speaker is not recommended for this horn.

CONSTRUCTION

The corner horn is made from one-half inch particle board. One enclosure requires approximately three-quarters of a 4' x 8' sheet. In addition to the piece listed in *Table 1*, you also need a piece of 1" x 1" pine stock sawed into several 2" lengths for cleat blocks. The angled corner reflectors may be made by ripping a corner off a 1" pine board with a table saw blade set at 45°.

When cutting out the pieces make sure the 14⅜" common dimension is very close for all the pieces concerned as any significant deviations will affect the construction. The plans require only simple angles, and angle guides for setting the table saw can easily be made by making several copies of the plans and cutting out triangles incorporating the appropriate angle.

Figure 1 shows the throat configuration.

The boards labeled "I" are cut into the trapezoid shape shown in *Fig. 1* and then are laminated into two 1" thick trapezoid boards which determine the initial flare rate. Next cut out the 2" x 8¼" throat in board A. Boards A, B and I are then glued and clamped together, making sure that the top and bottom edges are flush and aligned according to *Fig. 1*. Line up the speaker holes on board A, and drill mounting holes all the way through board B. The bolts should be 2½" to 3" long depending on the speaker basket construction. In the prototype model I used "tee" nuts for holding the speaker mounting screws. However, the confined space in the speaker chamber makes it very difficult to tighten the screws, so this alternative mounting method is recommended.

The top and bottom are not listed in their correct final size in *Table 1*. I chose this procedure because we need the full size to do our layout correctly. We will cut off the excess later. Place the throat assembly on the bottom board and align it according to *Fig. 2*. (It is important to do a pencil layout like *Fig. 2* on the bottom board beforehand.) Fit pieces D and G to the throat assembly on the bottom board.

When the fit and the alignment are satisfactory, temporarily nail the cleat blocks to the bottom board along the throat assembly, the back piece (G), and the diagonal pieces (D). (Remember to nail only the cleats to the bottom board.) Remove the boards labeled G and D as well as the throat assembly, spread glue along the adjoining vertical edges, and place them back in the cleats with perfect alignment. Do not glue to the bottom yet. At this stage clamping can be done with one long frame clamp running along the center line from the top of G to the top of B. The diagonal boards (D) will have to be toe-nailed to A to prevent slippage.

FINAL ASSEMBLY

Next cut a ⅛" wide ⅜" deep groove along the edge of boards C and F where they join. (Most tungsten carbide table saw blades make a ⅛" wide cut). Now cut a ½" wide strip of ⅛" thick masonite long enough to make a spline joint. Glue and nail piece C to B, and glue the corner reflector for rigidity. Also at this time you can glue a triangular sound reflector in the center of the throat assembly. The masonite spline is forced into the groove of C, and the piece F is fitted onto the spline with glue. Next glue the corner pieces labeled E into place between pieces G and D. The enclosure should now resemble the photograph *Fig. 3*.

For final assembly put the side pieces H into place and align the top. You may find some over/under hang of piece H, in which case you may have to recut H to fit. I found that for my first horn, the alignment was perfect, but my second horn's piece H was off by ¼". These inaccuracies are of little consequence if the joints are tight and strong. One assembly technique which works well is to place a large piece of paper over the interior assembly, then rub a pencil lead over the paper to produce a template of the board edges. Now glue and nail the sides (H) in place and with glue on the top edges of the interior assembly, place

Continued on page 18

Fig. 2. Top view of the horn.

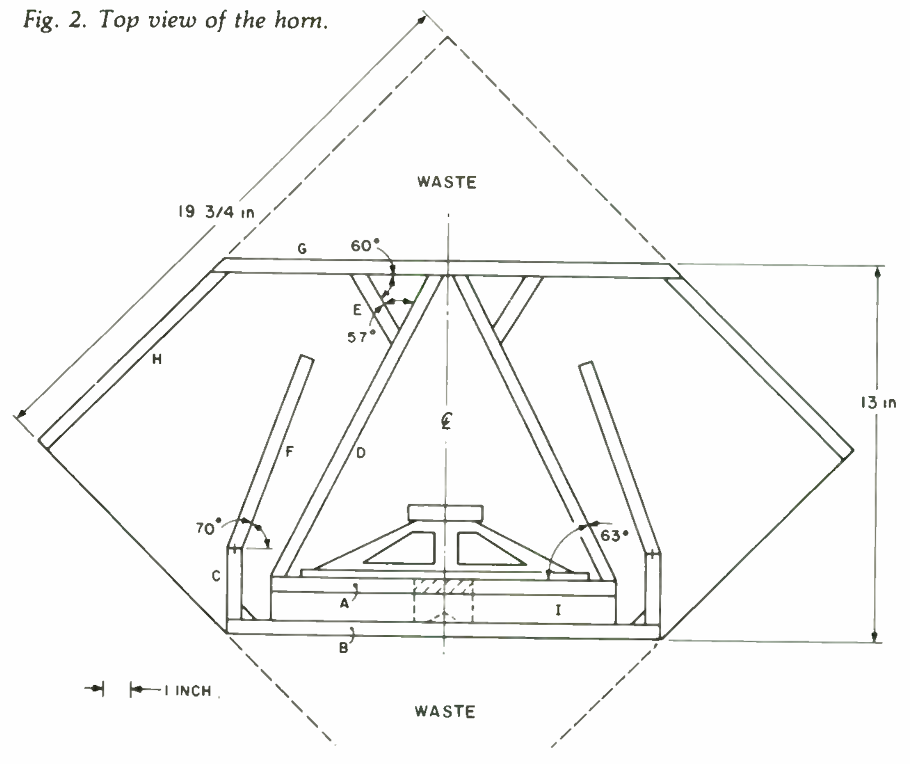


Fig. 3. Internal horn assembly.

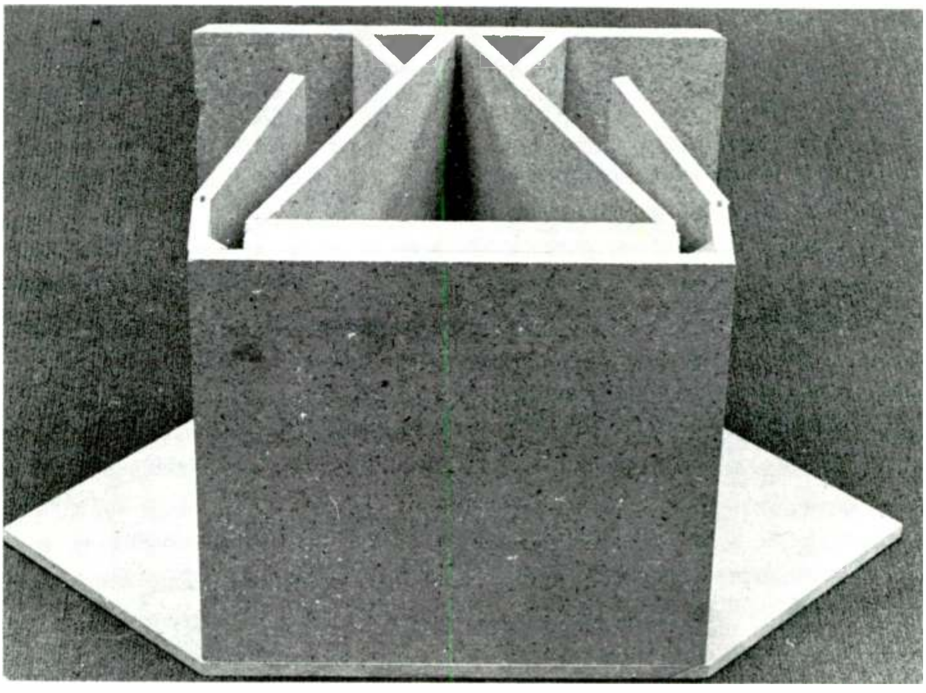
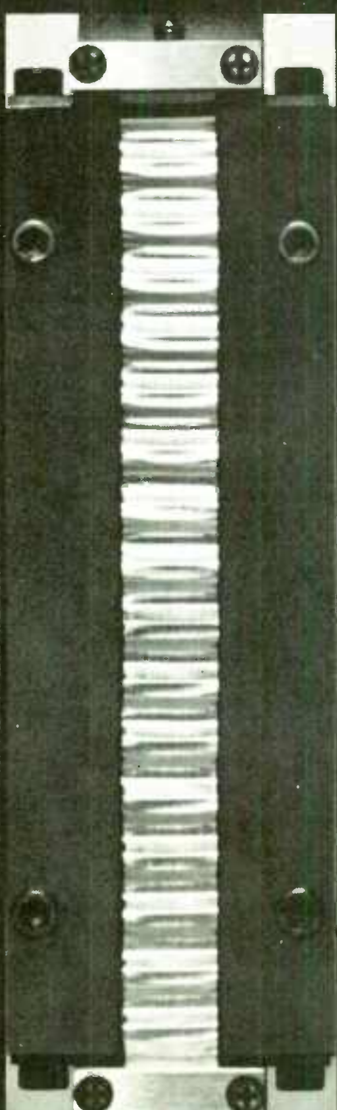


TABLE 1

PIECE	NUMBER OF PIECES	DIMENSIONS
A	1	14⅜"x12"
B	1	14⅜"x15"
C	2	14⅜"x2½"
D	2	14⅜"x12"†
E	2	14⅜"x3"†
F	2	14⅜"x7½"†
G	1	14⅜"x16¾"†
H	2	14⅜"x9"†
I	4	12"x3⅟₁₆"*
Top,Bottom	2	19¾"x19¾"

*See Figure 1 for exact shape.
†See Figure 2 for angled cuts required.

HF-1 Ribbon Loudspeaker



Actual Size

- The Best High End In The Business Designed By Dick Sequerra.
- True Force Over Area Transducer.
- Frequency Response To 50 KHz.
- Built-In Crossover.
- Built-In Step Attenuator.
- Sensitivity-89Db/1W/1M.
- Pulse Rise Time Less Than 6 Micro Seconds.
- Ribbon Size 0.5 Inches Wide, 5 Inches High.
- Ribbon Mass 10 Milligrams.
- Maximum Peak Power 200 Watts Pink Noise (RMS).
- List Price $595.00 Per Pair.
- Information Available Upon Request.

PYRAMID
Loudspeaker Corporation
131-15 Fowler Avenue
Flushing, New York 11355

A CORNER MID-RANGE HORN

Continued from page 16

the top on. The template, placed on the top board, becomes a nailing guide. Nail through the paper, tear the paper away, and then hammer the nails flush to the surface.

Turn the horn over and remove the bottom with the cleats still on. A speaker access hole is made by cutting out a section of the bottom with a saber saw. You can see the access in *Fig. 4*. I fitted pine strips along the edge of the speaker chamber and attached the cutout section with screws and silicon rubber caulking. The exact details of this procedure are left to the constructor since it is a cut and fit operation.

Now you may trim the top. Leaving an inch over-hang on the back gives protection to optional terminal strips or crossover. Now repeat the paper pattern procedure for a nailing guide for the bottom. Remove all cleats except the one on the back and the one in front of the throat assembly. These help to preserve the alignment. Glue and nail the bottom piece, and trim to fit. The final product is shown in *Fig. 4*. Install the driver, bring the leads out through a caulked hole in the rear, and add fiberglass to the speaker chamber.

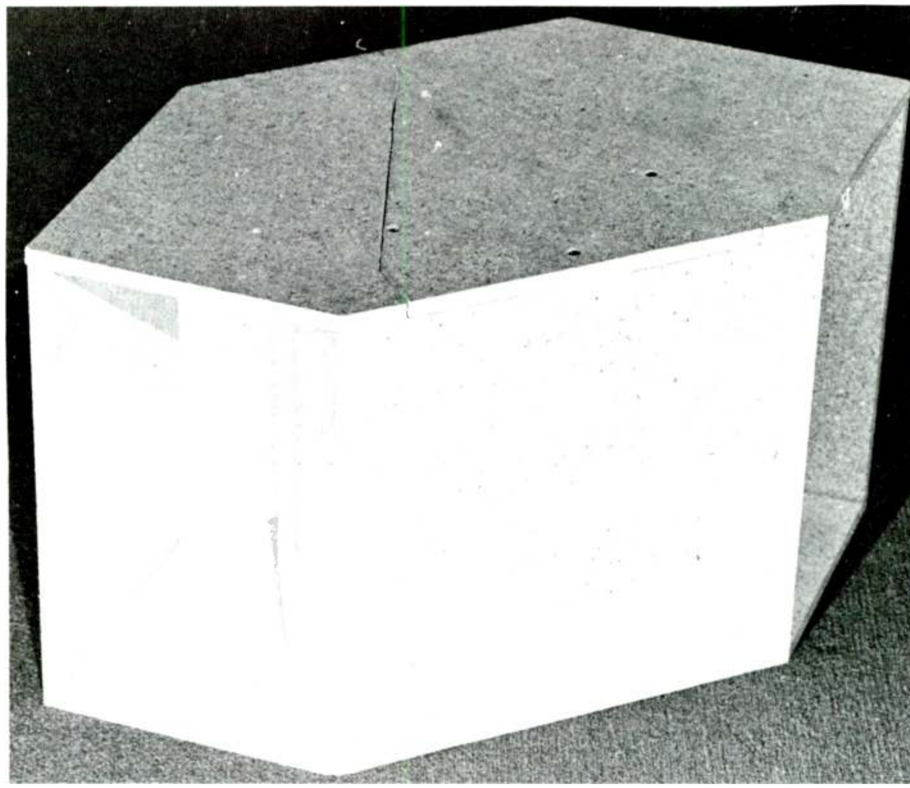


Fig. 4. Completed horn, showing speaker access cutout.

RESULT

We did white noise tests on the speaker using FM receiver interstation hiss, a HP 3580 spectrum analyzer, and a Sennheiser MD 421 microphone in the author's 19'x20'x8' living room. *Figure 5* graphs the measured frequency response with the room response subtracted. I was surprised by the lack of measured low frequency response below 200Hz, but this may be the result of low frequency measurement problems in small rooms. A signal generator test gives an aural response down to 90Hz.

The extended high frequency response is no doubt effected by the corner reflectors and the small dimensions of the initial bends as suggested by Carlise[7]. One could add a mid-range tweeter to the corner horn for PA work, but experiments with several speaker combinations indicated that the corner midrange horn could handle the voice spectrum quite adequately by itself.

The optimum back chamber volume was calculated to be 295 cu. in. The actual volume of my horn was calculated to be between 300 and 400 cu. in. depending on the displacement of the speaker. Greenbank[8] indicates that bass response of a self-enclosed horn depends on the volume of the back chamber and that the actual volume needs to be higher than optimum value. The folding of the corner horn in this case did not allow for experimentation with different back chamber volumes.

PERFORMANCE

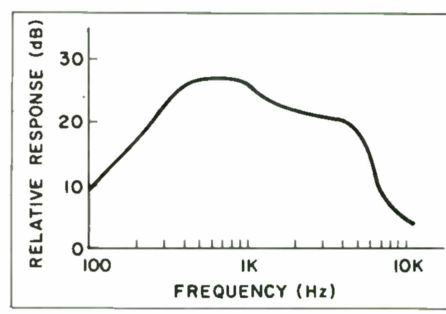
Many commercial PA horns exhibit air overload distortion caused by overdriving the speaker diaphragm (usually 1"-2" dia.) at the throat. It is little wonder that the mid-range horns of the fifties earned the nickname of "squawkers." I tried overdriving my corner horn with a 20 watt amplifier with very little identifiable distortion but driving my wife out of the house. This absence of air overload distortion is probably due to the stiffness of the cone and the large size of the 10" driver compared with the throat area which allows the horn to handle the large throat pressures without breakup.

The efficiency is also outstanding. In one experiment I connected a KLH 17 sealed baffle speaker to one stereo channel and the corner horn to the other channel. No one who auditioned the pair could tell that the KLH speaker was operating since the corner horn was radiating so much more acoustic power. This experiment indicates that the corner horn is at least 3dB more efficient than a sealed box speaker, since people's ears discriminate in 3dB steps.

APPLICATIONS

The author also auditioned music selections through a stereo pair of corner horns in his living room. With the loudness compensations switched in, the speakers give a very creditable HiFi performance. With certain types of organ music and choral music, the results are outstanding. Choral voices are very distinct and clear. Of course this observation is partly due to the response peak in the mid-range, but it is more probably a result of the unit's distortion characteristics and to its creation of spherical waves which produce an excellent stereo image regardless of listner position. The latter observation was also noted by Greenbank[8]. With an efficient sub-woofer

Fig. 5. Frequency response.



and a tweeter, the corner horn could become a integral part of an excellent system.

Another obvious application for the corner horn is electric guitar amplification. The high efficiency and reasonable size make it a natural for small rock groups on tour. In fact, the sound requirements of large rock concerts of the recent decade have been the primary stimulus in the recent commercial interest in horn speakers.

When we installed the two corner horns in the fellowship hall, the results were very satisfying. The system has generated good sound levels with up to 400 people in the 70'x100'x12' room. A barber shop singing convention was most impressed with the quality of choral reproduction. Installation into the ceiling corner seems to allow for the creation of a surface wave along the ceiling which scatters from exposed ceiling beams placed every 20' across the hall.

In retrospect this speaker project brings the author full circle from his first speaker construction project, a pseudo-folded horn described in *Popular Electronics*[9], which he made as a teenager in the 50's. It was about the same physical size as this corner horn, and I suspect that I haven been subconsciously trying to do a correct design ever since.

NOTE: Radio Shack has discontinued the prototype's 10" guitar speaker in its 1980 catalog. However, some dealers may still have it in stock. Other 10" guitar or PA speakers could be tried. An example would be the CTS-10400 offered by McGee Radio and others. Another possibility is a 6"x9" speaker which might better match the slot throat. □

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An Electrostatic Speaker System

Part II

by Roger R. Sanders

ESL CELLS MAY BE constructed in many different ways. The method described below has several advantages: 1. low cost 2. quick, easy construction 3. readily available parts 4. excellent performance 5. light weight 6. true surface accuracy with a high degree of uniformity. The only disadvantage is an efficiency level down 3 to 6dB from the most efficient types that can be constructed. Since 3dB is barely audible, I believe this is not a problem.

Construction uses a sheet of perforatec aluminum and insulating spacers to make one stator. Two stators comprise each cell. The diaphragm is 0.00025" (¼ mil) thick polyester film (brand name Mylar® by DuPont) coated with powdered graphite to make it slightly conductive. Epoxy glues bond together the film and acrylic sheet (brand name Plexiglas®) or polycarbonate sheet (Lexan®) for the insulating spacers. You will need some special tools including a piece of ¼" plate glass as a building base and a special steel bar frame to stretch the diaphragm to tension when you mount it.

The ideal stator material for the perforated metal sheets is about 20 mil aluminum sheet punched with IPA (Industrial Perforators Association) Standard Hole Pattern No. 105 or No. 107. These two patterns have holes approximately ⅟₁₆" in diameter with an open area ratio of about 40%, which gives the highest efficiency. However, you can successfully use metal sheet that has larger holes and different amounts of open area. Different patterns, have absolutely no effect on the sound other than loudness. The ESL's total size determines the frequency response, and only grille cloth and/or associated electronics affect sonic detail.

Acceptable cells can be made from Lincane® pattern, decorative aluminum sheet by Alcoa that is sold in hardware stores or in home improvement centers. It comes in plain or gold anodized finish; both work equally well. The price is about $4 per 2x3' sheet.

This is an excellent size for the metal stators, and if necessary, you can carefully cut it to size with scissors or with a metal shear at your local sheet metal shop. Notice that the holes have sharp edges on one side and smoother ones on the other side. It is extremely important that the *rounded* side of the holes *face* the diaphragm. If the perforated metal is to be shipped to you, specify that it must be packaged to prevent creasing. I advise that, if possible you pick it up in person.

INSULATORS

The insulators can be cut from ⅟₁₆" acrylic or from 80 mil polycarbonate sheet, often sold as single strength unbreakable windows. The acrylic (Plexiglas®) is nearly twice as expensive as the polycarbonate (Lexan®) and is not as uniform in thickness. These materials can be found in glass shops or home improvement centers.

The plastic can be cut with a fine blade, using a table, radial arm or band saw. To prevent the plastic from riding up and over the blade of the table saw, clamp a piece of wood above the blade just high enough to allow the plastic to slide under, and raise the blade until it cuts into the wood. No blade can cut the plastic without chipping its edge; just take some medium grit sandpaper and smooth any sharp edges.

The strips can also be broken off after scoring, as one would do with true glass. However, this is difficult to do with a long strip unless you use a slotted tool to snap the entire length at one time. You can usually get a glass shop to cut the strips for you, but it can be expensive.

