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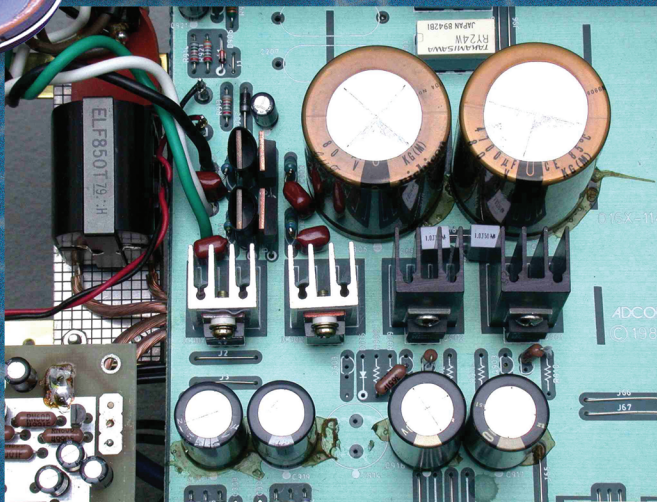
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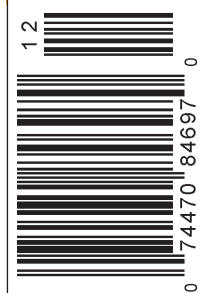
Slanted Speakers:
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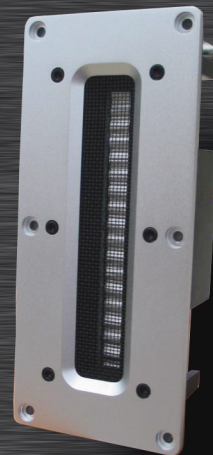
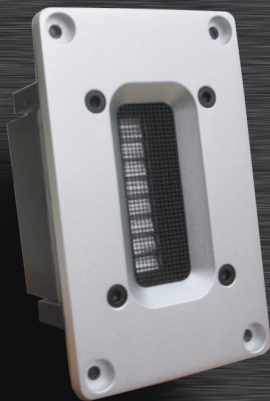
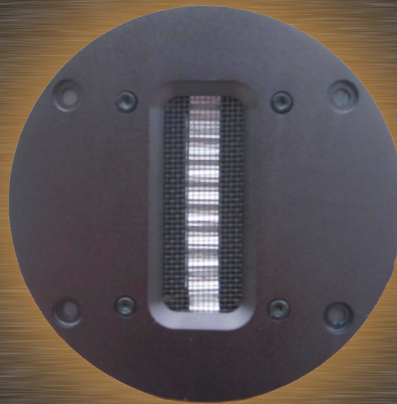
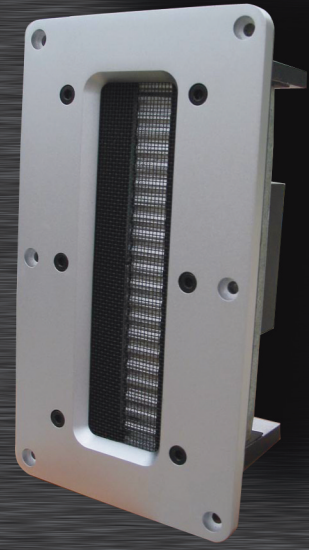
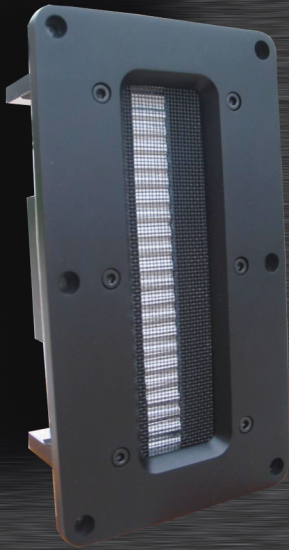
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FEATURES

BUILD A BOOSTED TRIODE AMPLIFIER

Here's a clever circuit design that boosts the output power of a single-ended triode-connected 6L6 or 807.

By Larry Lisle 8

A HEGEMAN SUBWOOFER

This slightly different approach to good bass reproduction revives a 35-year-old design.

By Cornelius Morton 12

CONSIDERING NEGATIVE FEEDBACK: OP AMP SIMULATION OF A TUBE AMP FEEDBACK LOOP

The author presents a tube amp simulation that investigates feedback effects.