DIAPHRAGMS

The diaphragm must be made from clear polyester film. Quarter mil is best because its small mass will not affect the sound until the frequency reaches about 32kHz. Therefore, for audio purposes, you have a massless speaker. Strength is a problem with thinner films. Thicker films can be used, but then the mass starts to roll off the sound in the audible range. Film is most easily available in 36" width.

This material can be obtained from large plastics houses. However, there is usually a $50 minimum order. Purchase about four times the amount you think you will need to allow for errors. Readers have found that 40 feet is adequate. Because of the problem in obtaining small amounts, I will supply readers with small quantities for 25¢/running foot in 36" widths.

Epoxy adhesives are the only type to use. (I find the Devcon brand to be the most consistent.) Five-minute epoxies work well and you can glue an entire set of cells in one evening. However, unless you have access to suitable applicators, such as medical syringes, the material "goes off" too quickly to give adequate time to work with it. The best adhesive is the "2 Ton," epoxy by Devcon which takes about 6 hours to go off. Heat shortens curing time considerably and if you work in a hot garage in the summer, for example, you can probably get adequate bonding in under three hours. It is better to lay up one stator per night and let the epoxy cure well than to push the project and have broken glue bonds later.

FLAT GLASS

Your base of ¼" plate glass on which you will assemble the units must equal the size of your cell. Have the glass shop sand the edges or do that yourself with some 100 grit aluminum oxide sandpaper and a sanding block so there are no sharp edges to cut the mylar. The usual method of taping the edges is not suitable for our purposes since the diaphragm is stretched across the edges and we want it to lay flat.

You will need a tube of fine powdered graphite of the sort commonly used to lubricate locks which costs about $1 per

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Soundbox offers you speaker parts and accessories similar to, and more often than not identical, parts used by the major speaker companies. We all buy from the same handful of manufacturers (OEM). The latest computer technology and the series of equations developed by Thiele (Tēl) and Small enable Soundbox to offer some of the most advanced designs and plans available today, and they are free with the appropriate woofers.
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ELECTROSTATIC SPEAKER CONSTRUCTION PART II

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tube. I buy mine from Western Auto stores, but most hardware stores should have it. Some single edge razor blades and a sharpened putty knife about 1" wide will be useful, as will cotton or rayon balls for rubbing on the graphite.

Begin the stator construction by gluing the insulators to the aluminum. (*See Figs. 14A and 14B.*) These strips are necessary because the diaphragm must be supported about every 6 inches for adequate stability. (The rule of thumb is that the unsupported distance must not be more than 100 times the diaphragm-to-stator distance.) It is better if the strips are glued to each other first, and then the assembled "grid" glued to the aluminum and weighted with books until the epoxy goes off. A quick and easy way of gluing the strips to each other is to use one of the cyanoacrylate adhesives such as "Crazy Glue," "Zap," or "Hot Stuff." You can find these in hardware stores and hobby shops.

Place a sheet of waxed paper over the plate glass along each side where the joints will be in the grid. Lay out the insulators in their approximate position, hold each joint closely together and put a single drop of glue on it. It will run into the joint and fuse the plastic in about 20 seconds. This type of glue does not fill gaps. If your joints do not fit well, use a bit of baking soda to fill the gap and then place the glue on the soda. The soda will become like concrete. The joint does not have to be a good one since we are only trying to "tack" the pieces into position so that we may place the aluminum on top of the strips that are inside the perimeter. They must mate with strips on the other stator when the two are sandwiched onto the diaphragm, requiring accurate placement. You may find that putting masking tape on the reverse side of the glass to mark the exact locations of the insulators will make it easier to properly position them for gluing, and aid in having the stators match up.

After you have tacked the grid together, sand the glazed surface of the insulators so that the glue will adhere. 180 grit aluminum oxide sandpaper works well for this. Sand the glue joints well, since we want the aluminum to lay flat.

DRILLING & CLEANING

Take the aluminum sheets and drill a small hole in one of the corners. Carefully remove the burr left by the drill by manually twisting a much larger drill bit or a countersink in the hole. This corner will be bent at right angles to the cell after the cell is completed, and a bolt will be placed through the hole for attaching your electrical connection.

The tab need only be about ½ inch. If you prefer to have all the connections in the same corner of the speaker, remember that the stators will be mirror images of each other.

Remove all grit from your plate glass, aluminum, and insulator grid with a vacuum cleaner. Lay the grid on the plate glass and place a small thread of epoxy along the insulators, making sure it is continuous because unglued spaces may rattle later. Do not put epoxy on the area where your tab will be because you will want to be able to bend it. You do not need much on the insulators to get a solid bond with the aluminum.

Position the aluminum, remembering that the rounded sides of the holes go down facing the glass. Place the waxed paper over the aluminum and then carefully weight it flat with a large number of books or similar weights. Be sure to have the books spanning at least two insulators so that the pressure exerted by the books is distributed over the insulators and does not deform the aluminum.

Allow the epoxy to cure well and then remove the stator from the glass and do the next one. Note that the stator will still be bowed and warped just as the aluminum was before you glued the insulators to it. Do not be concerned about this since it will be flat when you are done.

INSULATING PAINT

Now paint the stators with insulation. Before painting, take some masking tape and mask off the insulators so that you can glue to a bare surface later. Also put a bit of tape over the hole in the stator tab.

A variety of materials will serve for insulation. I have always used red GLPT insulating varnish, which has a lacquer base and is quick drying. It is distributed by GC electronics. Unfortunately it only comes in ½ pint cans, which are expensive, or gallons (about $20/gal). Some readers recommend a green Epoxy Insulating Varnish which comes in a 12 oz. spray can, distributed by Dayton Electric Mfg. Co.,

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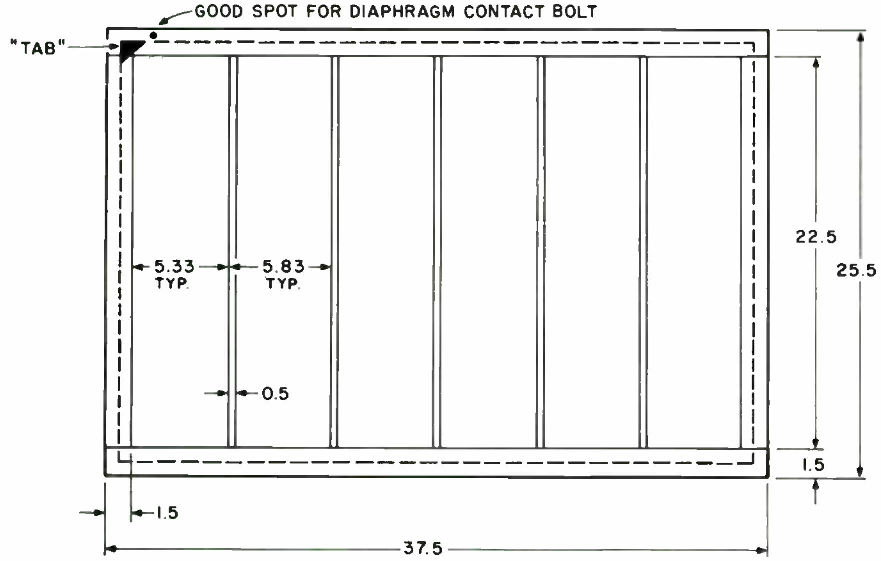

Fig. 14A. Layout for the insulator grid for each panel. The dotted line indicates the border of the perforated aluminum panel.

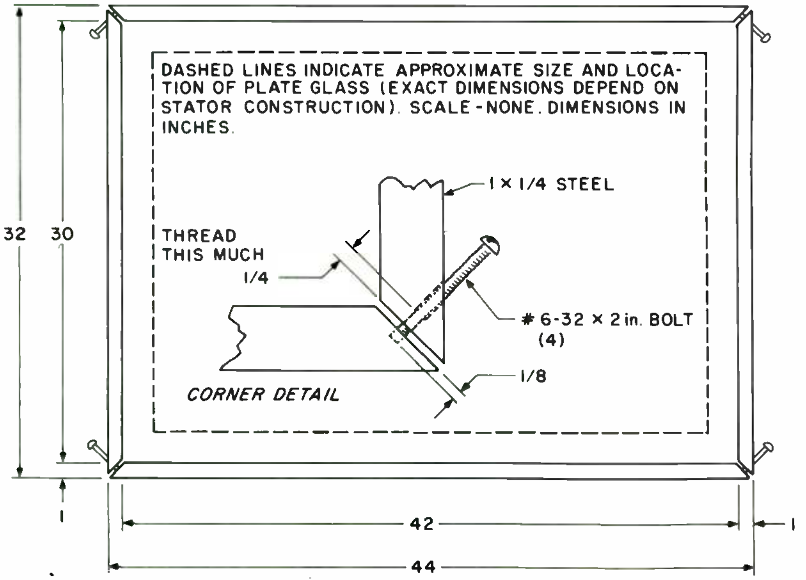

Fig. 14B. The steel stretcher frame for flattening the diaphragms and mounting them on the plexiglas frames.

Not because we say so, but because they say so. . .

"The *'New Yorker'* of audio magazines"

—ESS, Input, Sacramento, CA

Audio Amateur is a magazine that continues a great American tradition—a tradition that loves tinkering and experimentation and embraces rather than eschews technology. Readers of this magazine, I suspect, don't simply discuss the latest heavily advertised "quantum leap" forward. **TAA** subscribers are impressed more by an interesting project they can build from scratch. They love to extract, by modification, the greatest possible perfection from classic and recently introduced audio products.

Like the **New Yorker,** the **Audio Amateur** publishes articles that are measured and thoughtful, articles that are beyond superlatives by the bushel basket found in most of the mass circulated audio magazines. The reasoned tone results in part from the considerable contributions made by English writers, including the late B.J. Webb. Edward T. Dell, Jr., the editor, almost always includes a thoughtful editorial that, alone, is worth the cost of admission. Unlike some of the little audiophile magazines, **TAA** is generally beyond clannish allegiance to a few manufacturers. Articles on projects to construct and modify appeal to the fondness of its readers for a wide range of projects.

Audio Amateur has served up a smorgasbord of projects over its ten year existence. How to properly adapt a Grace arm to an AR turntable, build a record cabinet, modify a Formula-4 tonearm to improve low frequency reproduction, or build a 10 dollar three-element Yagi antenna have all been offered as appetizers, projects that require some familiarity with tools and a few nights of your time. The main course offerings demand various degrees of more sophisticated electronic skill. If you've only assembled a one tube radio (twenty years ago), many of the electronic projects are going to more than you can chew. Numerous past articles have shown how to improve classic Dynaco products. Recently, Nelson Pass of the Threshold Corp. discussed how to build a 40 watt per channel class A amplifier. Electronic articles typically assume an ability to find the parts necessary to build the projects. Chances are you'll spend some time searching through parts catalogs and local surplus houses before you can begin to wade into the actual construction.

Sophisticated articles that examine specific audio problems but do not involve building projects also abound. Walt Jung, contributing editor, has discussed slewing induced distortion in amplifiers in a series of articles. How we actually perceive sound and how many speakers may be necessary to recreate the closest possible approximation of the live event has also been discussed.

If speaker building is your forte, past articles have dealt with horn loaded and transmission line designs. Instructions on how to build electrostatic transducers from scratch, and box fabrication for sub-woofers with an accompanying active crossover have also been features. It's a measure of **TAA** contributor ingenuity that a complex driver like the Heil air-motion transformer has been built by an amateur — complete instructions on how to build a home version of the large Heil appeared in the magazine in 1977.

An excellent analysis of recently introduced audio kits is a regular feature. Kit reviews are technically very thorough and are often more objective than you find elsewhere. A regular feature, "Audio Aids," offers all kinds of informative hints from readers. A letter section from readers comments on past articles and present concerns and lends a thoughtful and inquiring tone to the magazine. Advertisements, themselves, are often helpful to the reader since many of the ads list parts that are vital for project construction. Most of the better kit manufacturers also advertise in **Audio Amateur.**

If you are already an audio craftsman, or would like to become one, **Audio Amateur** is an excellent touchstone. For less than the price of a good meal and a movie ticket, you can receive four issues a year.

—George Hortin, Staff Writer
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ELECTROSTATIC SPEAKER CONSTRUCTION PART II

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Chicago IL 60648. It should work fine and would eliminate the need for a spray rig.

The insulation must be sprayed on since it tends to pull away from the edges of the holes and brushing it on will not give even coverage at the edges. Spray the insulation at a 45 degree angle, going first to the left, then to the right, then up and then down. Go over lightly this way several times to get good insulation build up at the hole edges. The insulation should be reasonably thick; you should not be able to see any trace of metal through it. Avoid runs, however. The GLPT dries so quickly that by the time you have sprayed all 8 stators, you can reapply it without causing runs.

Do both sides of the stators. The outside is not important except to keep you from getting shocked on bare metal, so you need not use the 45° angle technique there and it does not have to be thickly applied. Note that even with a good coating of insulation you will still get arcing through it. The prime purpose of insulation is to prevent the voltage breakdown of the air gap between the stators.

When the stators are dry, put them in matched pairs. You may find that by careful selection you can get the insulators to match closely when the stators are placed together, and you want the tabs to be in the same corner on each side. Mark the stators so that you will be able to identify the pairs at any time.

CONNECTIONS

Next drill a suitable hole for a 4-40 bolt through both stators near the corner where your tabs are located. Be careful if you use standard metal and wood bits, since the bit grabs and shatters the plastic at the completion of the hole. There are several solutions to this problem: You can drill part way through the plastic and then turn it over and drill the rest of the way from the other side, or you can drill most of the way through and then turn the drill backwards while you gently force it the rest of the way, you can use a drill press at high speed and go through slowly, or you can use special plastic drill bits that do not grab and shatter plastics. Do not drill closer than ¼ inch from the edge of the aluminum to avoid arcing from the bolt to the aluminum. These holes must line up perfectly at final assembly, so be careful to put them in the identical place on both stators. It is a good idea to leave the masking tape in place until after the holes are drilled as this helps to prevent shattering and chipping. Take one of the stators in each pair and enlarge the hole. One quarter inch is generally a good size. The object is to make the hole large enough to allow the head of the diaphragm contact bolt to pass through it. The bolt must make direct contact with the diaphragm for solid electrical connection.

Strip the masking tape off the insulators. Do not bend the tabs yet. Your stators are done.

STRETCHER STRUCTURE

Making the diaphragm is the next procedure. First, you must make a stretcher. I used steel bar stock 1"x¼" thick and consider it marginal but adequate. You will need 12 feet of steel. Cut the steel with a hack saw to the dimensions shown in *Fig. 14B*. Tap both ends of the short sides. Drill about ⅛" into the other bar so that it will accept the bolt for stability.

You will have to sand the bars to the bare metal on one side, using 100 grit aluminum oxide sandpaper. Place a strip of Scotch brand double sided tape on the bars on this side. Take some regular tape or masking tape and wrap it around the bars about 1 or 2 inches from the corners to prevent the double sided tape from pulling off at the corners, where the tensions will be highest.

It is important to remove every trace of grit for the next step, so vacuum carefully. Your plate glass should be lying on the table with a light colored surface under it so you can see the graphite on your diaphragm as you work with it.

Lay the mylar for the diaphragm over the glass, and cut it, leaving a large enough margin to attach the stretcher. Take some pieces of masking tape and tape down the mylar edges to eliminate most of the wrinkles. Now place the steel stretcher, one piece at a time, sticky tape side down, on the mylar. I start with a long piece, then add the short side pieces and finally the last long side. If you have the bolts protruding about ¼" you will be able to hold one end of a piece of steel up while engaging the other end in the piece laying on the mylar. With its end stabilized, you will be able to position the rest of the steel easily.

Once all your pieces are in place, screw in the bolts evenly all the way around; maximum tension is not necessary yet. The frame will expand and you will have a tight, wrinkle-free diaphragm. Do not be alarmed if you have a few tiny wrinkles in the corners of the diaphragm, but these wrinkles should not extend over the plate glass.

GRAPHITE DRUDGERY

Coat the diaphragm with a small amount of fine powdered graphite and rub it in with a cotton or rayon ball. Begin rubbing lightly and gradually increase the pressure until you are rubbing quite hard. Examine the mylar closely for grit, between it and the glass because if the chunks of grit are large you will tear the mylar as you rub. Remove any grit with a dry, lint free cloth or cotton ball, and rub over the area again.

The only failures I had in my original speakers occurred because I did not rub in the graphite hard enough. You must get a conductive coating all over the diaphragm to avoid "dead spots" which will produce no sound. The border must be conductive to help distribute the electrostatic charge over the entire surface.

After you have finished rubbing, vacuum up all excess graphite. Then take a paper towel or more cotton balls and rub off as much graphite as you can. Any loose graphite left on the diaphragm will eventually be burned off, but the speakers will hiss for anywhere from several hours to seveal months in doing so. Take on ohmmeter and touch its leads a few inches apart over several areas of the diaphragm. You should get anywhere between 50k and one megohm resistance at all test points, which indicate evenly distributed graphite.

Lift one edge of the stretcher to get a little air between the glass and the diaphragm. Tighten the stretcher as much as possible. It should start to bow and bend slightly. The limiting factor will be the double sided tape's tack, which will start to arc, pop, and pull loose from the corners. You can expect to deform the mylar at the corners.

Cut four pieces of aluminum foil, about ½"x1". These will be used to make contact to the diaphragm. Place some epoxy on the insulators of the stator of each matched pair that has the large hole for the diaphragm contact bolt. Put the aluminum foil over the hole making sure no epoxy oozes into the bolt hole. There should be a little epoxy under the foil to adhere to the insulator; however, there should be none on the other side of the foil because it must make clean contact with the graphite on the diaphragm.

Now, lay the stator, insulators down on the stretched mylar. Press firmly to squeeze the epoxy to a uniformly thin film. Weight the assembly with books and let it set up solidly.

FINAL FIXES

When the epoxy has gone off, cut the diaphragm away from the stretcher with a razor blade, and disassemble the stretcher. Leave the mylar pieces attached to the tape to keep the dust off it so that it can be used for the next diaphragm. You will probably be able to use the same tape for the entire project.

Gently lift one corner of the stator to work a little air under the diaphragm and lift the assembly from the glass. The diaphragm should be smooth. But, the stator will be bowed and warped because the diaphragm is pulling on it. If you let it bend it wrinkles the diaphragm. That is all right if there are no big wrinkles in the diaphragm when the stator is laid flat on the glass. Diaphragm tension should be high enough so that it will take three or four quarters to push it across the $\frac{1}{16}$" gap to the stator, maybe even more. Little creases are of no importance.

Take the other stator from the matched pair and hold it in place on the assembly, if everything fits as expected, lay this stator on the plate glass with its insulators pointed up. Position the stator and diaphragm assembly on it so the cell is in its finished form.

Gently poke a sharp pencil into the hole for the diaphragm bolt until you puncture the aluminum foil and the mylar film. Now place the bolt in the hole to be sure it fits. A word of caution: The bolt head will rest against the aluminum foil and mylar, which is very fragile. Never allow the bolt to turn when it is in contact with the aluminum foil or you will destroy the contact. Also, avoid moving the stators around with the bolt in place as this puts stress on the foil and the holes.

Remove the bolt and the stator, and diaphragm assembly. Apply a layer of epoxy to the insulators of the stator resting on the glass, after you have carefully vacuumed everything. Carefully position the stator/diaphragm unit on the stator. It is easiest to align two corners and then lay the assembly down. Try to avoid smearing the mylar with epoxy. When the stator is in place, and the corner is exactly aligned, insert the diaphragm contact bolt. Press the stators carefully and firmly together. Weight with books and allow to cure.

COMPLETED CELLS

When the epoxy has cured, the cell may be gently lifted. It will be rigid with the stators absolutely flat. Nothing can bend unless the glue joints are broken, which can easily happen since nothing adheres to graphite coated mylar very well. It is particularly important to avoid holding the cell in a horizontal position like it is on the plate glass. There is much less stress on it if it is suspended vertically from the upper corners when you are carrying it.

Thread the nut on the diaphragm contact bolt, preventing the bolt from twisting by holding a screwdriver on the head and turning the nut only. Finally, bend the tabs on the aluminum upward, insert the bolts, and tighten. Trim off any excess diaphragm material with a razor blade or with sandpaper. Repeat this process for the other cells.

You will probably have to replace a diaphragm for various reasons. It can be done easily. Position the cell flat on the plate glass. Take a sharp putty knife and run it along the bond between the stators to break it around the perimeter. The bond across the center insulators will probably break loose if you just gently lift the stators apart. If this doesn't work, take a sharpened end of a metal yardstick and slide it between the insulators.

You must clean all the old epoxy off the insulators with the putty knife before you can repeat the diaphragm process. Be careful not to damage the stator insulation. If you do, varnish applied with a Q tip will touch it up.

Frames are up to you. I used 2"x2" oak in which I cut a slot to accept the edge of the cells. Remember that wood is not a good insulator when dealing with high voltages, so do not allow the aluminum to touch the frames.

When the speakers are first turned on, they will hiss, but with time this will cease. Adjust the polarizing voltage until the diaphragms "cave in" or start a low frequency popping noise (you will see an arc with each pop if you look closely), then back off about 25%. If you get to full voltage and they play fine and there is no sign of arcing or instability, don't worry about getting higher voltages.

DISPERSION ISSUES

If dispersion is desired, make strip cells about 5" wide and 36" long. No cross insulators will be needed because the maximum unsupported distance is 5". Five or six of these cells should be arranged around the surface of a cylinder. The angle between each strip should be less than eight degrees for minimum "venetian blind effect." Sand the edges carefully to remove all traces of stray diaphragm material; if you don't, you will get arcing from one cell to the next.

Keep the long border insulators very narrow (under ½" if possible) so the diaphragms are as close to each other as possible. Run some tape or use foam between the cells so there are no significant air leaks between them. The group of cells should act as one. You probably will not use a stacked set of cells if you make them wide dispersion. Since you will have poor vertical dispersion, make your enclosure so that it leans back to aim the beams upward.

The cells can have stators made from wire, which is the most efficient, but there are several disadvantages. First, they are quite expensive. Second, 50 mil music wire is hard to find. Third, the wires are not straight and you can get better uniformity with perforated metal. Finally, they are very heavy. Several readers have turned instead to $^{1}/_{16}$" plain copper welding rod. These are spaced 10/inch rather than 12/inch as they are in my earlier design with music wire. For those of you who wish to build wire cells anyway, please refer to my article in *TAA* 4/75.

SETTING UP

The planar speakers must be set up properly, accurately placed an equal distance from your listening location, and pointed directly at you. They should be vertical and not twisted. If any of these conditions are not met, you will find that the speakers do not sound balanced and that possibly the frequency response is down in one channel.

To set them up, take a tape measure and hook it to a pin that you have stuck in your listening chair at your body midline. Set one speaker where you want it and measure on the floor to he inside edge of that speaker. Place the other speaker with its inside edge at the same distance. If you change the direction of one speaker, always move the other as well.

If your speakers are set up as room dividers with spring feet at the top as mine are, you will need a level to position the speaker vertically as well. When seated, you should be able to see your reflection centered in the speaker diaphragms. Rotate them to achieve this.

Woofers should be set up so that they are also the same distance from you as the ESL's. KEF B-139 drivers are flat and it is easy to measure from the ESL diaphragm and then duplicate that measurement to the woofer surface. If you use a cone woofer, I cannot say for sure where the effective "surface" of the driver is, but guessing from the recent designs that use "phased" arrays of drivers, I would place the woofer ⅓ of its cone depth closer to the listening location than the ESL.

CURVED CELLS

Curved ESL's provide completely uniform dispersion. Several attempts have been made in the past to accomplish this, but in my opinion, none have been successful, even though there are several patents outstanding. The problem with curving ESL's is that when you bend the cell, the diaphragm is pulled into the inner stator. The usual solution has been to use various types of supporting structures to keep the diaphragm spaced evenly from the inner stator. The result is either many flat cells whose supporting structures break up the smooth curve of the diaphragm, or, if a continuous support is used (such as a sheet of foam), you do not have linear motion and/or a push/pull speaker. These techniques ruin efficiency and make high SPL's impossible.

I have proposed a solution to this problem, and Bob Unterbrink has spent countless hours perfecting the fabrication techniques. A patent has been granted to us covering both the concept and the construction techniques, which I will present here. This speaker design will be marketed by us under the company name Sanders Systems. Although full patent protection covers the design, individuals who wish to attempt construction for their own personal use and not for commercial sale may do so.

The design allows for a fully push/pull speaker, high SPL's, perfectly uniform dispersion, low distortion, and a totally free diaphragm. The disadvantage is that it is nearly impossible to build.

Study into the causes for the diaphragm collapsing into the inner stator reveals that there is tension on the diaphragm in all directions. Horizontal tension on the surface of the cylindrical shape pulls the diaphragm straight so it cannot follow the curve of the stator. It will tend to form a straight line between the support points of the diaphragm and will be pulled into the inner stator.

The solution is to have only vertical tension on the diaphragm. If you can imagine the diaphragm as an infinite series of straight lines running vertically across the curved insulators, you can see that there should be no tendency to bow towards the inner stator.

The curved cell is constructed in the same manner as a flat cell, with an insulating grid glued to the aluminum stators. However, the gluing must be done on a curved surface, known as a jig. The curve should be greater than what your finished shape will

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by HUNTER KEVIL

Loudspeaker Literature

WITH THIS ISSUE begins a new column in *Speaker Builder*: a quarterly bibliography of current literature dealing with loudspeakers and their performance. Although the need for better control of the literature has long been apparent, this bibliography represents the first attempt to satisfy it. A simple example will suffice. A. N. Thiele published his classic paper on bass-reflex theory in 1961 in an Australian journal, but it did not begin to exert a significant effect on speaker engineering until after it had been republished in the ***Journal of the Audio Engineering Society*** a full decade later. Had Thiele's ideas been widely known soon after publication, we might have been spared ten years' worth of poorly designed vented speakers. If this bibliography can help promote, among professionals and amateurs eager to substitute an informed technical intuition for guesswork, the quick diffusion of knowledge and information concerning loudspeakers, it will have served its purpose well.

The bibliography will cover journal articles, books, technical reports, patents—in fact, any source of significant information on speakers and their performance. Coverage will begin, like *Speaker Builder* itself, with the new decade; publications earlier than 1980 will thus be excluded.

For each quarterly survey, a select group of journals and magazines will be consulted. Materials chosen for inclusion will be listed here a relatively short time after publication, usually no more than nine months. These journals are listed below. As the list grows, as it doubtless will, the new titles will be mentioned here. But with estimates of the world total of technical periodicals ranging to as high as 50,000, our coverage cannot hope to be complete. Fortunately an extensive secondary literature selectively covers thousands of journals. Examples are ***Engineering Index, Physics, Abstracts,*** and the ***Monthly Catalog of U.S. Government Publications.*** These and similar special-purpose publications, such as the *Official Gazette of Patents*, will also be consulted regularly. Entries from these sources will naturally be listed with a greater time lag.

I will also include pamphlets from manufacturers, such as the Electro-Voice *P A Bible* listed below. Such pamphlets are not usually found in the secondary literature, and manufacturers are invited and encouraged to send copies of important pamphlets and reports of an objective, non-commercial character to the "Loudspeaker Literature" editor.

The bibliography will be as complete as is reasonably possible within a few simple guidelines. Only papers of some objective stature with direct bearing on speakers will be included. This excludes advertisements, articles not germane to the performance of speakers, e.g. those on marketing or retailing, and thoroughly popular ones. Announcements of new products will also be excluded. Many of these will be found in the column "Good News" at the beginning of every issue. Finally, test reports will also be excluded. Articles in foreign languages, particularly the major ones, will not be excluded simply for that reason; but more stringent criteria of significance will be applied to them. Translations of titles will be given for those listed.

For convenience, I have subdivided the field of loudspeakers into 14 sub-groups. Not all sub-groups will be used in a given survey, but the order in which they are presented will remain the same. This will facilitate literature searches through many issues. Within each sub-group, entries will be arranged alphabetically by name of author, or by name of the sponsoring organization when no author is named. Brief abstracts will be given for interesting articles and for articles whose titles do not accurately describe the contents.

Finally, to set the bibliographies into a broader context, I want briefly to mention a few important books. Everyone seriously concerned with loudspeakers should own two essential books, Martin Collom's *High-performance loudspeakers* (second edition, 1980) and *Loudspeakers; an anthology*, edited by Raymond E. Cooke (1978). Colloms omits PA, but intelligently and succinctly discusses almost everything else. He also provides excellent bibliographies. The book is published by Halsted Press, a division of John Wiley, at $21.95. The anthology reprints the best papers published in the ***Journal of the Audio Engineering Society*** between 1953 and 1977. The classic papers by Thiele, Small and Heyser are all included. It is available for $19

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PERIODICALS LIST

Acustica (AC)
(Eng. Fr. Ger.) Deutsche Physekalische Gesellschaft, Hirzel Verlag, Postfach 347 D-7000 Stuttgart 1 W. Germany DM 148.

Applied Acoustics (APA)
Applied Science Publishers Ltd., Ripple Road, Barking Essex, England £12.

Audio (AU)
CBS Publications, 1575 Broadway, NY, NY 10036 $12.

Audio Amateur (TAA)
PO Box 576, Peterborough, NH 03458 $14. Q

L'Audiophile (Paris) (L'A)
PO Box 576, Peterborough, NH 03458 $48. Bi-M.

Hi-Fi News and Record Review (HFN)
Link House Dingwall Ave., Croydon CR9 2TA England $35.00

High Fidelity (HF)
1 Sound Ave., Marion, OH 43302 $13.95

IEEE Transactions on Acoustics, Speech, and Signal Processing (IEA, IES, IESP)
345 East 47th St., NY, NY 10017

Journal of Sound and Vibration (Southampton) (JSV)
Academic Press, 24-20 Oval Rd., London NW1, England £99.30 fortnightly

Journal of the Acoustical Society of America (JASA)
American Institute of Physics, 335 E. 45th St., NY, NY 10017

Journal of the Audio Engineering Society (JAES)
60 East 42nd St., NY, NY 10017 $45 non-members

Noise Control Engineering (NCE)
Herrick Labs, Purdue University, W. Lafayette, IN 47907. Subs: Box 2167, Morristown, NJ 07960 $30 Bi-M.

Noise/News (NN)
Noise Control Engineering, Box 1758, Poughkeepsie, NY 12603 (Members only)

Popular Electronics (PE)
Ziff Davis Publishing Co., One Park Ave., NY, NY 10016 $13.

Popular Mechanics (PM)
224 W. 57th St., NY, NY 10019 $8.97

Popular Science (PS)
380 Madison Ave., NY, NY 10017 $9.94

Proceedings of the IEEE (Pr IEEE)
345 East 47th St., NY, NY 10017

Radio Electronics (RE)
200 Park Ave., NY, NY 10003 $9.98

SMPTE Journal (Society of Motion Picture and TV Engineers) (SMPTE)
862 Scarsdale Ave., Scarsdale, NY 10583 $35.

Sound and Vibration (SV)
Acoustical Publications Inc., 27101 E. Oviatt Rd., Bay Village, OH 44140 $10. (free to qualified persons)

Soviet Physics—Acoustics (SV—A)
American Institute of Physics, 335 E. 45th St., NY, NY 10017. $85. Bi-M.

Speaker Builder (SB)
PO Box 494, Peterborough, NH 03458. $10. Q

Stereo Review (SR)
Ziff Davis Publishing Co., One Park Ave., NY, NY 10016 $9.98

Studio Sound and Broadcast Engineering (London) (SS)
Link House Publishing Ltd., Dingwall Ave., Croydon Surrey, England £4.17

Wireless World (London) (WW)
Dorset House, Stamford St., London SE1 9LU England $31.00

All prices are for one year, all are monthly unless indicated otherwise. Q = Quarterly; Bi-M = Bimonthly.

ELECTROSTATIC SPEAKER CONSTRUCTION PART II

Continued from page 25

be because the composite tends to spring back when cured.

The diaphragm is stretched vertically over the curved surface and coated with graphite. Then the stator is glued in place. This assembly is removed, the remaining stator is placed with insulators up, and the diaphragm/stator assembly is glued onto it. The laminations hold the assembly in an arc that is determined by the amount of curve built into the jig. 20 degrees of curve are sufficient but you may put in as much as you wish.

IMPOSSIBLE DREAM

This construction sounds simple, but it is nearly impossible to do.

To begin with you need a building jig, a table whose surface is very smooth and has an appropriate amount of arc. At each end of the table is a curved steel bar with tape on it to attach to the diaphragm. A lever is attached to the bars, and they can pivot as directed by a turnbuckle to tension the diaphragm. The various parts of the cell are held in place by nylon or leather straps and cinching buckles while the epoxy cures.

Some other problems are that you will still need a slight bit of horizontal tension to get the wrinkles out of the mylar, it is hard to get the grids to match on both stators, the glue joints are highly stressed and tend to pop loose, and the diaphragm tends to move more easily towards the inner stator under dynamic conditions.

Some of the solutions are thinner insulators on the outer stator for more even movement, nylon bolts through the insulators to help hold the glue bonds, careful mounting of the cell in a supporting frame, and a more highly curved surface for easier construction, so that the tendency for spring back brings the cell to the desired curve rather than past it, thus requiring the glue bond to hold the shape.

Our operational cells of this type are four feet tall and two feet wide and one per channel is used in conjunction with a pair of KEF transmission line woofer systems. The sound is exactly as expected: perfectly uniform dispersion throughout the listening area with absolutely no "venetian blind effect." Such a cell still needs all the electronics and equalization of a planar cell, so do not omit the equalizer.

I strongly advise you not to attempt to build such a cell, since you are very unlikely to succeed. If anybody can figure out an easy way to make this type of cell, I will buy the rights to use it. Even better, I will purchase completed cells from him/her for our commercial use. □

Part three, next time, will include details on building the woofer enclosures.—ED.

Literature

Continued from page 26

from the Audio Engineering Society, 60 East 42nd St., New York, NY 10017. (A companion anthology treating *Sound Reinforcement* is also available at the same price from the same source; both volumes for $35.) The home experimenter will want to have David Weem's book, or the *Loudspeaker Design Cookbook*, both discussed on page 30 of the last issue.

JANUARY-MARCH 1980

(1) THEORETICAL AND GENERAL

Chrétien, Gérard. L'élaboration d'une enceinte acoustique. ("Designing a loudspeaker") ***L'Audiophile*** 14 (Feb. 1980), pp. 72-79. (text in French) No refs. Interview with Jean-Claude Tornior of Phonophone about the design of his unusual model BG speaker.

Kagawa, Y., T. Yamabuchi, *et al. Finite element approach to acoustic transmission-radiation systems and application to horn and silencer design.* ***Journal of Sound and Vibration*** 69:2 (22 Mar. 1980), pp. 207-228. 9 refs. and appendix. Deals generally "with acoustical systems with an opening to semi-infinite space." After the general case of "sound radiation from a circular opening in an infinite baffle," conical and exponential horns are considered, and frequency response and directivity are calculated.

Kagawa, Y., T. Yamabuchi, *et al. A finite element approach to a coupled structural-acoustic radiation system with application to loudspeaker characteristic calculations.* ***Journal of Sound and Vibration*** 69:2 (22 Mar. 1980), pp. 229-243. 10 refs. This complements the previous paper, in conjunction with an earlier paper ***JSV 53 (1977, 357-374)*** that examined sound pressures inside a speaker enclosure. This paper calculates natural frequencies of a diaphragm and pressures inside and outside an enclosure. Comparison of calculations with measured data is promised.

(2) LOUDSPEAKER DRIVER UNITS

Bottenberg, Louis M. and K Raj. *The dependence of loudspeaker design parameters on the properties of magnetic fluids.* ***Journal of the Audio Engineering Society 28***: 1-2 (Jan-Feb 1980), pp. 17-25. 17 res. The authors are with Ferrofluidics Corp.

Harwood, Hugh D., J. Y. C. Pao, and D. W. Stebbings. *Diaphragm material for moving-coil loudspeaker, may be laminated or integral with surround.* U.S. Patent No. 4,190,746. (***Official Gazette of U.S. Patents,*** Feb. 26, 1980, p. 1430.) Patent for the polypropylene-diaphragm drivers used by Chartwell and Harbeth. The French and German applications corresponding to this patent are discussed in Adrian Hope, *Audio Patents,* ***Hi-Fi News and Record Review 25:1*** (Jan. 1980), p. 59.

Hiraga, Jean. Le problème de fractionnement de membrane. (*"The problem of cone break-up"*) ***L'Audiophile 14*** (Feb. 1980), pp. 61-71. (text in French) No refs. A not overly sanguine comparison of the newest Japanese approaches with the traditional methods.

Matsushita Electric. (*a motional feedback system for loudspeakers*). U.K. patent application No. 2,010,639. Brief discussion in Adrian Hope, *Audio Patents,* ***Hi-Fi News & Record Review 25:2*** (Feb. 1980), p. 50.

Pioneer Corp. (carbonized diaphragm material). U.K. patent application No. 2,011,310. Brief discussion in Adrian Hope, *Audio Patents,* ***Hi-Fi News & Record Review, 25:3*** (Mar. 1980), p. 4.

(3) CROSSOVER NETWORKS, PASSIVE AND ACTIVE

Jung, Walter G., and Richard Marsh. *Picking capacitors; selection of capacitors for optimum performance.* ***Audio 64:2*** (Feb. 1980), pp. 52-62, Part I; ***Audio 64:3*** (Mar. 1980), pp. 50-63, Part II. 32 refs. List of manufacturers and distributors of "audio-grade capacitors."

(4) CABINETS

Bolon, Paul. *Finishing plywood like the pros.* ***Popular Science 216:1*** (Jan. 1980), pp. 114-116.

Kral, Robert C. *Diffraction—the true story.* ***Speaker Builder 1:1*** (Jan. 1980), pp. 28-33. 7 refs. On the basis of steady-state, not impulse, tests, the author concludes that diffraction effects will not "be apparent in a normally reflective listening environment."

Peterson, Franklynn and Judi R. Kesselman. *How to make the most of new-generation particleboard.* ***Popular Science 216:1*** (Jan. 1980), pp. 117-119. Part 2 of 2. The first part was published in ***PS*** Dec. 1979, pp. 96-99.

Reddy, C. V. Ramachandra, N. Ganesan, *et al. Response of plates with unconstrained layer damping treatment to random acoustic excitation.* ***Journal of Sound and Vibration 69:1*** (8 Mar. 1980). Part I: *Damping and frequency evaluations,* pp. 35-43, 11 refs. Part II: *Response evaluation,* pp. 45-57, 15 refs. Useful for theoretical evaluation of a damped speaker panel and for a survey of the literature.

(5) MEASUREMENTS, TEST EQUIPMENT, AND SPEAKER EVALUATION

Grubb, R.N. *Non-echoic acoustic measurement with the H-P 3582A.* ***Wireless World 86*** (Mar. 1980), pp. 45-49. refs.

Halliwell, N.A. and J.J.P. Shelton. *Loudspeaker Research 1; improving performance with a laser.* ***Hi-Fi News & Record Review 25:2*** (Feb. 1980), pp. 41-43. 4 refs. The authors are with Southhampton University's Institute of Sound and Vibration Research. "A new design of Laser Doppler Velocimeter (LDV) has been developed to measure the surface velocity of a loudspeaker cone (...)."

Lane, Basil. *Loudspeaker Research 2; R&D at B&W.* ***Hi-Fi News & Record Review 25:2*** (Feb. 1980), pp. 45-49. No refs. How the British manufacturer B&W used a laser inferometer and impulse testing to develop the model 801 loudspeaker.

Pfeifer, John E. and William Eppler. *Build a low-cost white/pink noise generator.* ***Popular Electronics 17:2*** (Feb. 1980), pp. 67-73. No refs. Parts list, ordering information. Kit available for $40.

Staff writers. *Dynamic measurement instrumentation buyer's guide.* ***Sound and Vibration 14:3*** (Mar. 1980), pp. 14-17. Manufacturers and suppliers of analyzers, calibrators, generators, meters, recorders and displays, etc.

Thomsen, Carsten. *Applications of new pocket sound level meters.* ***Sound and Vibration 14:3*** (Mar. 1980), pp. 8, 10. No refs. The author is with Brüel & Kjaer and discusses the B&K integrating sound level meters types 2225 and 2226.

(8) HORNS

Atkinson, John. *Horns in the home; 2. over one's head.* ***Hi-Fi News & Record Review 25:3*** (Mar. 1980), pp. 55-56. No refs. Describes the bass horns of Mr. Nagami, head of Sony's "Esprit" division; horns extend 1.85m into the ceiling.

Henricksen, Clifford A. and Mark S. Ureda. *Loudspeaker horn.* U.S. Patent No. 4,187,926, assigned to Altec Corp. (***Official Gazette of U.S. Patents,*** Feb. 12, 1980, p. 504.) The "Manta-Ray" horn, which the authors have fully treated in ***Journal of the Audio Engineering Society 26:9*** (1978), pp. 627-634.

Walker, Colin. *Horns in the home; 1. under one's feet.* ***Hi-Fi News & Record Review 25:3*** (Mar. 1980), pp. 51-53, 57. No refs.

(9) METHODS OF BAFFLING WOOFERS

Alard, Michel. **Optimalisation d'un bass-reflex sur calculatrice HP 97.** ("Use of the Hewlitt-Packard calculator to optimize bass-reflex designs") ***L'Audiophile 14*** (Feb. 1980), pp. 51-59. (text in French) No refs. Gives a model of the action of bass-reflex woofer and a program for the HP 97 to predict frequency response; a optimum enclosure for the new Audax PR 38 S 100 38cm woofer is derived. Based on earlier work by P.J. Snyder (***Audio Engineering Society Preprint No. 1307***).