By Dennis Colin 24

MAKING YOUR OWN RUBBER SURROUNDS

Follow this DIY approach to extending the life of your speaker, and even improve speaker response.

By Angel Luis Rivera 30

WHY SPEAKERS HAVE SLANTED FRONTS, PART 1

We begin an interesting series that examines the advantages of tipped front panels and how to design your own.

By G. R. Koonce 38

ADCOM'S GFP-565 PREAMPLIFIER, PART 2

The author continues with his modifications—showing you how to improve the sound of this classic preamp.

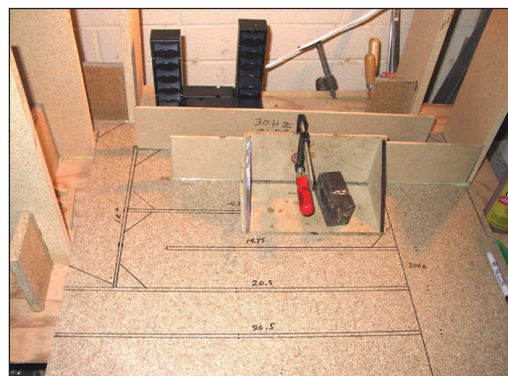
By Gary Galo 42

REVIEWS

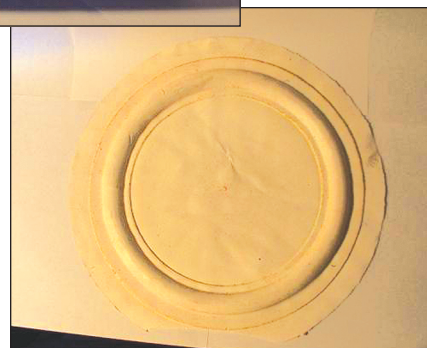
ONKYO DV-SP800

A look at the features of this new audio player that handles both DVD-Audio and SACD formats.

Reviewed by Gary Galo 52



page 12



page 30

audioXpress (US ISSN 0004-7546) is published monthly, at \$34.95 per year, \$58.95 for two years. Canada add \$12 per year; overseas rates \$59.95 per year, \$110 for two years; by Audio Amateur Inc., Edward T. Dell, Jr., President, at 305 Union St., PO Box 876, Peterborough, NH 03458-0876. Periodicals postage paid at Peterborough, NH, and additional mailing offices.

POSTMASTER: Send address changes to: **audioXpress**, PO Box 876, Peterborough, NH 03458-0876.

page 52



DEPARTMENTS

EDITORIAL

A look back on 35 years of publishing
By Edward T. Dell, Jr. 6

XPRESS MAIL

Readers speak out 58

INDEX

This past year's articles arranged by category and author 64

GLASS SHARD

Four Unusual Electro-Voice Amps
Courtesy of Lance Cochrane 69

IN EVERY ISSUE

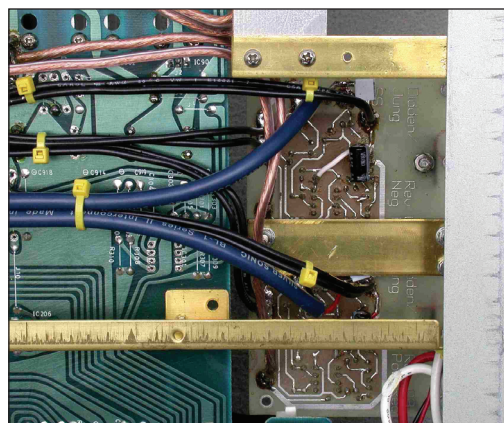
CLASSIFIEDS

Audio-related items for
sale or wanted 70

AD INDEX 71

YARD SALE

Free classifieds
for subscribers 71



page 42

Articles and letters identified with the following symbols:

CODE



solid state



tubes



speakers

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Editorial

Another Milestone

By Edward T. Dell

Here in New England we are partial to keeping old milestone markers intact. It has been a century since horse-drawn conveyances carried people and goods east and west on the street where I live and work, but a granite milestone still stands in a neighbor's yard marking some distance or other to points east or west.

Looking at my calendar recently, I realized that this enterprise will mark its 35th year in 2004. The first quarterly issue of *Audio Amateur* went out to subscribers—late—in the spring of 1970. Since that time, as they say, a good deal has happened.