Newman, Raymond, J. *Dipole radiator systems.* ***Journal of the Audio Engineering Society 28:1-2*** (Jan-Feb. 1980), pp. 35-39. 8 refs. Open-baffle systems using standard moving-coil woofers.

Weems, David B. *A second life for vented speakers; how modern design approaches have revived interest in reflex speaker systems.* ***Popular Electronics 17:1*** (Jan. 1980), pp. 48-50, 56-57. No refs. Lists Thiele-Small parameters for seven woofers.

(10) PROFESSIONAL SOUND SYSTEMS

Electro-Voice, Inc. *The PA Bible.* This comprises a basic guide of 16pp, with supplements issued irregularly. According to E-V, "We've tailored our comments to the real world of the performing musician, but our material is helpful in designing high-quality fixed installation sound reinforcement systems too." As of June 1980, five supplements have been issued. They treat: drivers and horns, power-handling capacity, microphone types, equalization, and system inter-connection. The *PA Bible* and all existing and future supplements may be obtained by sending $1 to Electro-Voice, Inc., 600 Cecil St., Buchanan, MI 49107.

(11) CONSTRUCTION PROJECTS

Clark, David L. and Bernhard F. Muller. *An ambience reproduction speaker system.* ***Speaker Builder 1:1*** (Jan. 1980) pp. 12-16. No refs. A letter by Peter W. Mitchell (***Speaker Builder,*** April 1980 p. 35) gives a positive comment on this article and updates the list of delay devices.

(14) MISCELLANEOUS AND UNCLASSIFIED

Staff writers. *Addenda to annual equipment directory.* ***Audio 64:1*** (Jan. 1980) pp. 38-40 for loudspeakers; pp. 44-46 for car speakers.

Stamler, Paul J. *How to improve that small, cheap speaker.* ***Speaker Builder 1:1*** (Jan. 1980), pp. 22-27. No refs. Table of Thiele-Small parameters for 32 drivers. See ***SB*** April 1980, p. 34, for correction of misprints.

United States. Dept. of Commerce, Bureau of the Census, Industry Division. *Current Industrial Reports; radio and television receivers, phonographs, and related equipment, 1978. (SuDocs No. C3.158: MA-36M(78)-1; Monthly Catalog No. 80-3883). Government statistics on speakers for year 1978.* □

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Bookwork

Reviewed by Robert M. Bullock

ACOUSTIC TROUBLESHOOTING OF AUDIO SYSTEMS

Well over half of *Acoustic Troubleshooting of Audio Systems* by Michael Ryerson (Reston Publishing, 1979, 195 pp., $14.95) consists of a discussion of sound propagation from a source or sources and how it is altered by the listening environment. The first chapter covers room resonance, speaker directionality, reflection, reverberation, noise, feedback and diffusion, among other topics. The next two chapters contain accounts of stereophonic and quadraphonic sound dispersion. The remainder of the book is made up of a chapter each on Speaker Enclosure Acoustics, Microphone Acoustics, Acoustic Tests and Measurements and Motor Vehicle Acoustics.

According to the preface "Acoustic troubleshooting is concerned with the control and optimization of those physical characteristics that affect reflections of sound waves within a listening area and thereby determine the aural environment." The reader discovers in the first three chapters that "control and optimization" are invariably implemented by (1) adjustment of audio system controls, (2) rearranging listening area furnishings and/or system components, (3) redecorating and/or remodeling the listening area, (4) using a different listening area or (5) using an equalizer. The audiophile must wade through over ninety pages of turgid, pseudo-technical prose to glean these five techniques and even then he may not catch them on the first (or even second) reading. I could find no further troubleshooting procedures to add to the above five in the remainder of the book.

An abundance of terminology is introduced in passing, never to be mentioned again. The author seemed bent on including as many acoustic and audio terms as possible, even if they did not aid in the exposition. This, together with the paucity of useful information, leads me to believe that the following quote from the preface best describes the purpose of this book: "It can be especially appreciated by sales personnel who will become more knowledgeable [by reading the book] and thereby more effective in dealing with customers." I do not see this book as a useful work for an audio enthusiast, even ignoring its inflated price tag.

HI-FI INSTALLATION SIMPLIFIED

Derek Cameron's book *Hi-Fi Installation Simplified* (Reston Publishing, 1978, 184 pp.) can be considered to consist of two parts. The first is concerned with the set up and interconnection of hi-fi systems. Two

Bookwork

chapters deal with speaker placement, use of controls, cables, connectors and turntable adjustment. A third chapter provides thirty pages of specifications and interconnection diagrams for a variety of commercial audio equipment. The second part of the book contains a chapter each on antenna installation, interference, residential wiring and checks and tests.

The first part of the book might be useful to novice hi-fi installation personnel as examples of possible interconnections of commercial components to form a system. The individual who wishes to set up a system for himself would probably be better served by using the manufacturer's information supplied with the equipment.

In my opinion, the second part of this book is of doubtful value since none of the topics are discussed in sufficient detail for practical application.

The jacket description says this book will be "especially appreciated by sales personnel because they will find understandable information which will make them more knowledgeable and more effective in customer relations." This is probably the best use to which the book can be put since I see nothing to recommend it to the audiophile, either novice or expert.

PROBLEMATICAL PORTFOLIO

The cost benefit ratio of *Acoustic Suspension Design Portfolio* by Dan Cohn (23 pp., $12.95) is abysmal. *Loudspeaker Design Cookbook*, which I reviewed in *Speaker Builder* 2/80, p. 30, gives a much more coherent, careful and objective description of acoustic suspension design procedures and sells for half the price. The only real virtue of this portfolio, three design examples which are correct in their small signal aspects, is negated by the cost of $4.00+ per example, one glaring error (1% reference efficiency for a KEF B110!) and a questionable analysis of large signal performance.

The portfolio commences with the observation that an acoustic suspension system behaves analogously to a second order high pass filter and that a filter's transient response is related to its "Q." In particular, the portfolio states that if Q is greater than .707 a filter will ring, while if it is less than .707 it will not; this is false. The correct transition Q is one half. The next assertion: Q = .707 is generally accepted as the ideal trade-off. I assume the author means it is the ideal trade-off for loudspeakers, which is not necessarily true. Many designers of excellent systems consider a broad range of Q values appropriate. For example, the Rogers LS3/5A has a Q of about one, while its companion subwoofer system has a Q of about one-half.

After a brief discussion of possible closed box responses, the portfolio then has a list of symbols, definitions and formulas, half of which are never used in the sequel. Those that are used are left in needlessly complicated form, since the portfolio considers only a system Q of .707. For example, the general form of the cut-off frequency formula is quite messy, but if Q = .707, the formula reduces to $fe = f_c$. The formulas do however, make a most impressive array. Following this, there is still another page of formulas which seem to be lifted bodily from Badmaieff and Davis' book on loudspeaker design. The general discussion concludes with a page titled "Construction Notes" which consists mostly of ramblings about the use of sound absorbing materials in the box.

As for the design examples, let's take them one at a time. The portfolio refers to the first example as a general purpose "Advent type" loudspeaker system. The calculations are correct until the large signal performance is determined. The author's calculation of the maximum acoustic power radiated is based on the assumption that the system will be thermally limited at its cut-off frequency. It is much more common for the system to be displacement limited at low frequencies. On this basis, cone excursions on the order of .46" would be required to produce the claimed .437 acoustic watts output. I know of no 10" drivers capable of linear one half inch excursions and so, at the very least there would probably be extreme distortion at this high level.

A more realistic cone excursion of .2" would give a displacement limited should pressure level of 103 decibels in the author's listening room. This is still a quite respectable output for a general purpose system, but it does not approach the claimed 111 dB. This example concludes with a calculation for crossover frequency which seems to be based only on diffraction considerations. Many other matters must be considered in the placement of crossover.

Cohn's second example is a mini monitor type system he describes as a "slightly improved version of the Rogers LS3/5A." The author also claims that his system's 79 Hz. cut-off frequency is slightly better than the LS3/5A. But, using the book's own data on the B110 gives the LS3/5A a cut-off frequency of 57Hz. I guess a higher cut-off frequency is better for a mini monitor. The portfolio also claims a maximum sound pressure level of 108 dB for this system. In addition to the author's unfounded assumption that the system is thermally limited rather than displacement limited, his figure is obtained by using an incorrect value for reference efficiency. The correct efficiency is .303% rather than the 1.03% stated in the portfolio. A more realistic displacement limited sound pressure level for this unit is 96dB, which is in close agreement with the advertised 95 dB of the LS3/5A.

The third example, a subwoofer system, is not even an acoustic suspension design. By definition, a closed box system is an acoustic suspension design if the system compliance ratio is greater than three, but in this example, it is 1.97. This distinction is not necessarily an academic one. If a driver is optimized for acoustic suspension designs, as Speakerlab's units are, a large box may not provide the necessary air cushion for the driver and damage could result. The 3.75 $ft.^3$ box of this example might be small enough, but I would check with Speakerlab to make sure. As in the other two examples, the calculated sound pressure levels are optimistic. For such a low cut-off frequency, 27 Hz, the displacement limited SPL would be closer to 93dB than the 107dB quoted by the portfolio.

Following the examples the author lists the advertised parameters for a number of drivers. This information can be obtained from the manufacturers of the listed drivers, sometimes for a nominal charge. The portfolio concludes with a procedure for the determining of driver parameters which uses a more complicated test set-up than the procedures with which I am familiar. Also, the formula for calculating V_{AS} is an approximation which can be greatly improved by taking additional measurements.

Rather than pay $12.95 for this portfolio, a serious designer would be better off to invest $24.95 in a copy of Collom's *Loudspeaker Design Cookbook*, $5.00 in a copy of Badmaieff and Davis, *How to Build Speaker Enclosures*, and $6.00 or so to acquire manufacturers' data directly. This would not only contain the required information, but would constitute a useful and versatile library for only three times the cost of the portfolio.

OUTDATED HOW-TO

How to Build Your Own Stereo Speakers by Christopher Robin (Reston Publishing, 1979, 193 pp., $6.95) contains detailed plans for the construction of various speaker enclosures depending on the driver diameter and type of system. It also devotes a chapter each to musical instrument speaker enclosures, speaker accessories and basic woodworking.

Even though the book's copyright is 1979, the material it contains is sadly out of date. For example, enclosure design is based solely on driver diameter without mention of any other parameters which influence response. Also, the only discussion of crossovers is a diagram of a first order two way system without any guide to component selection. Finally, the construction techniques used were common in the 1950's, but are seldom used today.

This book could be used to construct an enclosure to house drivers, but I would not recommend it, since high quality performance could not be expected and would occur only by luck. In short, *Speaker Builder* readers will find very little of value in this work. □

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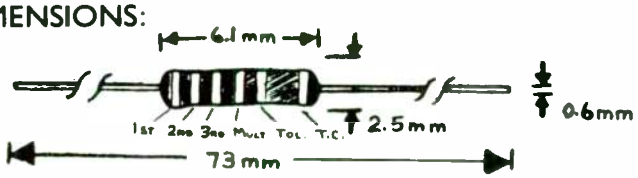
PRECISION METAL FILM RESISTORS:

Meet Specs for: MIL R10509 RN55, MIL 55182 RNR55

Tolerance: ≤ 1%
Max. Power: 0.35 W @ 70°C, derated linearly to 0 W @ 165°C.
Max. Voltage: 250 V
Temperature Coeffecient: 50 ppm/C°
Current Noise: ≤ .05 uV/v to 10k
≤ .1 uV/v to 100k
≤ .25 uV/v to 1M

DIMENSIONS:



VALUES:

For those of you unfamiliar in working with 1% metal film resistors, we might note that the values given are on the MIL-BELL scale. These are usually within 1% to 1½% of the corresponding IEC E24 values commonly used in domestic equipment. This gives a consistently much tighter tolerance to the specified value that a 5% or even 2% carbon film resistor. At the same time metal films provide less than half the noise, and much greater temperature, time and load stability, and better linearity than carbon film or composition types.

VALUES AVAILABLE

10	100	1 k	10 k	100k
20	110	1.1 k	11 k	110k
27.4	121	1.21k	12.1k	121k
30.1	130	1.3 k	13 k	130k
39.2	150	1.5 k	15 k	150k
47.5	162	1.62k	16.2k	162k
68.1	182	1.82k	18.2k	178k
75	200	2 k	20 k	200k
82.5	221	2.21k	22.1k	221k
90.9	249	2.43k	24.3k	243k
	274	2.74k	27.4k	274k
	301	3.01k	30.1k	301k
	332	3.32k	33.2k	332k
	365	3.65k	36.5k	365k
	392	3.92k	39.2k	392k
	432	4.32k	43.2k	432k
	475	4.75k	47.5k	475k
	511	5.11k	51.1k	511k
	562	5.62k	56.2k	562k
	619	6.19k	61.9k	619k
	681	6.81k	68.1k	681k
	750	7.5 k	75 k	750k
	825	8.25k	82.5k	825k
	909	9.09k	90.9k	909k
				1 MEG

GOLD PLATED CONNECTORS

Our connectors and associated hardware are 23.9K gold plated (0.000020" gold). This is a plate of the highest quality, and has been chosen for its suitability in electronic contact applications.

PHONO PLUG

A shielded (gold plated brass handle) plug that mates well with our gold plated phono jack as well as the gold plated phono jacks commonly and now on high quality equipment.

PHONO JACK A

A jack that mounts from the rear of the panel (up to ¹³⁄₆₄" thick) in a hole of ⅜" diameter. The design allows the hex brass body to be firmly held, while the external nut is completely tightened. This results in an installation that is free from the loosening problems commonly encountered in panel mount phono jacks. All hardware is supplied in gold plate to insure optimum grounding continuity.

PHONO JACK B

Conventional front-of-panel mount with washer, lug, and nut mounting on rear of panel. Requires ¼" hole. All hardware gold plated.

NYLON INSULATORS

Sold in sets of ten, each insulator consists of a nylon step washer and flat washer.

⅜" SIZE— Large insulator for our phono jack described above, and other ⅜" connectors. Requires ½" mounting hole.

¼" SIZE— Can be used on phono jacks from H.H. Smith, Keystone and Switchcraft (3501FP). This insulator fits our older gold plated phono jack. Also useful for the insulation of metal banana jacks (H.H. Smith # 101, # 109; Pomona # 3267; E.F. Johnson # 108-0740-001.)

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PRICING IS AVAILABLE ON THE CURRENT ORDER FORM.

Minimum order is $10.00. Please order on the form provided. It helps us to process your order smoothly and without errors. We reserve the right to return any order not placed on the **current** order form, or under the $10.00 minimum. Orders on MasterCharge or Visa are welcome by mail.

We ship all orders by First Class Mail or UPS. Usual delivery time should be 2-3 weeks. Please include appropriate additional funds for special handling (UPS Blue Label etc.). OVERSEAS ORDERS should add 10% to their total order to cover extra shipping charges. If you pay by personal check, please allow an additional 10 days for the check to clear.

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P.O. Box 243, Peterborough, NH 03458
Successor to Component Systems of Indianapolis, Indiana

Tools, Tips & Techniques

by The Engineering Staff
Crown International

The most common of all speaker protection schemes is a fuse in series with the load. The fuse may be single, fusing the overall system; or (in the case of a multi-way speaker system) multiple with one fuse on each speaker. Fuses help to prevent damage due to prolonged overload but provide essentially no protection against damage that may be done by large transients and such. To minimize this problem, high-speed instrument fuses (such as Littlefuse 361000 series) are most appropriate for such applications. (For a nomograph showing the case of fuse size vs. loudspeaker ratings, refer to *Fig. 1*.)

Another form of load protector is shown schematically in *Fig. 2*. Whenever the load is overdriven a relay switches a lamp in series with the load, smoothly relieving the overload. The lamp then doubles as an overdrive indicator as it glows. This system, by adjusting the relay tension adjustment and the protection level control is useful from 25 to 200 watts for a typical 8 ohm load.

Another (but more sophisticated) form of overload protector relieves the overload by controlling the amplifier's input signal which is creating the overload. This form of protector not only saves the load, but also eliminates amplifier overload. With this device, it is possible to operate the amplifier at its maximum level with a minimum of clipping. This device is shown schematically in *Fig. 3*, and features an overdrive indicator, distortionless photo-optical control, and a protection level control—giving adjustment for 1W to infinity when driving 8 ohms.

A common problem which causes damage and irritation is the turn-on thump—typical to many signal sources such as Hi-Fi preamplifiers. *Fig. 4* shows the schematic of a muter which, when inserted in the input signal line, mutes for several seconds before connecting the source to the amplifier; thereby eliminating turn-off transients which occur after the relay drops open (less than 0.1 sec.). □

Editor's Note: Readers are referred as well to Walt Jung's article in Audio Amateur, *Issue 3, 1977 p. 4 "The Speaker Saver" which is a device to protect speakers and amplifier output stages as well. The 1977 series is available only as a set for $10. from* TAA, *Box 576, Peterborough NH 03458.*

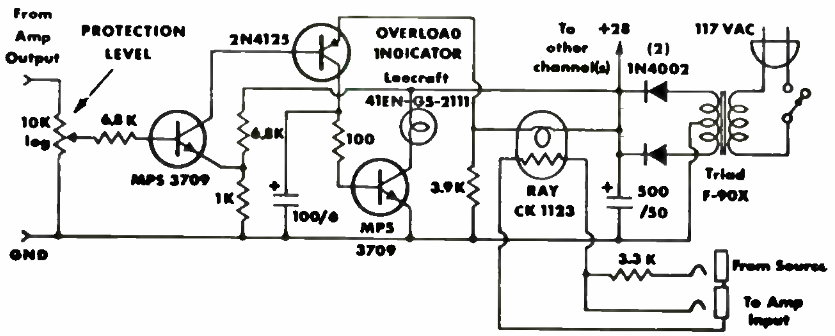


Fig. 3 Peak-power limiting compressor with overdrive indication.

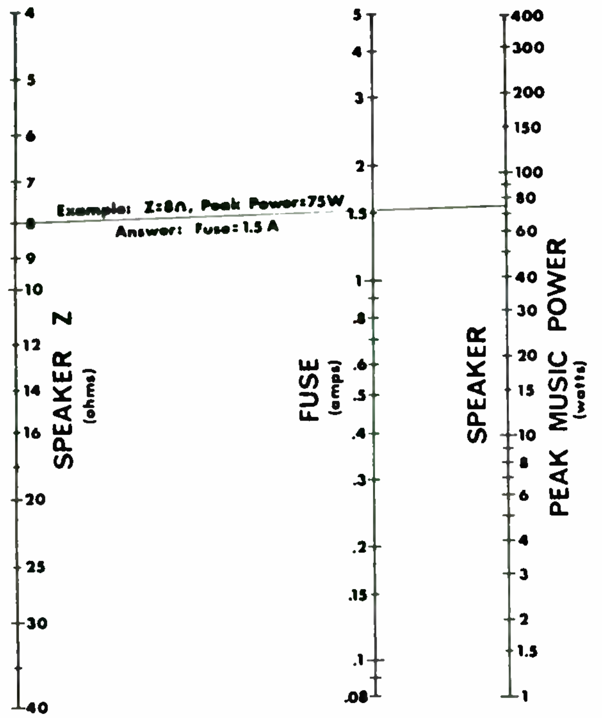


Fig. 1 Fuse selector nomograph for loudspeaker protection.

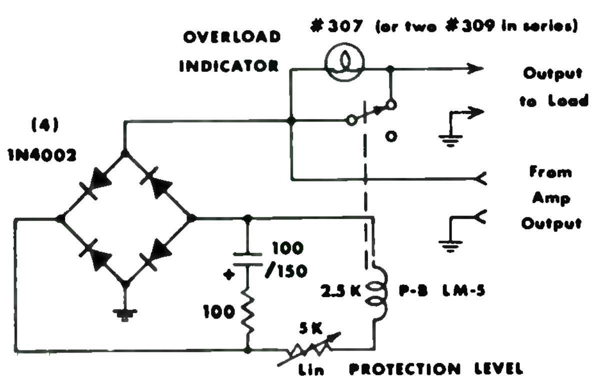


Fig. 2 Relay-controlled protector.

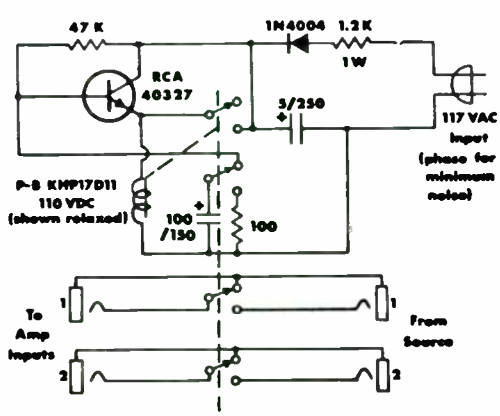


Fig. 4 Turn-on-transient muter for load protection.

Builder's Report

SEAS 603-K Speaker Kit and **603CK cabinet kit** combine to make a bass reflex configuration offered at suggested retail of $159. and $99.00 respectively by dealers throughout the US. Manufacturer: SEAS Fabrikker, A.S. Ryggeveien 96, Hoyden, 1500 Moss, Norway. U. S. Distributor: SEAS-U.S. PO Box 64 (Dept. SB) Maple Glen, PA 19002. Dealers: The Speaker Works, Box 303 Canaan, NH 03741, J C Electronics, 2001 Springfield Ave., Maplewood, NJ 07040, C.C.S. Distributing, 5070 E. 22nd St., Tucson, AZ 85711.

by The Staff

Fig. 1. The 603 driver/crossover and cabinet kits are available separately.

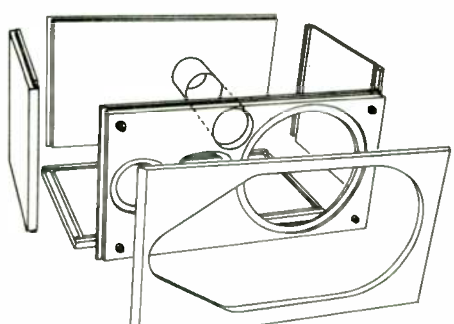
Nothing quite equals the pleasurable anticipation raised by the arrival of large boxes of speaker kits. I set aside some holiday time with a lot of suppressed eagerness to get into those boxes and put together a new pair of loudspeakers.

My task was putting together the bass reflex enclosures for two three-way units from SEAS, a Norwegian firm making drivers of exceptionally high quality. Their reputation was a rather underground one, since most people did not realize they were the sole supplier/manufacturer for the justly famous and popular Dynaco loudspeaker line throughout the 70's.

With the sale of Dynaco to ESS, SEAS apparently made a decision to set up independent marketing for their products in the United States. The designs they are offering do not, in general, appear to be similar to those in the Dynaco line. SEAS are more conservative, offering as they do, one acoustic suspension type and four bass reflex. Three of the bass reflex types are three-way with the principal difference being the size of the cabinetry and the woofer and a slightly different mid-range for the two larger systems. Power ratings differ slightly, as well. The largest of the four aligned/ported systems is their Disco-47 which doubles the drivers, the cabinet size and the power rating and adds a horn tweeter. Curiously, the rated range is less than that quoted for the 603 system which we built.

SEAS offer their kits of drivers and cabinets separately. The booklet (in four languages) which comes with the driver/crossover kit gives full instructions on how to make a suitable cabinet for the speakers. Thus one can buy the drivers only and build his own cabinetry quite easily.

The cabinet kits, packed separately, would be very difficult indeed to duplicate however, without power tools and experience in the woodworker's craft. This is only to say that the complex joints and veneering are quite excellent and not easily reproduced by the home builder.



The cabinet does not require fancy joints and the builder could easily duplicate the 304x400x660 mm enclosure (12¼x16x26¼ inches), using butt joints that were fastened with battens and copious amounts of sealer, screws, and woodworker's glue.

The instructions are simple and straightforward. A few ambiguities might have been cleared up with a bit more attention to detail, however. I will get to those as we go through a step-by-step recounting of the construction.

TOOLS NEEDED

Strictly speaking a builder of the SEAS 603 could reasonably put this enclosure kit together with only a collection of heavy books, bricks or large weighty objects. I found it very helpful to have a couple of 1½' 2x4's, 2 pipe clamps, a pair of gloves for installing fiberglass, an awl, a ⅟₁₆" drill bit and some sort of hand or electric drill, plus a good stapler and a pair of scissors. I found a "strap clamp" also very useful in the glueing process. Two would have been ideal.

Clear away about a 10x10' space for clear working area and spread corrugated board or newspapers generously on the floor.

WHAT YOU GET

The cabinet kit comes packed in a sturdy corrugated box containing a fully cut baffle board painted flat black, sides and rear panels with grooved edges for interlocking joinery, a black painted particle board frame for the grille, top, bottom and back panels, grille cloth, fiberglass for all inner surfaces, plastic mounting pegs for a snap-on-grille cover and plenty of carpenter's glue as well as an instruction book. The front and back panels, and top and bottom panels, are ¾" particle board and the ½" grille frame is of the same material. The sides appear to be solid hardwood, however and were quite heavy. These pieces, as well as the veneered top and bottom, were finished quite nicely in a very deep, rich looking stain with a protective varnish covering it. My only complaint about the finish is that the finishing room wasn't far enough from the sawdust pile. A few, perhaps three or four, pieces of sawdust were covered in the lacquer. Not very noticeable but with workmanship of this level, it ought not to have happened. The finish is not something that attracts attention to itself. It is tough, practical and unobtrusive.

Specifications: SEAS 603
(provided by the manufacturer)

Type:	Bass reflex Three-way
Freq. Range	30 to 25,000Hz.
Nom. Power	80W
Operating Power	3.2W
Sensitivity	91dB
Enclosure	60 liters
Amp. Power	8-150W
Bass Driver	33F-WB 12"
Mid-range	11F-M 4½"
Tweeter	H-107 1" dome
Crossover	600/3k Hz.
Impedance	8 ohms
Prices:	
Driver kit	$159.00
Cabinet kit	$99.00
Assembled unit	$430.00

ASSEMBLY NOTES

Note that the sides, top and bottom have finished and unfinished edges. The unfinished edges should be assembled so that they are hidden by the grille when completed. No mention of this appears in the instructions. The bass reflex tube for tuning the port as well as its bezel are contained in the driver kit. This is a logical place for it but the builder must get it out and put it in place fairly early in the assembly of the cabinet if one follows the instructions. Hence, if you plan to build the cabinets and order the drivers later, you may find it inconvenient to install the tuning tube after the cabinet is assembled.

It is a good idea to carefully clean any chips out of the joint grooves before assembling the unit. The instructions suggest you do a "dry run" before applying glue to anything which is wise for both cabinets. The joints fit very neatly and snugly. As you can see from the accompanying photos, one side of the cabinet becomes a "base" to which one glues, in order, the back, the top, the front panel, the bottom, and finally, the remaining side. Glue is spread in the bottom of the joint grooves and on the sides of the matching "tongue" which fits the groove. Any glue that squeezes out of the joint should be wiped with a damp paper towel as soon as possible, although water will remove any remainder after the joints are dry.

I used pipe clamps, 2x4's and a handy strap clamp (made by Stanley) during the drying process. I must say, however, that the sort of joints SEAS provides in these cabinets lend themselves very well to heavy weights of books on top of the second side. The instructions suggest three hours drying time for glue and I found that quite sufficient.

GRILLE ASSEMBLY

Follow the instructions carefully in stretching the nice, thin grille cloth over the frame provided. The material is thin and obviously very transparent acoustically. It is stretchy as well, however, and it is easy to get it on crooked. It also has two sides, the outer one being darker. In the speaker kit supplies you will find a very nice little cast metal SEAS emblem for the front of your finished grille panel. The instructions, however, offer not one word of guidance on the matter of mounting it. I will tell you now that you had best drill the holes into the grille frame *before* you put the grille cloth on, because if you try to drill through the material the turning bit will grab the cloth and rip a nice round hole in it that the little emblem may or may not cover (mine did). I chose to put mine in "mirror image" positions to identify them for left and right use. The mounting legs are soft metal and likely to need straightening. Measure them carefully and find a drill bit to match. Drill two holes at the proper places and the emblems may be affixed after you have got the grille cloth in place.

After the grille cloth is attached, locate the holes you drilled for the name plate. Mark these and put a small amount of glue around each hole location, working it into the fabric. Leave this to dry. When it is fully dry, push you awl into the holes and carefully mount the medallions. The stems break easily so be sure they are positioned properly and push them into place gently.

I found that the grille cloth had a definite pattern of weave and that if I kept my eye on it, I had no trouble keeping the whole thing straight as I stapled. You will need scissors to cut off the excess at the four corners if the cloth is not to bunch up too thickly to allow the grille to fit snugly to the cabinet front.

Be sure you push the four plastic grille mount snap fasteners fully into the grille holes before putting glue into the matching speaker panel holes to push the fasteners home. It is too easy to leave one of the fasteners part way out of the front panel hole and have a grille that does not mount snugly. The fasteners are plastic and are also rather fragile. They do a good job of holding the frame on the front of the speakers, however.

After the cabinet joints are dry, it is an easy matter to clean off any remaining smudges of glue. All in all, it is a very easy task to assemble the cabinet for the 603. I estimate the whole job takes about 2½ hours, including reading the instructions, dry run, stapling grille cloth and affixing that medallion. Two people could do it a lot faster.

THE DRIVER KIT

Carefully packed in foam, the kit includes the three drivers, crossover, port tube with bezel, instruction booklet, foam speaker mount gaskets, plastic snap fasteners for the grille, 15' of #18 stranded zip cord with a speaker connector molded on one end, and all necessary screws. A plastic enclosure for the mid-range is also provided to acoustically isolate the unit from the main chamber.

The three-way crossover is assembled on a phenolic circuit board with wire of adequate length soldered into

Fig. 2. The driver kit, above, contains every part the builder needs to build the speaker except the cabinet. The cabinet kit, Fig. 3 right, includes solid ash sides, ash veneered top and bottom panels of chip board. The kit is an example of simple and excellent joinery, fully finished on all sides.

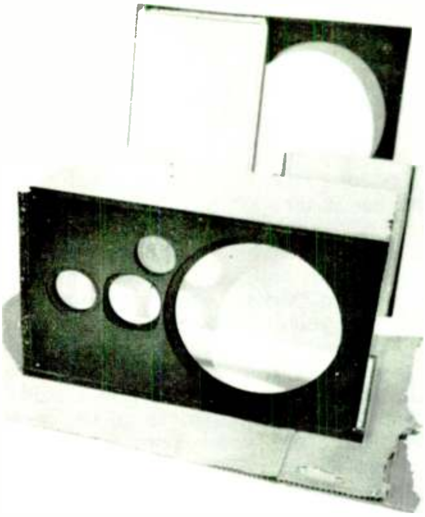


Fig. 4. Assembly is simple and easy, parts fitting snugly and easily the first time.

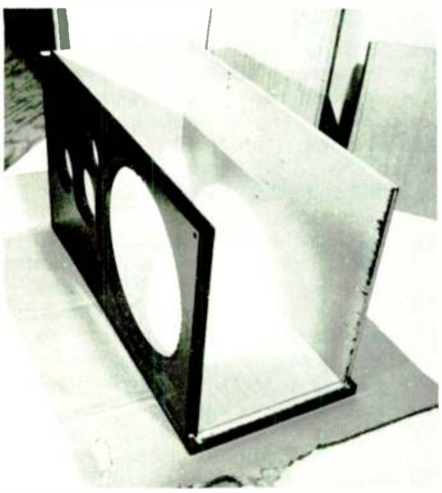


Fig. 5. View of the partly assembled cabinet before the bottom and final side are glued in place.

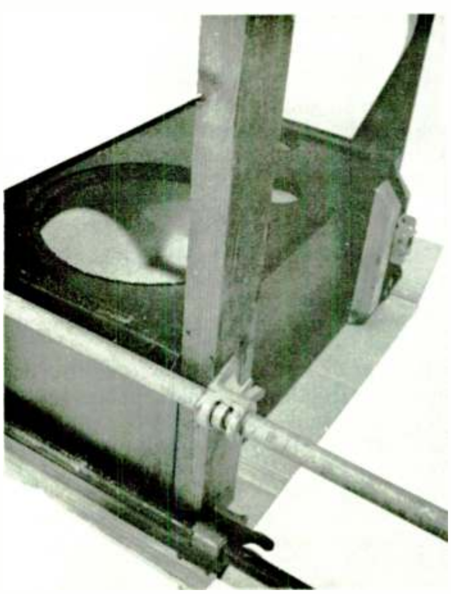


Fig. 6. We used pipe clamps and a strap clamp on the cabinet but books or bricks would have served as well. Drying time: 3 hours.

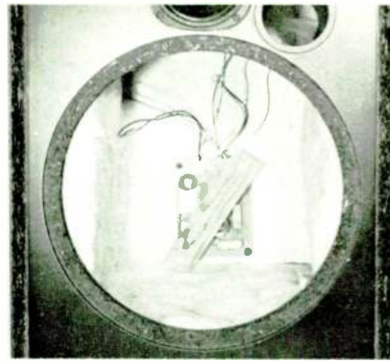


Fig. 7. Baffle board with the tweeter, midrange, port tube and crossover mounted. Note our extra piece of plywood over the crossover to ensure that the epoxied coil does not loosen in operation and rattle around in the box.

Fig. 8. The completed unit with the grille removed. The 15 ft. cord is #18 stranded type with DIN connector. Grille snaps into place on four posts.

Fig. 9. The finished 603.

place having spade lugs on their ends for connection to the speakers. No schematic is provided nor are the parts values designated; not helpful for the builder who may wish to trouble-shoot or repair. The capacitors and resistors are marked, of course, but the one ferrite cored and two air cored chokes are mysteries. On one of my test units, the large choke was hanging free from the board when unpacked. Epoxy had been used to attach it to the board. The board has a very shiny finish and no effort had been made to roughen the area beforehand. I re-epoxied the choke after roughening the mount area but was still dubious about the holding power of the adhesive, especially with the vibration of the speaker walls and the thin board during use of the speakers. The instructions suggest mounting the crossover board with two screws and standoffs. I used four and also cut a small piece of scrap 1/4" thick plywood to mount diagonally across the top of the mounted board to make certain the choke would not come loose later.

DRIVER MOUNTING

All three drivers are mounted from the front of the baffle and it is nicely routed so each driver is flush with the front panel after mounting. This avoids problems of diffraction but the grille frame somewhat negates this advantage. It is cut out in a large teardrop shape which neatly outlines the driver edges. It would have been better if this frame had been rounded or beveled on these inner edges so as to provide a smooth transition for the sound waves. Kit builders with a router or a large rasp could probably alter the frame easily to remedy this anomaly.

Marking the position for mounting the drivers is relatively easy. Drilling a 1/16" pilot hole for the screws makes inserting them easier. The mounting foam rings for the tweeter and woofer are excellent and give no problems. The one for the midrange mounts under the edge of the plastic cavity. It is much too flimsy for this use. It is also round while the cutout is a rounded square. It is a difficult maneuver at best. SEAS would do well to re-design the ring for the midrange.

The speaker wire provided is adequate with heavy plastic insulation with a red stripe on one side for coding polarity. Glue provided does a good job of sealing the rear panel wire hole, although I was dubious at first. The DIN connector, European style, is a molded plug with a large and a small spade prong which might well do a good job of attaching to an amplifier equipped with such a socket. The spades appeared to be silver plated but since that socket is seldom used in the

USA I removed mine in favor of large spade lugs.

The fiberglass is rather dense and about an inch thick. The pieces are cut to press-fit into the back and side walls as well as the top and bottom of the cabinet. Gloves are a good idea (preferably with cuffs over a long sleeved shirt) to avoid a few hours of the itches.

Instructions for attaching the crossover wires to the three drivers are quite clear and straightforward. The lugs fit very firmly and the wire is #18 stranded with good length to reach each unit. The midrange is connected out of phase which is becoming standard practice where the crossover is designed in a way that makes such connection appropriate.

Unfortunately the driver kit contains no really significant data about the characteristics of the drivers themselves nor about the crossover. Such information is being made available by many driver manufacturers these days, sometimes for a small charge. For those who may want to experiment with cabinety, such information is available for a charge from dealers. All characteristics are specified, including suggested Thiele/Small alignmentb.

HOW DO THEY SOUND?

We set up the two finished samples in our rather large listening area and listened to them for several months using both Boston's WGBH high quality FM signal, original tapes, and first class discs. A modified PAT-5WJ1A processed the signal to a succession of amplifiers including a Williamson 20/20, a modified Stereo 70, and Dyna Mark VI. We compared them closely to Fulton FMI 90's and to our old Bozak/Wharfedale/Janszen master system with electonic crossovers.

The sound is really quite remarkable for the cabinet size. The bass is exceptionally clean without tubbiness or any fat quality. Double bass and kettle drums are clearly defined and crisp. We were not as impressed with the mid-range and found some reason to complain of definition and imaging. The high end was exceptionally good without any evidence of breakup or overload. I am partial to electrostatics, but I found listening to this tweeter was satisfying and I could listen for long periods without evident fatigue.

The bass performance was significantly deeper than the FMI 90 but this is really no contest since drivers and volume are both larger on the 603. In the midrange area, however, the FMI 90's were better at definition and imaging. The Fulton units have no midrange, which may account for the difference in coherence. Users may like to try reversing the polarity of the midrange to see whether this effects a performance improvement in their particular rooms.

On balance the 603's are a very satisfactory and rewarding pair for long term listening. The kit version saves the user $172. over the built version—per speaker, $344. per pair. These are suggested dealer prices, of course. Two pairs of drivers and two speaker kits come to $516.

INSTRUMENT TESTING

Unfortunately we were not able to arrange for any significant or helpful testing program for these and other speakers by press time. We will make every effort to have such test results ready for readers by the time issue 4 of *SB* goes to press. The manufacturer will be offered full opportunity to comment on the review at that time as well.

SB Mailbox

QUESTIONS NEEDING ANSWERS

First, let me thank you for the excellent job you do aiding the amateur audio enthusiast such as myself.

Although I've been a hifi fan for years and have constructed several speaker enclosures, I am becoming increasingly curious about the theory behind the hardware. Of the many unknowns that bother me at present, I'm only able to formulate a few into words. First, there seems to be disagreement as to any improvement in transient response achieved by adding a subwoofer. Those using subwoofers argue that the upper harmonics which determine transient response are reproduced by midrange drivers and therefore are unaffected by adding a subwoofer. What confuses me is why the slew rate of the driver is not the determining factor in its transient response. It appears to me that although a L.F. driver may be used actively only below 100Hz, a driver with a faster slew rate will reproduce transients better. If this is true, don't I want to buy a transducer which has a high force constant in relation to its mass? Is this more important to natural sound than a smooth frequency response?

Furthermore, I've noticed that cone excursion tends to decrease with increasing frequency. Is this because the units are slew rate limited? And, if so, won't frequency response be dependent upon amplitude?

Forgive me if these questions are naive or if the answers are obvious, but I only have some acoustics textbooks and cannot find answers to specific questions in these.

Why are all present amplifiers low output impedance devices? If the amp were a current source could not the voice coil back E.M.F. be used to servo the cone motion? If a speaker were to be driven closed loop by the amp; would one wish to control speaker position, velocity, acceleration or some combination of these? Is S.P.L. dependent on position only or also on velocity?

I've come across a linear motor which is a surplus computer disc memory head drive which has about a 3" voice coil, linear force over 2.5" stroke, weighs 56 lbs. and is capable of a 145dB. pulse at 8 amps! I have thought about building a subwoofer using this unit and casting a urethane foam cone etc. but as you can tell am fairly ignorant about speaker fundamentals. Should I pursue this idea or drop it? The DC resistance of the voice coil is only 1-5Ω; how would I couple it to a standard amp? A huge transformer? In series with a resistor capable of dissipating the power?

Mark A. Nickerson
New London, PA 19360

WATLING, WOOD, & WISHES

I recently received my first issue of *Speaker Builder* and wanted to pass along my compliments. Your first selection of articles was most intersting. I was particularly pleased with "The Unobtrusive Stage" by Alan Watling. I am presently building a pair of LS3/5a-type speakers and his suggestions for testing look helpful. I would like to encourage you to continue and expand the "British Connection" since they apparently are quite experienced in homebuilt speaker construction.

In your Good News section, and in your editorial, you mentioned the topic of woodworking and suggested one catalog you felt your readers would find interesting. For those interested in exploring the topic further, I would recommend as one good source of information a publication called *Fine Woodworking*, published bi-monthly by The Taunton Press, Box 355, Newtown, CT, 06470 ($12 for 6 issues.) [A superb publication—Ed.] Although not designed for the speaker builder *per se*, it often contains articles which have application, as well as some very interesting advertisements for tools, catalogs, materials, etc.

I would also like to suggest that you explore the possibility of an article on protective circuits. I understand that your sister publication, *The Audio Amateur*, carried an article like this in the past and although I did not see it, I'm told the circuit described was rather complex. [*TAA*, 3/77, p. 4, W. Jung, The Speaker Saver.] I believe the circuit used in the KEF 101 is rather simple and a facsimile might lend itself to a construction project, providing patent infringement, etc., can be avoided.