We began by sending out almost 100,000 prospectuses to mailing lists maintained for McIntosh audio dealers across the nation. Over the first year some 2,000 readers sent in \$5 for four quarterly issues. We kept track of these on an old, manual Scriptomatic mailing system with cards kept in zip-code order.

I developed an inexpensive way to use an IBM Selectric® typewriter and press-on type to produce the pages for offset printing of the issues. English authors who published in the British *Hi-Fi News and Record Review*, *Wireless World*, and *The Gramophone* were amenable to being reprinted in a new U.S. audio magazine.

This editor had a lot of help from his young family as well as J. Gordon Holt, editor of *Stereophile*, who offered his list for promotional purposes. Over those first years in Swarthmore, Pennsylvania, we worked out of our home at 307 Dickinson Avenue, where several volunteers turned up, two of them from Swarthmore College, who did yeoman service on all sorts of chores. One of the

most important of these new people was a highly talented editor/typist/assistant in the person of Judith Cadigan, who took over much of the production drudgery. In late 1973 the editor quit his day job to work full time on *Audio Amateur* as well as the ancillary tasks like Old Colony Sound Lab.

In 1975 the editor decided to move the whole establishment to New England on what was a purely personal whim. Nothing wrong with Pennsylvania, you understand, but annual visits to the hills and stone walls of New England induced nostalgia for the yankee ethos, despite the fact that I had no birthright to the place—but it was also the only place I had ever lived that felt like home.

Through a very well-defined plan of action, we finally bought an 1832 house with an attached barn in Peterborough, N.H. The moving van transported the house furnishings, and the editor drove four large truckloads up into the hills at the southern end of New Hampshire's mountains. Almost two years after the move, we finally managed to get *Audio Amateur* issues mailed on time. In 1978 we welcomed a new assistant to the editor in the person of Karen Hebert. This year we celebrate her progress through almost every job in the company to Vice President/General Manager, completing 25 years of invaluable service to the enterprise.

In 1980 we published our first “splinter” magazine, *Speaker Builder*, which became an almost immediate success. In the second issue we published a review of a small volume on Thiele-Small theory by Vance Dickason, and persuaded him to revise his text for an updated third edition. Since 1987, over

90,000 copies of *Loudspeaker Design Cookbook* have been published in seven languages.

In 1988 we moved, after a long search, into larger quarters in West Peterborough, and out of our old barn. Lots of changes had been ongoing in our technical infrastructure. We have, since the very beginning, been self-sufficient, doing our own graphic production in-house, as well as circulation fulfillment.

Moving to Peterborough landed us in the middle of a publishing hub—mostly of technical publications. *Byte* came to town just before we did, and other computer titles seemed to pop up like overnight mushrooms. In 1985, we attempted to join the computer group with *Computer Smyth* which, for three years, went the wrong direction and into oblivion. In 1989 we piggybacked a small initial issue of *Glass Audio* with *Audio Amateur*. The response was very positive and tube enthusiasts everywhere rejoiced. We have had a steady and ongoing program of reprinting tube technology classics, including tube manuals and a CD version of F. Langford Smith's monumental *Radiotron Designer's Handbook*.

At about the same time we launched a modest newsletter *Voice Coil* for the loudspeaker industry. We re-launched this monthly as a business-to-business controlled circulation periodical in 1993. Today *Voice Coil* is a widely accepted business medium with a worldwide circulation tracking the loudspeaker business. We also added an annual *Loudspeaker Industry Sourcebook* to our offerings.

(to page 71)

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Build A Boosted Triode Amplifier

With the price of big audio triodes going up and out of sight, how would you like a single-ended triode-connected 6L6 or 807 that puts out about 3W with less than 5% distortion and sounds great? **By Larry Lisle**

It isn't often that a breakthrough comes along in tube audio these days, but one may have occurred when EDN, an on-line publication (www.edn.com), included a design by Dave Cuthbert of Boise, Idaho, in its April 3, 2003, issue. Basically, Dave's idea was to increase the output of a triode-connected 6L6 by raising the screen voltage above that of the plate with an auxiliary power supply. Like many important new developments, Dave's concept is remarkably simple, but it contains some problems that must be overcome before a practical device can be built.