Finally, I would be interested in corresponding with any of your readers who may have built and used the Atkinson "State of the Art" design published in *Hi-Fi News* back in 1976. I am interested in their description of its sound quality, whether they may have A-B'd it with other speakers, etc. Also, since I have only one set of plans (apparently not from the original article) I would like to verify the dimensions on my blueprints. I recently constructed a scale model of this speaker and found some of the measurements had to be altered in order for things to fit together properly.

Again, my congratulations on your first issue. I eagerly await forthcoming issues and hope for your continued success.
Charles G. Lyle
Minneapolis, MN 55417

Those wishing to write to Mr. Lyle, other correspondents, or to authors, should send their letters to SB c/o The Editor, and include a stamped, self-addressed return envelope if you expect a reply. —Editor

DIPOLE DISTRESS

On page 22 of 2/80 the editor inserted a note "There are those who believe a highly directional loudspeaker is superior to wide dispersion types. (See J. Newman, 'Dipole Radiator Systems,' *Journal* of the Audio Engineering Society, Jan/Feb 1980; Vol. 28, Nos. 1 & 2, pp. 35-39." Reader L.R. Palounek of Raleigh, NC wrote to ask where in the referenced article Newman of Electro-Voice says that directional speakers are superior to wide dispersion types. The editor did not mean to imply that "Those who believe . . ." and Newman were the same person. Newman's article examines the dipole, open backed format rather thoroughly and the editor supposed such work would be required reading for "Those who believe . . . etc." We are sorry for those who were, understandably, confused.—Ed.

HOT HIGH FIX

Paul Stamler (*SB*, 1/80, p. 18) seems to be concerned about a "slightly sizzly high end" which he attributes to the T27 tweeter and has attempted to correct by attenuating the input to it. I believe this to be only part of his problem. With the B110 used as a woofer in his comparatively large enclosures (compared to the Rogers) he probably has a rising high end on the B110 which seems to be coming from the tweeter.

The KEF DN-13 crossover he shows in *Fig. 1* seems to cross from woofer to tweeter at about 2300Hz. I believe the B110 will exhibit a 3-4dB rise in this area compared to the low end of its range. A 2.0mH inductor and a 16μF capacitor are connected in series across the LF ouput of the crossover. The inductor and capacitor are in series resonant at 889Hz at which frequency the impedance is nearly zero and places almost a short circuit across the B110 coil diverting most of the power from the driver at this frequency.

He can, I believe correct this situation and subdue the high frequency rise in his B110 by removing the 2.0mH inductor and replacing it with an 8Ω, 5W resistor. This becomes a high frequency shunt which attenuates the high frequencies but has little effect on the low frequencies. In *TAA*, 1/75, p.5 Fig. 2, we can see that B.J. Webb used the same device for the same reason. You can experiment with resistor values between 4 to 10 ohms to determine which sounds best.

I'll admit that the T27 needs some attenuation but maybe not as much once the change is made in the crossover to the B110. To make myself crystal clear, the modified crossover circuit is shown in Fig. 1.

Webb used 10Ω in series with 10μF, but he was using 3500Hz for crossover which I believe to be a better frequency for B110 and T27. By the way, the woofer low pass is 2nd order and the tweeter is high pass 3rd order.

I have tried your diffraction ring and it works well. Thanks.
Bob Ballard
Johnson City, Tenn. 37601

CROSSOVER CAPACITORS

One of the easiest ways to improve a speaker system is to replace any electrolytics with good quality film capacitors. (see *Audio* March 1980, *Picking Capacitors*, W. Jung & R. Marsh 1/80.) The electrolytics produce "grit" in the system due to many imperfections not least of which is high percent of dielectric absorption. Rectification is also a problem. Electrolytics are best replaced with polypropylene film units. Motor run capacitors of polypropylene construction are available in large values. The next best choice is polycarbonate film. As a last choice mylar capacitors can be used. It is important to bypass large capacitors with a smaller (0.47 μF) polypropylene for optimum results. My Fried speakers came alive with this easy change. It is a pity manufacturers use inferior units in high quality speaker systems.
Don Spangler
Dayton, OH 45449

KUDOS, WALKER REDIVIVUS

My congratulations on Issue 2. The Pass article was topical, thorough and more useful than any others I've seen on cable (much better than the nonsense in the "authoritative" *Audio Critic*). I was also glad to see the Linkwitz articles reprinted/updated. The book reviews were useful.

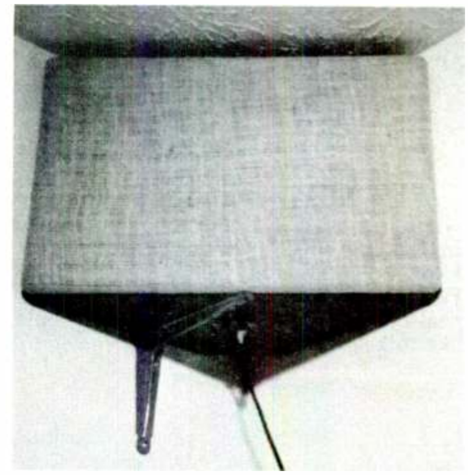
Might I suggest reprinting the Walker articles on ESL's, since Sanders and other authors make reference to them and they are not widely available?
Marc Nowakowski
Huntington Woods, MI 48070

REALITY STRIKES AGAIN

About two years ago I bought a book called *Hi-Fi Loudspeakers and Enclosures by Abe Cohen (Hayden 2nd Ed. $9.65 from Old Colony #10)*. At the time I had some 5¼" full range speakers that came with my Craig compact (8 yrs. old). I had read some articles in various stereo magazines and was constantly putting these little boxes in different locations all over the room.

After reading the book I decided to do a little "investigating." To my horror I found that the wood bracing in front of the speaker was large enough to kill what treble there was. Also, only a small strip of fiberglass decorated the interior. It was then that I decided to build an appropriate cabinet.

I had all sorts of dreams of exotic folded horns and new miracle designs. When struck with reality I decided upon a corner speaker with three ports. I assumed that a speaker so small had very little bass. By putting each port in a corner and putting the speaker very close to the ceiling I thought that would give me some bass. I have since been informed of mid-range "ring" by *SB's* first issue.



I made measurements for ½" plywood, bought a sheet, cut it up and found that none of the pieces would fit with each other. Then, measuring the wood thickness, I found it was ⅝" instead. Recutting and assembling with 4p nails and white glue produced a box. Ports are 4" square each and 8" long. This was a wild guess as was the box of ½ cubic foot.

I noticed an irritating boominess in the upper bass. My second cabinet was 150 inches cube larger. I also increased the ports to 5" square. The sound was much better but there is still a peak, only somewhat lower down and not so irritating.

Six months later I added some inexpensive tweeters (dt 50's from Speakerlab). As G.A. Briggs said, "You'd be amazed at what a good tweeter can do to bad bass!" I used Mylar caps and air core inductors with a 6dB/octave crossover at 2800Hz. The reason I crossed over so high is that I felt my woofers make good midrange speakers. They *do* sound better. My reluctance is that the bass is weak and has a bad peak (not to mention a dip right after the peak).

Next, to cover up the works, I built some grilles. I used ½" quarter round and filed off the edges. For adhesion I used a staple gun with 7⁄16 inch staples. My grille cloth is burlap (is that okay?). I also took a trip down to the local fabric shop and bought some velcro tape.

I've been using a subsonic filter of 35Hz with 6dB/octave. Six dB's is rather slow but it kills turntable rumble nicely.

Lately I've been thinking of subwoofering the system and using the leftovers as satellites. What would be an ap-

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propriate crossover? An 8 or 10 inch subwoofer is all that I care for. I guess that budget and small amplifier determine this. How large should my satellite speakers be? Will subwoofering do away with that awful peak? So far I have $100. invested. I would like to keep the cost down.

MARK GHOLSON
Harrisburg, IL 62946

Sorry Mr. Gholson we can't do consulting and get a magazine out too. Perhaps some of your fellow readers will want to offer a helping hand. We will say that burlap is not likely to be very transparent acoustically.

SPEAKER EFFICIENCY

YOUR INITIAL ISSUES OF *Speaker Builder* raise a confusing point regarding the calculation of loudspeaker efficiency. Both Paul Stamler[1] and Robert Bullock[2] state that efficiency depends on enclosure volume and/or enclosure type (closed or vented), echoing the statements made in many popular speaker-building books and articles. However, the original articles of both Thiele[3] and Small[4,5,6] present the equation for reference efficiency (η_o) as:

$$\eta_o = (4\pi^2/c^3)(f_s^3)(V_{as})(1/Q_e), \qquad (1)$$

where c is the speed of sound in air, f_s the driver free-air resonance frequency, V_{as} the air-equivalent volume of driver compliance, and Q_e the driver electrical Q. Based on this equation, reference efficiency is clearly determined by driver parameters alone and thus should be independent of enclosure volume or type.

However, loudspeaker efficiency can also be calculated from cutoff frequency (f_3) and enclosure volume (V_B), as Stamler apparently did, by the formula:

$$\eta_o = k\eta f_3^3 V_B, \qquad (2)$$

but the calculation can only be performed if the efficiency "constant" $K\eta$ is known. Hoge[7] suggested a range of values for k_γ from 20×10^{-7} to 30×10^{-7} sec³/m³ for vented enclosures and from 9×10^{-7} to 15×10^{-7} sec³/m³ for closed enclosures. Stamler appears to have used "average" values of 25×10^{-7} for all of his vented box calculations and 13×10^{-7} for all of his closed box calculations.

The point of confusion then is whether Eq. (2) tells us the same thing as Eq. (1). If so, how can loudspeaker efficiency be both independent of, and yet dependent on, enclosure volume and type? If not, which is correct? To answer these questions we first must know more about $k\eta$.

According to both Thiele and Small, $k\eta$ is not a constant "constant" but varies according to the equation:

$$k\eta = (4\pi^2/c^3)(f_s^3/f_3^3)(V_{as}/V_B)(1/Qe). \qquad (3)$$

When Eq. (3) is used to calculate exact values of $k\eta$ in place of "average" values, the presumed differences in efficiency due to enclosure volume or type disappear. Why this should occur is apparent if we rewrite Eq. (3) in the form:

$$k\eta = (4\pi^2/c^3)(f_s^3)(V_{as})(1/Q_e)(1/f_3^3)(1/V_B),$$

and substitute it into Eq. (2).

$$\eta_o = [(4\pi^2/c^3)(f_s^3)(V_{as})(1/Q_e)(1/f_3^3)(1/V_B)](f_3^3)(V_B).$$

Since the terms containing f_3 and V_B cancel out, one is left with exactly Eq. (1). Equation (2) is simply a recasting of Eq. (1), using different but related parameters. The apparent increase in efficiency when f_3 or V_B is changed in Eq. (2) is exactly cancelled because $k\eta$ is changed but by exactly the inverse of f_3 and V_B in Eq. (3). This produces the identical result that would be obtained directly from Eq. (1). Also, changing enclosure type merely produces a different combination of f_3 and V_B, resulting in the inevitable compensation in $k\eta$ via Eq. (3), and therefore the results from Eqs. (1) and (2) would still remain in perfect agreement.

In the table below are design parameters for several different loudspeaker systems that we have worked out from published or measured driver data using Eqs. (2) and (3). In every case, the calculated reference efficiency of a given driver remains constant despite radical changes in enclosure volume or type. Compare, for example, speakers #1-5 and #9; #6 and #10; #7 and #11; and #8 and #12. What *does* change is $k\eta$, as it must from Eq. 3 (the values we have calculated fall fairly well within the ranges given by Hoge).

In an attempt to verify the independence of efficiency from enclosure volume or type, we built loudspeakers #2, #3 and #9 with the same driver. Using near-field measurements at 500Hz and providing identical drive voltages at the speaker terminals, we obtained identical sound pressure levels from all three designs.

How about it, all you back-room engineers: have we misinterpreted Thiele and Small at some critical point, or have other writers ignored the relations between Eqs. (1), (2), (3)?

MAX KNITTEL, Dept. of Physics/Astronomy
ROD REES, Dept. of Psychology
Western Washington University
Bellingham, WA 98225

See next issue for responses from authors Stamler and Bullock. —EDITOR

DRIVER	f_s (Hz)	Q_{ts}	Q_{es}	V_{as} (x10⁻³m³)	Q_{tc}	a	f_3 (Hz)	V_B (x10⁻³m³)	$k\eta$ x10⁻⁷sec³/m³	η_o (%)
Closed Box										
1. Polydax HD20 B25 H 4C12	28	.40	.42	83	.5		54.4	148	1.76	.42
2. HD20 B25 H 4C12	28	.40	.42	83	.58		51.3	75.5	4.10	.42
3. HD20 B25 H 4C12	28	.40	.42	83	.707		49.5	39.1	8.82	.42
4. HD20 B25 H 4C12	28	.40	.42	83	1.0		55.0	15.8	15.90	.42
5. HD20 B25 H 4C12	28	.40	.42	83	2.0		94.3	3.46	14.40	.42
6. KEF B139	25	.37	.40	164	.707		47.8	61.9	9.13	.62
7. Altec 411-8A	19	.35	.38	830	.707		38.4	269.5	9.46	1.44
8. Richard Allan HP12B	23	.36	.40	217	.707		45.2	75.9	9.08	.64
Vented Box										
9. Polydax HD20 B25 H 4C12	28	.40	.42	83		1.1	26.6	75.5	29.4	.42
10. KEF B139	25	.37	.40	164		1.5	30.0	109.3	20.9	.62
11. Altec 411-8A	19	.35	.38	830		1.7	24.7	488	19.6	1.44
12. Richard Allan HP12B	23	.36	.40	217		1.6	28.8	136	19.6	.64

REVIEW REBUTAL

I wish to offer some additional comments on Robert Bullock's review of *Loudspeaker Design Cookbook*, (*SB* 2/80). Having used this book for several months, and having read most of the other literature on loudspeaker design, I think it important to point out a number of errors the review did not note. Although it is a generally useful book, the reader should know about some things before fastening the grille cloth in place.

I have various quibbles with almost every chapter, and quibbles with Mr. Bullock's quibbles, but the most important errors are in the "High level passive crossover networks" chapter which was passed over entirely in the review. Even here the errors are too lengthy to list in full, so I will give only a representative sampling.

Section 2, "Driver impedance" concerns impedance equalization: adding circuitry to the driver to make its impedance (more or less) constant with frequency. The technique described is adequate, but the formulas given (and some are missing) are not correct.

Section 3, "LC networks," contains formulas for Butterworth filters in both low and high pass configurations. Entirely missing is any mention of bandpass filters. The sample crossovers given imply that low and high pass sections may be cascaded to give a bandpass filter with identical cutoff frequencies. This is not so.

The effects of phase on crossover design are ignored entirely. Problems of amplitude variation due to driver interference, and of network delay error, are the most difficult part of crossover design; but even such conventional wisdom as "second order networks should be connected out of phase," is missing.

There are similar errors in sections 4, 5, 7, 8, and 9. The cumulative effect might be rather disastrous for the unwary speaker builder.

Richard Saffran
Ann Arbor, MI 48104

In Robert Bullock's review of the *Loudspeaker Design Cookbook* (2/80, p. 30) we neglected to include the address from which to obtain a copy. The address is Speaker Research Assoc., 1505 SE 32nd Street, Portland, OR 97214.

QUERIES AUTHORS

I have just finished sucking dry *SB*'s second issue, and I'd like to try to throw my congratulations on the pile.

Even prior to receiving Vol. 1 No. 1, I had been sketching out ideas for an article on my current and past speaker projects. In 15 years of trial and error, I have reached several plateaus of prejudice, some commonly-held and some not. This article is nearing completion, and will be submitted in due course.

I had planned to send it in for consideration unannounced, but as it is taking longer than expected I am left in a bit of a pickle. You see, Issue #2 raised several points covered in my article, and incorrect or inaccurate (i.e. different) conclusions are put forth. I can't really write a "letter to the editor" without explaining the whole process by which I reached my conclusions, which is the purpose and substance of my article. Therefore what follows is unsupported difference of opinion, for which experimental proof will be forthcoming shortly, with luck.

First, in Siegfried Linkwitz's "Three-Enclosure Loudspeaker System", the statement is advanced that stereo bass reproduction produces boosts of approximately 6dB (SPL doubled) over single driver configurations. This is potentially true only with different signals (and power supplies) for each driver, and in actuality phase cancellations are certain to prevent it even then. We are, after all, dealing in most cases with a single point source. To clarify the illustration, take a logical extreme: would forty drivers produce more acoustic power from a given electrical power?

Linkwitz also sizes his enclosures by wavelengths rather than resonant frequencies. With his small drivers, and acoustic suspension cabinets, he can almost get away with such an approach; but his success will be limited by it. Dispersion characteristics do not necessarily preclude the construction of larger, more accurate systems, and to assume they do is an incorporeal limitation. The distortions in linearity caused by incorrect acoustic suspension coupling are several orders greater than those caused by cabinet diffractions and secondary radiation.

Last, from the photos of his installation it appears that his "wing" speakers are mounted some two feet in front of the bass elements. My experience suggests that greatly improved imaging will result from aligning his drivers in a horizontal plane, preferably by relocating his woofers in a free-standing cabinet (thus also removing the adverse effects of planar diffraction). Vertical alignment would be equally meliorating, but his given design criteria seem to preclude this.

Roger Sanders' article on ESL's appears to be very well researched, and I have no experience to contradict there. I believe he errs, however, when recommending a "horn or transmission line enclosure" as the best low frequency complement to his electrostat panels. Both designs have insurmountable time-delay distortions, which would be especially unfortunate in an otherwise fast-transient system.

On the positive side, both authors are to be commended for pointing out that current recording techniques are often limiting factor in music reproduction. General recognition of this fact is the only hope for bringing studio standards up to par. There is little advantage in owning an automobile capable of 180 m.p.h. when the speed limit is 55.

Robert Carlberg
Seattle, WA 98116

MR. SANDERS REPLIES

First, thank you for the compliments regarding my research, etc. It is always nice to be appreciated. I feel that your views about my choice of woofer systems deserve comment. You stated that both transmission line and horn systems would be a poor complement to the ESL system because of "insurmountable time-delay distortions." This is simply not true. Let me discuss T.L.'s first with respect to time delay. Please bear with me if some of what I am about to say is review.

The "perfect " T.L. would completely lose the driver's rear radiation and thus prevent it from affecting the sound. A long tapered tube stuffed with massive amounts of damping material prevents large resonances, allowing only an infinite number of small ones. The damping material should slow and absorb as much acoustic energy as possible. In real life, we find it *is* indeed possible to achieve this goal in the bandwidth from the crossover frequency to some very low frequency (determined primarily by the length of the line). In this range, all the energy delivered by the woofer is direct front radiation and therefore there is no time delay distortion. Note carefully that this range encompasses the critical low midrange/mid bass area.

At very low frequencies, the damping will not absorb all the energy and some energy will be released from the port. This will be greatly out of phase with the direct radiation, so much so that radiation resistance is falling at these frequencies and the frequency response tends to fall also because of this. This is the same problem that superb infinate baffle systems experience. This out of phase information supports the low frequencies and effectively extends the system's deep bass response. Should you doubt this, simply take a gated spectrum analyzer and take 1 cm frequency response measurements and 4 metre measurements. You will note that the near field response drops off in the low bass (because the electronic gate prevents measurement of the port information), while the far field response remains flat or even rises a bit.

Since you are being extremely technical, I will admit that the port information supports the cycle following the one that generated it rather than supporting the cycle that generated it. However, very low frequencies do not have rapid decay times and in real music this effect does not cause sonic problems.

Turning to horn systems, there certainly is considerable propagation delay, however this is far from an insurmountable problem. This effect can be virtually eliminated by simply moving the woofer closer to the listener.

The above discussion is an introduction to the real point of this reply. Your comment is a perfect example of the "techno-freak" mentality to which I referred many times in my article. The reason that I say this is because time delay distortion is an insignificant problem in comparison to the really gross problems that are inherent in speaker systems. If you doubt this, simply move your woofer around in relation to your tweeter. This must be done out of doors so that frequency response colorations from the room do not influence your conclusions. This should be a double blind study as well.

You will find (as I have, after doing the test) that the differences are so subtle as to be very difficult to detect. The gross distortions to which I refer are frequency response irregularities, and loads of harmonic distortion. Frequency response problems are due to driver and particularly cabinet resonances. Harmonic distortion is caused by cone breakup due to poor materials, poor damping, and high mass which, when combined with high driving forces due to inefficient design, simply overcomes the cone stiffness and results in "doubling"(a polite term which means 100% distortion). Add to the above problems the common one of inefficiency. It becomes extremely difficult to keep the system together, much less free from distortion if it takes a kilowatt to drive it to 100dB!

T.L.'s and horns with carefully selected drivers and careful design and construction each do a rather good job of reducing distortion, cabinet resonances, increasing efficiency, and extending the deep bass. How you can get excited about a little time delay distortion which has truly minimal sonic effect, is not present in T.L.'s, and can be readily solved in horn systems amazes me.

Finally we get to the bottom line: Regardless of what theory says, the only thing that really counts is how the system performs sonically. I have tried all types of woofer systems and many variations of each. I solidly stand by my statement that in my experience, *only* T.L.'s and horns sound clean and coherent next to the ESL.

I would be more than willing to further discuss this or any other topic related to audio. Please have objective data supporting your comments available. I welcome constructive criticism as my system is not perfect. I do not have all the data I would like to have, and am always looking for ways to improve my system.

MR. CARLBERG REPLIES

First of all, thank you for your lengthy reply to my letter. I suspect both of us have achieved a primary goal for the fledgling *Speaker Builder*, viz. at least we're talking to each other. Such healthy dialogue, and I would hope, gentleman's disagreements, are intrinsically good for the non-industry.

I will be honest with you and admit that I probably *did* incorrectly understand the workings of a transmission line enclosure. Your letter explains to me quite well why you feel about it as you do, and I must admit your reasons for liking the T.L. are similar to my reasons for liking bass-reflex. In short, both designs are unabashed compromises; but they're the best we've got.

Port radiation, in fact, probably is not often exactly one cycle behind the cone movement—but, like you, I have found the particular distortions thus produced not disagreeable. Low frequency wavelengths must resist the sorts of phase washing that can become so annoying in high ranges, or be of such an order that it becomes trivial.

Regarding horns, repositioning the enclosure may well close the time-delay gap, but what of the intermodulation distortion within the horn itself? This is a problem not so quickly dismissed. Horns were popular in the days of five and ten watt amps for their obvious amplification characteristics. Today's superpower amps, however, open up a whole new area of full range dispersion research.

Last, I feel compelled, somewhat against my will, to defend myself against your "techno-freak" accusation. As I took pains to point out in my original letter, all of my prejudices are resultant from trial-and-error experience, with liberal logic and common sense thrown in. I do not evaluate my speakers with a spectrum analyzer—I use the two Nature gave me.

Perhaps I would feel more comfortable if we agreed to label my attitude as "perfectionist." The two are miles apart in my mind, and perhaps you would agree to look at it from my viewpoint?

I was of course assuming that the relatively easy hurdles of flat response, adequate dynamics, and low harmonic distortion had been cleared, when I spoke of the finer points of three-dimensional imaging and transient distortions. By the technical level of your article, I quite naturally assumed we were dealing on this plateau—one incidentally reached by a half-dozen or more production units and a rather large percentage of home-builts. It was taken for granted that such concerns are subjacent to the baser criteria, as you so rightly point out.

KEF/FALCON FACTS

As retailers of both the excellent Falcon products and of KEF drivers, we were naturally most interested in Mr. Stamler's article in Issue 1/1980. We trust that author Stamler will not take it amiss if, in a spirit of contribution rather than criticism, we add some further thoughts to his article:

1. Tweeter polarity shown in *Fig. 1.* is incorrect. In the case of the DN13 SP1017 the tweeter is connected in reverse polarity and the configuration shown at *Fig. 1* will produce suckout at the crossover frequency. Although KEF's own publication (presumably through a printing error) shows the tweeter connected in the same polarity as the bass driver, this is not their practice on the actual network and is as one might expect from an 18dB per octave crossover.
2. Your more enterprising readers may be tempted to construct this crossover using the circuitry provided in *Fig. 1.* This diagram does not however tell the full story and it is our view that home construction of this crossover is simply not feasible for the following reasons (amongst others):

(a) the capacitor values shown are nominal values only. In every case capacitors will have been selected for exact value, loss factor, etc., and one cannot get round this by simply purchasing high grade 1% types. The capacitor concerned may have been selected to a tolerance of −12 to −17% or +13 to +18% or whatever—there is no way the amateur can know this, and in the examples quoted 1% types would be very wide of the mark. Similarly the loss factor must not be overlookded and particular care has been paid to this in the case of the 104 aB network.

(b) The DC resistance of inductors is all important and it does not follow that the DC resistance must always be low. The 0.8mH inductor in the bass section of the DN13 1017 is a ferrite cored type having saturation levels in excess of the handling capacity of the drive unit. Those tempted to use an air cored type would be using inductors having a high DC resistance and no benefit in terms of saturation. Conversely a study of the circuit in *Fig. 1* might lead one to assume that the tuned circuit across the bass driver, apparently consisting of a 2mH inductor and a 16μF capacitor contains no element of resistance. In fact the 2mH inductor in this case is wound from very thin wire so as to exhibit internally a high DC resistance, obviating the need for a separate series resistor. This is simply the efficient engineer's way of reducing component costs and a constructor using a standard 2mH inductor would run into problems here. A standard 2mH inductor could have a DC resistance only 10% of the required value, and the result would be very serious suckout in the 1 to 2kHz region with a corresponding very nasty dip in the impedance curve.

The internal resistance of the .3mH inductor in the 104 aB network is similarly tailored.

(c) The terminal voltage response of a well designed crossover is the inverse of the acoustic response of that particular set of drivers in that particular enclosure. The ex-

Mailbox

act value of capacitor and the exact DC resistance of inductors will reflect this so that the final combination produces the optimum acoustic response. Whatever may be the real or imagined advantages of Mylar capacitors, author Stamler's proposals to substitute that type would certainly throw out the frequency response of the network and this would more than offset the theoretical benefits arising from the change of type. Our experience is that Mylar, polyester etc., capacitors offer no advantage whatever over *carefully selected* reversible electrolytic and substitution is hazardous.

It is not our wish to stiffle experiment, and this would certainly be quite inconsistent with the objects of *Speaker Builder* magazine. In cases such as author Stamler's the safest course is without doubt to use the prescribed crossover from ourselves or Falcon and so be sure of optimum results.

The cost will be only marginally (if at all) more than obtaining separate components.

As a matter of general interest, we supply Falcon crossovers in preference to KEF's own—without compromising the standards above, Falcon have generally managed to upgrade the KEF designs and in our opinion they represent first class value.

On page 35 contributor Mr. Bauza mentions the Daline design. Should any enquiries arise, you may like to know that our catalogue contains a reprint of the Daline article. This interesting design is justly very popular here in England and parts are still very much available.

Barry Hughes
Badger Sound
Lytham St. Annes, Lancashire
England

AGENDA OFFERED

It seems to me the biggest problem faced by an amateur speaker builder at every phase of his endeavor is a lack of data. Granted that speaker design is an art, it is still based on physics. The failure of manufacturers to systematically test their products according to the procedures outlined by Thiele, Small, and Ashley, *and then publish full specifications,* is most regrettable. However, a publication like yours ought to be able to (a) apply more leverage to get the data or (b) test the drivers yourselves.

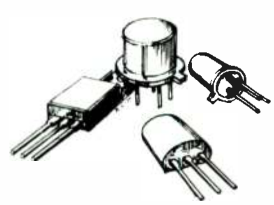
It is more useful to have the design data in hand before buying the speakers, which may turn out to be unsuitable. Also, it strikes me as uneconomic, to say no more, to shell out a thousand dollars or so for test equipment with which to measure one or two speakers. I bought the drivers for my systems based on guesswork and the highly unscientific descriptions in the McGee Radio catalog, and they have worked out pretty well (I think), but I have been lucky—and I understand speaker design better than the average audiophile.

The other place where the amateur builder runs into trouble is in verifying his design. This is especially hard to take because when an amateur creates a design, the prototype is what he has to listen to in his living room. It seems to me that the measurement approach outlined in B&K Applications Notes no. 17-197, using a ⅓ octave-band pink noise test record and a sound-pressure level meter, should be feasible for the amateur. However, one of the local audio shops has informed me that the B&K test record is no longer made. If this is so, you could provide an invaluable aid for your readers by producing one. Also, a glance at the schematic of the Radio Shack SPL meter has convinced me that such a device could be built *very* cheaply if someone would publish plans and a circuit board layout.

With these two items—a pink noise test record and a sound level meter—the amateur would be in a position to measure the frequency response of his "prototypes," experiment with room placement, and in other ways improve his system. One possibility, mentioned in the B&K publication mentioned earlier, is the adjustment of crossover network components and incorporation of R-L-C circuits to smooth out "bumps" in the response curve. An article dealing with this possibility in your magazine would be most welcome to those of us who cannot afford equalizers and real-time analyzers.

David G. Miller
Saint Louis, MO 63116

We hope Mr. Miller will plan to try his hand at duplicating the Radio Shack sound level meter but for the $40. price tag, one has a real bargain, and a shorter wait. We suggest Columbia's STR140 test record available through our Old Colony facility as a possible alternative to the Bruel & Kjaer disc. —Editor



SOLID CONNECTIONS

The Nelson Pass article on speaker cables (*SB*, 2/80, p.6) was very interesting, and I'm sure many readers were pleased to have the information.

Considering the high price of the ultra cables I wonder whether many wouldn't prefer a less expensive approach. What would be the results from the use of heavy gauge (#10 or so) single conductor spaced some distance apart on its way to and from the speaker? The spacing would reduce the capacitance between the two sides and one could actually "tune" the wire for a specific situation by changing the distance between them.

Mr. Pass' article also points out that no matter how well planned and carried out, the assembling of the highest quality components will not necessarily result in the highest quality sound. "Mere" corrosion of connections can send the whole system down the tubes. I sometimes wonder if *all* connections shouldn't be soldered.

Roy V. Childs
S. San Francisco, CA 94080

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NEW LIMIT: Because of our new technology we now have more room in the classified section and we're increasing the number of words in private ads to 50.(rather than 40) as before. If your private ad is over 50 words, please send along a check with your text for 15¢ per word over the 50 limit. Number and street count as one word as do Zip codes with the state abbreviation.

PLEASE help us by typing or printing your ad on a separate piece of paper or card—including your name and address exactly as you want it to appear.

YOUR AD will not be repeated unless you re-submit it for subsequent issues. If we receive your ad too late for one issue, it will appear in the next one. Private ads are not acknowledged unless you send us an addressed postcard for the purpose.

ADDRESS all classifieds to "Classified Department." It helps. Please make full use of this service. Your offerings of equipment will delight others who are searching for them. Readers are welcome to use these pages to search for information about equipment.

SPEAKER CABINETS—factory close out of rich walnut vinyl laminated cabinets constructed of ¾" particle board. Shipped assembled with grill frames. Speaker openings can be cust to your specifications. Measurements 24x13x13. Only $19.95. **FABER,** 1625 Kelley St., Santa Rosa, CA 94501. T1/81

TOP QUALITY SPEAKERS AND KITS. Send $1.00. ***SPEAKER WAREHOUSE,*** 809 North Route 441, Hollywood, FL 33021. T1/81

ACTIVE ELECTRONIC CROSSOVERS

Plug-in Butterworth (maximally flat) filters in 6dB, 12dB, or 18dB per octave attenuation, any frequency specified. Filters flat beyond 100kHz.

Complete crossover in attractive metal cabinet with all terminations and regulated power supply.

STEREO BI-AMP $139

Tri-amp, quad-amp, and monoaural types available at comparable prices. Other available features: summer for "single woofer" systems, Subsonic noise elimination filters supplied with or without bass boost, level controls.

FOR OEM'S AND HOME ASSEMBLERS

500 Series dual filters and/or plug-in filters, regulated power supplies.

FREE CATALOG & PRICE SHEET
Write to:

DeCoursey ENGINEERING LABORATORY

11828 Jefferson Bl., Culver City, CA 90230
Phone: (213) 397-9668

BIG #12 gauge speaker wire twisted with outer jacket 100 ft. $40. C.O.D. ok. Sample $1.00. ***AUDIO HOUSE,*** 4304 Brayan Dr., Swartz Creek, MI 48473. (313) 655-8639 T4/80

GOLD PLATED phono jacks $1.10 plugs 85¢ ea., $1.00 handling. Also custom 1% capacitors, 0.5% resistors. Details SASE. ***REFERENCE AUDIO,*** Box 368M, Rindge, NH 03461. T1/81

ALLEVIATE DIFFRACTION with our tweeter damping rings. ¼" thick felt with adhesive backing 2" Id 4" Od for one inch domes $4.00/pair. Check or money order only. ***SPECTRUM LOUDSPEAKERS,*** Caller #2998, Toledo, OH 43606. T3/80

AMPLIFIERS, SPEAKERS, CROSSOVERS, wire cables, (shielded and unshielded), noise gates. Send for flyer: ***PHASE CONCEPT LTD.,*** 3975 Omaha Dr., Norcross, GA 30093. (404) 923-1127. T1/81

LONG HAIR WOOL carded-cleaned for stuffing speakers. $8.75/lb. including shipping. ***J. EBBERT,*** 770 Holly Rd., Wayne, PA 19087. (215) 687-3609 T2/80

Musicality The Speaker Shop offers you Hafler kits (in stock), Conrad Johnson, Quad (England) KEF, 3D Acoustics, D.E.A. Cobra, Mitsubishi, Aiwa, Signet, Micro-Seiki, Burhoe, Monster Cable, AT620 cables, French import albums (beautiful classics). Write us: 3419 Bailey Ave., Buffalo, NY 14215. (716) 837-1557. T3/80

METAL FILM RESISTORS, RN55, 0.35 watt, 107 values from 10 ohms to 1 Meg., 25¢ ea., 10 per value/$1.80, 50 per value/$7.50. Send stamped self addressed envelope for list of values and order form. New gold plated brass rear mount phono jack, $1.75 ea. Gold plated shielded RCA type phono plugs, $2.00 ea. Minimum order $10.00, quantity discounts available. **OLD COLONY PARTS,** Dept. SB, PO Box 243, Peterborough, NH 03458.

AUDAX AND SEAS drivers, crossovers, crossover components, and kits. Specials for this issue. Audax HD17B25J2C12 8" bextrene woofers—$23.25. Audax HD13D37 1½" dome tweeters—$13.25. SEAS 25FEW 10" woofers as used in Dyanco A-25—$20.00. SEAS 13FGMB x 5¼" midrange as used by Scandinavian Broadcast Industry—$29.00. Send $2. for catalog to: **THE SPEAKER WORKS,** Box 303, Canaan, NH 03741 T3/80

ESOTERIC COMPONENTS at tremendous savings. Substantial savings on a wide variety of hi fidelity components. Many hard to get items. Extensive selection of moving-coil cartridges and tonearmms. **AUDIOWORLD,** (616) 243-6314, Box 7518SB, Grand Rapids, MI 49510. T3/80

SAVE 50%. Build your own speaker system. Write: ***McGEE RADIO ELECTRONICS,*** 1901 McGee Street, Kansas City, MO 64108. T4/80

CUSTOM MADE FOAM SPEAKER GRILLS. Any size, thickness, color, quantity. Send 15¢ stamp for information. **CUSTOM SOUND**—SB, Algonac, MI 48001. T4/80

"An authentic musician and artist" was Jean-Pierre Rampal's description of pianist James Boyk. We are pleased to offer two disc of Boyk in concert at California Institute of Technology, where he is Artist in Residence. Unedited performances, crossed figure-eight miking; no limiting, compression, EQ, or bass blend. PR-1 ($8.95 ppd.): Beethoven Sonata Opus 111 & three Scarlatti sonatas. PR-2 ($11.95 ppd.): Schumann Scenes from Childhood & Chopin Fantasy in F Minor. **PERFORMANCE RECORDINGS,** Dept. SB, 2135 Holmby Ave., Los Angeles, CA 90025. T4/80

CROSSOVERS COILS CAPICATORS
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DYNACO AF-6, FM-5, FM-3, FM-1 FANS; Scott LT-110 Fans: PLL Stereo Demodulator is assembled and tested and features the KB4437 (Separation: 45dB, THD: 0.04%) with pilot canceller circuit for greatly improved sound quality. Send for free info. **VSM AUIDO,** PO Box 114, Maspeth, NY 11378. T3/80

NEW GOLD PLATED PHONO JACK. Rear mount, gold plated, solid brass jack w/gold plated ground flag and hardware, $1.75 ea. Will interchange with Audio Research SP3A-1's phono jacks. Gold plated solid brass shielded phono plugs, $2.00 ea. Send stamped self addressed envelope for flyer and order form. Minimum order $10.00. **OLD COLONY PARTS,** PO Box 243, Peterborough, NH 03458.

AUDIO HORIZONS

P.O. BOX 10973
St. Louis, Missouri 63135

Issue #4 is now available. It contains reviews of CRAMOLIN contact cleaner, the DYNAVECTOR DV-100R and DV-100D moving-coil cartridges, the LINN Ittok LVII pickup arm, the MARCOF "Glass Mat" platter plate, the HAFLER DH-200, MICHAELSON & AUSTIN TVA-1, SUMO "Power", and SUMO "Gold" power amplifiers, the MICRO SEIKI BL-91 and ORACLE turntables, the MUSICAL FIDELITY bb-1 and POWERLIGHT MC 4 pre-preamplifiers, the SAEC SS-300 platter plate, and the SPECTRA Disc Cushion. Issue #4 also features a survey of interconnecting cables with reviews of cables from AGI, AUDIO-CRAFT, AUDIONICS, AUDIO NOTE, AUDIO-TECHNICA, BELDEN, DISC-WASHER, FULTON, MELCO, MITCH COTTER, NEUMANN, PETERSON, SAEC, SOUND CONNECTIONS, SOLAR TRADING, SUPEX, and ZEPHYR.

Subscription rates to AUDIO HORIZONS™ for four (4) issues are: U.S. - $16 ($20 by FIRST CLASS MAIL); Canada and Mexico - $18 ($22 by FIRST CLASS MAIL); and outside North America - $24 (AIR MAIL). PLEASE REMIT IN U.S. FUNDS ONLY. Sample copies of all issues of AUDIO HORIZONS are available for $5.50 each (U.S., Canada, and Mexico), and $7.00 each (outside North America).

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STOP THE AGONY! Get yourself a set of Custom High Quality Speakers. For Ultra unique speaker design book send $3.50 to: **WOOD "N" THINGS WORKSHOP,** PO Box 1043, Binghamton, NY 13902. T2/81

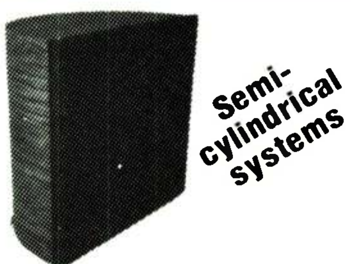
ELECTRONIC CROSSOVER—All types. Definitive booklet $5. **HUNTINGTON ELECTRONICS,** Box 2009, Huntington, CT 06484. T3/80

RAW FRAME SPEAKERS—All Types—All sizes. Philips, C.T.S., Peerless, Polydax, Dealer pricing. **APOLLO ELECTRONICS,** 1437 Santa Monica Mall, Santa Monica, CA 90401. (213) 393-0794. Mon.—Sat. Stuart. T2/82

AUDIO CONCEPTS offers: Dalesford 5" woofer-mids $28.90, 10" $69.90, 12" $96.90. Jordan 50mm modules $119. pr, Dyna A50 10" woofers $10. SEAS ferro-fluid tweeters $15. All ppd. to you. Fast. Send $1 for info on drivers, cabinets, and x-c. 1919 S 19th St., LaCrosse, WI 54601. (608) 788-0366. T3/80

HIGH PERFORMANCE LOUDSPEAKERS factory direct. LS/5A and other equivalents. European drivers, speaker enclosures, kits, finished systems. Student reps needed. Box 18009 and Box 12242, Jacksonville, FL 32209. T2/81

FRIED SPEAKER KITS. Fried speakers are exceptional. We offer the ABSOLUTE lowest price on Fried speaker kits. Selection includes: (1) raw speakers, crossovers, hardware and assembled enclosures (2) assembled enclosure ready for speaker & crossover attachment and (3) custom built, finished complete speakers ready to connect to your amp. We have ready for delivery models B11, C.D.O. and the Super Monitor. All enclosures are made from particle board, wood veneer and solid wood in Oak, Birch, or Walnut. Shipping is free on several models. **AUDIO SALON,** 608 Pecan Ave., Charlotte, NC 28204. (704) 377-6590. T3/80



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10 GOOD REASONS TO READ TRANSCENDENTAL AUDIO'S New Catalog. 1. The Jordan 50mm module—A wideband (150-22kHz) midrange/tweeter from England. The dynamic driver that rivals the transient detailing of fine electrostatics. 2. Polystyrene and Polypropylene Audio Grade Capacitors, .001uF, NPE's in 125VAC 3. Low DCR air core inductors in 5.0m.h. #16 wire. Why use "super" speaker cable without 'em? Custom winding available. Dealer inquires invited. 4. Unique subwoofer designs with twin bextrenes in push-pull vented enclosures for articulate bass to 23Hz with seamless crossover. 5. The new Dynaudio 8¾" woofer from S.E.N. Labs in Denmark that handle 1 kilowatt for 10 milliseconds! 6. Cylindrical "sandwich" construction enclosures for 6½" bextrenes and Jordan modules. Non-resonant. 7. Polydax soft domes and bextrenes from 5¼" to 10". 8. Ribbon and Polymer supertweeters from JVC, Decca and Foster. 9. 18dB/ocatve electronic crossover and subsonic filter kits from Rowland Research. 10. Driver application, crossover and enclosure design assistance available. Send $1.00 for catalog, $3.00 for catalog and 26 page Jordan manual. **TRANSCENDENTAL AUDIO,** 6795 Arbutus St., Arvada, CO 80004 (303) 420-7356 9:30 to 5:30 Mountain time. T3/80

AUDIO CLUBS

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

AUDIO SOCIETY WANTED in the Fort Wayne, Indiana area—for serious audiophiles only—contact: J. D. Reynolds, Jr., 703 Nordale Drive, Fort Wayne, IN 46804. Phone (219) 432-1294.

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

DO YOU LIKE CLASSICAL MUSIC AND AUDIO EQUIPMENT? Would you like to form a small society mixing music listening with audio equipment discussions? If you live in Nassau or Suffolk County New York in the vicinity of Plainview, contact: Alex Soave, 192 Central Park Road, Plainview, NY 11803. (516) 935-1704.

Southeastern Michigan Woofer and Tweeter Marching Society

Detroit area audio construction club.

CONTACT: DAVE CARLSTROM 10155 Lincoln Huntington Woods, Michigan 48070 313-54-48453

Books by G.A. Briggs

B-1 AERIAL HANDBOOK. *A Layman's Guide to Antennas.* (2ND EDITION) 176pp. by Briggs and R.S. Roberts on the principles of receiving aerials with details on building indoor, outdoor types as well as boosters and single frequency attenuators. Q & As included.
Softbound. **$2.80**

B-2 ABOUT YOUR HEARING. A thorough investigation into how we hear and how to care for ears. Correlates effects of age, noise effects, deafness, hearing aids. A valuable work on caring for the most vital part of your audio system. 176pp. Softbound. **$2.80**

B-3 AUDIO BIOGRAPHIES. Briggs' personal reminiscences about, coupled with dozens of autobiographies by, the people he met during his forty years of audio research and experiment. Briggs and many of his "guests" write in a vital, personal style, which illuminates the human side of audio. 344pp.
Hardbound. Each **$6.00**

B-4 CABINET HANDBOOK. A 112-page guide for the audiophile on design, woodworking, veneering and polishing of speaker cabinets. Deals with principles of everything from horns to bookshelf types. Sections on guitars and room treatment as well. Softbound.
Each **$3.25**

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AUDIO CLUBS

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

FT. WORTH AREA AUDIO SOCIETY being formed. Would like a diversified group (women welcome), for information send a stamped, self-addressed envelope to Richard P. Machos, 6201 Onyx Drive North, Ft. Worth, TX 76118.

DELAWARE VALLEY AUDIO SOCIETY? Why not? If you are interested, let us know. Write Jim Elliott, c/o HiFi Hospital, 306 White Horse Pike, Clementon, NJ 08021. (609) 627-1680.

AUDIO SOCIETY WANTED in the Sacramento CA area. Serious audiophiles and dedicated audio amateurs please contact Barry Waldron, 8811 Little Oaks Way, Stockton, CA 95207. (209) 478-9310.

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MINNESOTA AUDIO SOCIETY Monthly program—Newsletter—Special events. $10/year. Write: P.O. Box 3341, Trafffic Station, Minneapolis, MN 55402.

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

PRIVATE

FOR SALE: Dyna equipment, PAS preamp, FM-3 tuner, Stereo 70 amp, (2) Mark III amps. New tubes. Also have AR turntable with modified arm (anti-skating, lighter, black, etc) and Sony TC-127 deck (cheap!) Charles Davis, 4018 Brookmoor Dr., Arlington, TX 76016. (817) 429-3198.

FOR SALE: Thorens TD-125 turntable, $140; Dynaco PAT-5, $125; Dynaco Stereo 400, $325.; AR-11 speakers, $400/pair; Rabco SL-8E, for modification, $85; Koss PRO4-AA headphones, $20/pair. Josh Hill, (212) 867-0330 days.

FOR SALE: Garrard MRM 101 music recovery module $75; Sansui RA-500 solid state reverb system $65; Heath GD-61 reverb system $35; Wharfedale W15/CS woofer $40. **WANTED:** Acoustech 1A amp and RG Dynamic Processor Pro-20. R. G. Camp, Box 63, Winona, OH 44493. (216) 222-1601.

WANTED: Sansui TU-9900 tuner and CA-2000 preamp. John M. Johnson, 435 E. 70th St., NY, NY 10021. (212) 628-2461.

ADVERTISING INDEX

WANTED: Dynaco/Dyna units, all models, any condition. Send name and address with model and price. Jerry Runels, 3045 Lindon Ln., Decatur, GA 30033. (404) 455-0572

FOR SALE: Dynaco ST-70 $60; GAS Ampzilla II $550 or best offers. Must sell! Pasha Kaye, #1 Tunnel Spgs. Rd., Placitas, NM 87043. (505) 867-2492

FOR SALE: Raw speakers. JBL-STR system—LE15A, LE85, AR15, X over. Also LE-10A's Philips—best midrange 8 tweeters (4 pairs) all are used but in excellent condition. Any feasable offer. (914) 425-0224

FOR SALE: Dynaco ST150 mint $175., ST410 exc. $225., MKII exc. $125 pr., MKIII mint $225. pr., MAC MC75 exc. $200. pr., Oscilloscopes: Hickok USM105A, probes, cover, manual, mint, $225. Tektronix RM43A, 2 plug-ins, v. good, $275. Wanted: Ivie or similar RTA. Offers? Trades? Box 96, Canton, CT 06019. (203) 693-6067

FOR SALE: Dahlquist DQ-LP1 electronic low pass filter $200. Nikko Mosfet Alpha III power amp $300. Both in excellent condition. Mark Bailey, 7 Hancock Ct., Barboursville, WV 25504 (304) 736-9628 after 6 EST.

FOR SALE: Philips KAD3WXSP crossover, 150 watt, 3 way new $85. pr. Speakerlab S3 and S4 crossovers, both three way for use with 12" woofer, 5" mid, and 1" dome tweeter (S3) or T35 ElectroVoice horn (S4) $85 prs or B/O. Polydax mid-tweeters HD13D 34 new $30 pr. TW8B new $30 pr. KEF 104 crossovers B/O. Howard Helfant, 3300 Parkway Drive, Baldwin L.I. NY 11510. (516) 623-3059)

FOR SALE: Webb transmission line speaker components. KEF T-27, B-110, Celestion 2000, Falcon 4-way crossover, $225. Goldring G-900 cartridge $50. Micro Acoustics MA-2000 E, $35. Black Widow tonearm, $125. Kent Siegenthaler, 11805 102 Pl. NE, Kirkland, MN 98033. (206) 823-2165.

FOR SALE: Carver C-4000 Holographic preamp $600. Carver C-500 power amp 250W/channel $550. SME 3009 II imp.tonearm w/damping $100. Ortofon MC20 moving coil cartridge $100. Ortofon MCA76 head amp $150. DBX 119 compander $100. Mark McCalmont, BOQ RM 85, Nas Chase, Beeville, TX 78103. (512) 358-6377.

FOR SALE: Audax 8" bextrene drivers HD 21B 37R 2C12 1.5" VC guaranteed unused, original boxes, pair $75., list $115. Vince Palermo, 14543 Debbenham, Cherfleld, MO 63017. (314) 532-4308 evenings.

Old Colony KITS

POLICY: OLD COLONY SOUND LAB is a service agency for readers of *The Audio Amateur* and *Speaker Builder* magazines. It attempts to provide circuit boards and the basic, or hard to find, parts for construction projects which have appeared in the magazine. **Old Colony assumes that the constructor will use the** *Audio Amateur* **or** *Speaker Builder* **magazine article as the guide for building his unit.** Kits, with noted exceptions, are not priced to include article reprints or construction instructions. Old Colony kits, with stated exceptions, do not provide metal work, cabinets, line cords and the like. We suggest that before purchase amateurs secure and evaluate the articles, which give details on each unit. Kits vary widely in complexity and required construction skills. A very few can be assembled bv the beginner. If you are just starting in audio, get some experience building Heath or Dyna kits before tackling an Old Colony kit, or locate an experienced friend to help in case of difficulties.

CROSSOVERS

ELECTRONIC

For both electronic crossovers: crossover points and R_1, R_2, C_1, C_2 *MUST be taken from Fig. 3, p. 11, Issue 2, 1972, TAA. No other values can be supplied.*

KC-4A: ELECTRONIC CROSSOVER, KIT A. [2:72] Electronically divide the signal before the amplifier. Requires one amp for bass; a second for treble (or one stereo amp per channel). Lowers distortion and dramatically increases power capability. Single channel, *two-way*. Values of R_1, R_2, C_1, C_2 must be specified with order. All parts and C-4 circuit board. Includes new LF351 ICs. Each **$8.00**

KC-4B: ELECTRONIC CROSSOVER, KIT B. [2:72] Single channel, three-way. Values of R_1, R_2, C_1, C_2, must be specified with order. All parts and C-4 circuit board. Includes new LF351 ICs. Each **$11.00**

KK-6L: WALDRON TUBE CROSSOVER: Low pass. Single channel, 18dB/octave, Butterworth, [3:79] includes Bourns 3-gang plastic pot, level control, Mullard tubes, board, and three frequency range determining capacitors. *Specify ONE frequency range per kit please.* (Hz.): 19-210; 43-465; 88-960; 190-2100; 430-4650; 880-9600; 1900-21,000. Single channel. Each **$43.00**

KK-6-H: WALDRON TUBE CROSSOVER: High pass. Single channel, 18dB/octave, Butterworth, [3:79] includes Bourns 3-gang plastic pot, level control, Mullard tubes and 3 frequency determining capacitors. Please specify **one** of the frequencies above. No other can be supplied. Each **$45.00**

KK-6-S Switch Option. 6-pole, 5-pos. rotary switch, shorting, for up to five frequency choices per single channel. Each **$8.00**
When ordered with two kits above, Each **$7.00**

KK-7: WALDRON TUBE CROSSOVER POWER SUPPLY. [3:79] All parts, including board, transformer, fuse, semiconductors, line cord, capacitors. Will power four tube x-over boards (8 tubes), one stereo bi-amped circuit. Each **$88.00**

PASSIVE

KF-7: CROSSOVER FOR WEBB TLS. [1:75] Passive four-way crossover, in pairs, assembled. Components are included for both STC and Celestion tweeters. Made by Falcon of England. Pair **$76.00**

FILTERS & Speaker Saver

KF-6: 30Hz RUMBLE FILTER. [4:75] Rolls off system response at 18dB/octave below 30Hz to eliminate rumble and garbage on discs below 30Hz. Cuts speaker distortion and wasted amplifier power. Two channel universal filter card supplied with WJ-3 (F-6) circuit board and all basic parts, 1% metal film resistors and 5% MKM capacitors for operation as an 18dB/octave 30Hz rumble filter. 30Hz, 0dB gain only. Kit may be adapted as two- or three-way single channel crossover with added capacitors and resistors. Each **$19.75**

KH-2A: SPEAKER SAVER. [3:77] Protects speakers from destructive transient signals by quick shutdown of amplifier output. This basic two-channel kit includes board and all board-mounted components for control circuitry and power supply. It features turn-on and off protection and fast opto-coupler circuitry that prevents transients from damaging your system. 4PDT relay and socket included. Each **$35.00**

KH-2B: OUTPUT FAULT OPTION. If the amplifier goes into self-destruct mode, this added feature cuts off drive to output devices quickly. Additional board mounted components for speaker protection in case of amplifier failure. Each **$6.75**

KH-2C: COMPLETE SPEAKER SAVER WITH OUTPUT FAULT OPTION. Each **$40.00**

KK-8: COMPEX C. Signal compression ina repeatable format for tape recording or signal transmission. Two channel board with all parts to compress signal, including 1% polycarbonate capacitors and large tantalums. [3:79] Each **$45.00**

KK-9: COMPEX E. Signal expansion in tape replay mode or after transmission via limited phone lines. Two channel expansion board with all parts including precision Rs & Cs, [3:79] Each **$35.00**

SYSTEM ACCESSORIES

KH-8: MORREY SUPER BUFFER. [4:77] All parts & board for two channel output buffer to isolate tape outputs in your preamp from distortion originating in a turned-off tape recorder. Many uses for this versatile matchmaker. Each **$14.00**

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). Powered by amp's single or dual polarity power supply. Each **$5.50**
Two kits, as above **$8.25**

KK-14A: MacARTHUR LED POWER METER. [4:79] Two channel, two sided board and all parts except switches, knobs, and Mtg, 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**

KL-2: WHITE DYNAMIC RANGE & CLIPPING INDICATOR. [1:80] One channel, including board, with 12 indicators for preamp or crossover output. Requires ±15V power supply @ 63 mils. Single channel. Each **$49.00**
Two channels. **$95.00**
Four channels. **$180.00**

BENCH AIDS & Test Equipment

KH-7: GLOECKLER PRECISION 101dB ATTENUATOR. [4:77] As basic to measuring as a good meter, and more accurate than most. All parts except chassis and input/output jacks to build author's prototype including all switches and loads. Resistors are MF 1% and 2% types. Each **$50.00**

KB-8: INVERSE RIAA KIT. Six precision components to shape your audio signal generator's output to the response curve of a recorded disc. Checks phono preamp inputs. Each **$5.75**

KL-3C: INVERSE RIAA NETWORK. [1:80] Revised, precise, deluxe network. Two channels, 1% polystyrene capacitors and metal film resistors, gold jacks, cast aluminum box, solder lugs and alternate 600 ohm or 900 ohm r_2'/C_2' components. Each **$35.00**

KL-3R: INVERSE RIAA. [1:80] Resistor/capacitor package complete. Stereo R_2'/C_2' alternates. Each **25.00**

KL-3H: INVERSE RIAA. [1:80] Box, terminals, gold jacks, and all hardware, (No resistors or caps) in KL-3C. Each **$13.50**

E-2: JUNG REGULATED POWER SUPPLY. ±15V @ 1.5A. [4/74] Lab quality device but excellent for powering system components. Includes board, all board mounted parts plus two LM395K regulators. Transformer and filter caps not included. Each **$35.00**

KF-4: MORREY'S MOD KIT FOR HEATH IG-18 (IG 5818) SINE-SQUARE AUDIO GENERATOR. [4:75] Includes two boards and all added parts needed to modify the Heath unit to distortion levels of parts per million range. Replacement sine-wave attenuator resistors not included. 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] All parts to replace your VTVM's battery with a regulated supply. Each **$7.50**

KJ-6: CAPACITOR CHECKER. [4:78] All parts to build an accurate meter for measuring capacitance, leakage, and insulation. Check phono & speaker lead capacitance effects. Includes all parts with 4½" D'Arsonval meter. Each **$68.00**

KK-3: THE WARBLER OSCILLATOR. [1:79] For checking room response and speaker performance without anechoic chamber. All parts and board. Each **$56.00**

KL-6 MASTEL TIMERLESS TONE BURST GENERATOR. [2:80] Highly valuable and useful device for testing speakers and room response. All parts with circuit board. No power supply. Each **$19.00**

ORDERING INFORMATION

Prices, except as noted, are prepaid in the USA and insured. We prefer to ship via UPS, which requires a street address. If you cannot receive UPS delivery, please include an extra $2 for insured service via Parcel Post. We cannot accept responsibility for safety or delivery of uninsured Parcel Post shipments. PLEASE ADD $1 service charge for all orders under $10.

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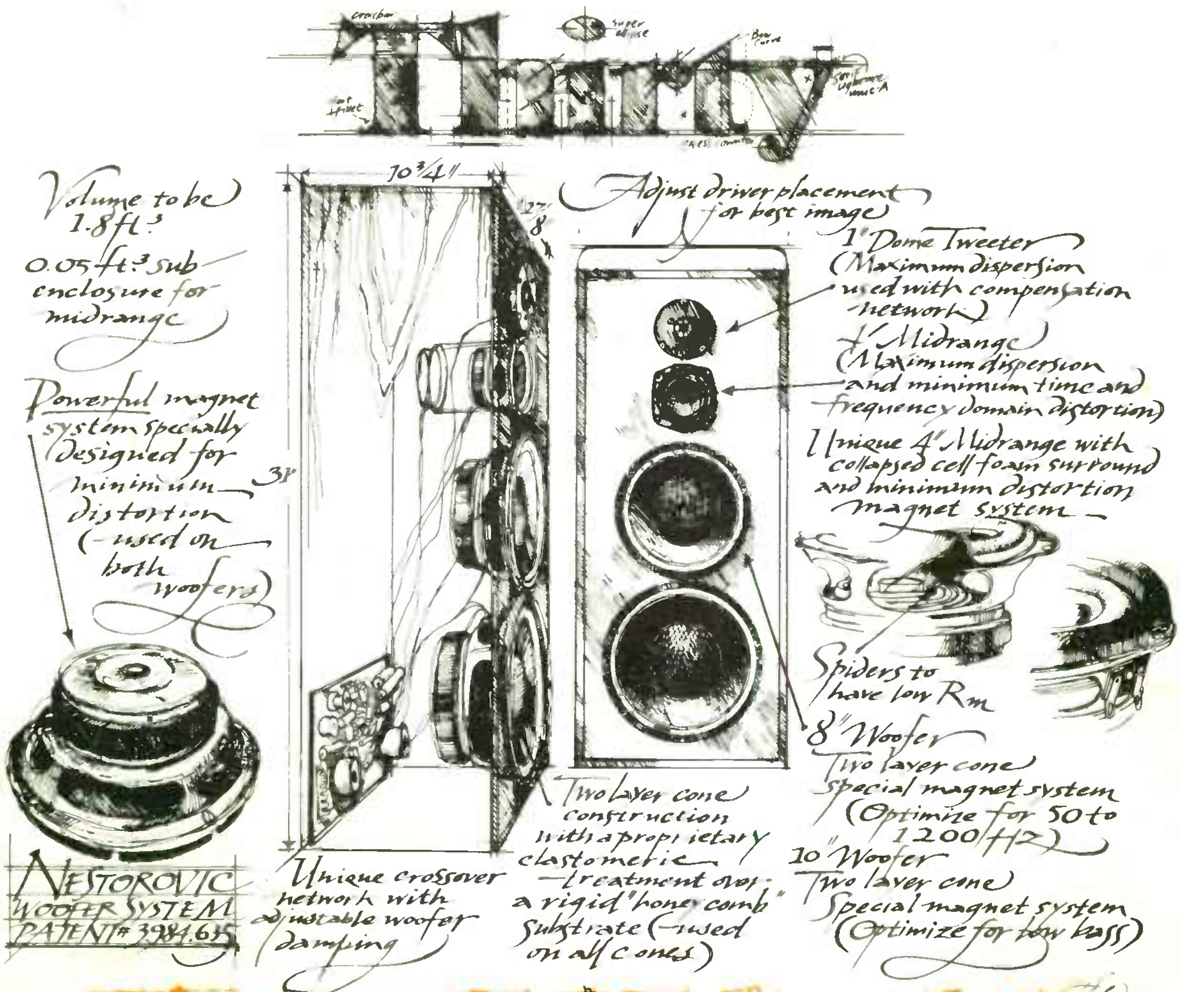

It's a musical instrument!

Our Speakerlab Thirties are the culmination of our acoustic technology and speaker building experience — in collaboration with one of the world's top acoustic designers, Mila Nestorovic. A speaker with better transient response in a smaller enclosure than any system we have ever offered. They're our Stradavarius.

Because our ears receive most information about a musical sound in its very first instant, a speaker's ability to react instantly to an impulse (called transient response) is extremely important. Our Thirties image so well that the speakers themselves actually seem to disappear. The pluck of a guitar string or the snap of a snare drum appear instantly in the Thirties field of sound.

Because they use the patented Nestorovic Woofer System™, Thirties achieve almost a full octave of extra low bass. Through a unique phase-control network and incredibly high flux density 8" and 10" woofers, you get amazingly tight bass transient response. The result is tremendous bass from a relatively small enclosure. Handling up to 350 watts/channel, Thirties are simply unlike any speaker system you have previously heard.

Experience the Thirties: handcrafted, technically precise instruments.

And Thirties are just one of ten different speaker designs from Speakerlab. We also have a wide range of speaker parts available. Send for our free catalog — it'll tell you more about us, our kits and our famous patented Nestorovic Woofer System™, Wave Aperture Drivers™, Polylam™ Cones and Subwoofer Drive Systems.

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