DIFFICULTIES

The first of these is that having the screen at a higher potential than the plate seems an invitation to secondary emission problems. Electrons will hit the plate at high velocity and dislodge others, some of which will be attracted to the screen instead of to the plate.

This is the foundation of the "Dynatron" oscillator. Increasing the plate voltage while keeping the screen voltage constant will, at certain values, cause the plate current to actually decrease instead of increase and form a "negative resistance" region. This is evident from meter readings and also by the noise heard in nearby AM or FM radios! The circuit actually becomes a transmitter!

I have not observed the effect with an output transformer in the circuit. The positive resistance of the transformer more than cancels the negative resistance of the circuit with the potentials shown in *Fig. 1*. If needed, you can find further steps for dealing with oscilla-

tion in the *Radiotron Designer's Handbook*, Chapter 13, Section 3.

Please remember that this is a new concept. Don't use your expensive speakers as guinea pigs until you've evaluated the circuit with your transformer, tube, and so on.

The second difficulty is the problem of bias. Dave's circuit shows -44V on the grid. In my experimentation I found this caused the tube to operate too close to the cutoff region and resulted in excessive distortion. Reducing the bias to -18V worked much better.

The third issue is that of tube ratings.

Using -18V bias and the voltages shown in Dave's circuit would soon cook the tube. I solved that by reducing the voltages to 300V for the plate and 80V for the supplemental supply for the screen and by switching to an 807 instead of a 6L6.

Even so, the tube ratings are slightly exceeded, but the 807 is a remarkably tough tube and there's long been a tradition among radio amateurs to run it hot. So far it's held up just fine. The only 6L6 version that I recommend without a further reduction of voltages is the 6L6GC, which costs three times more than the 807.

THE CIRCUIT

The circuit (*Fig. 1*) is very conventional, with the exception of the extra power supply in the screen circuit. I didn't show the details of the power supply in

FIGURE 1: The circuit for a practical boosted triode amplifier, based on an idea by Dave Cuthbert. This remarkable output circuit boosts the power of a conventional triode-connected 6L6/807 by a factor of three and sounds great.

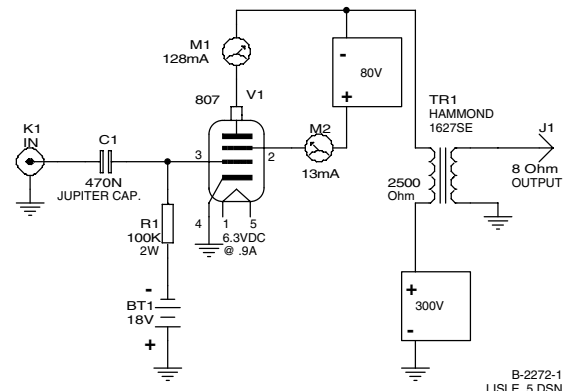
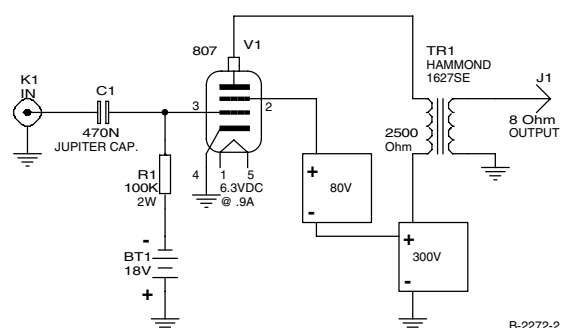


FIGURE 2: This might be called a boosted tetrode amplifier. It will produce 6W of power with predominantly second harmonic distortion of less than 5%. In this circuit the tube has an amplification factor of about 20, so it's remarkably easy to drive. It measures much better than the usual single-ended beam tetrode and sounds easy on the ears!



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Dr. Joseph D'Appolito has been working as consultant for Usher Audio since early 2000. A world renowned authority in audio and acoustics, Dr. D'Appolito holds BEE, SMEE, EE and Ph.D. degrees from RPI, MIT and the University of Massachusetts, and has published over 30 journal and conference papers. His most popular and influential brain child, however, has to be the MTM loudspeaker geometry, commonly known as the "D'Appolito Configuration," which is now used by dozens of manufacturers throughout Europe and North America.

Dr. D'Appolito designs crossover, specifies cabinet design, and tests prototype drivers for Usher Audio, all from his private lab in Boulder, Colorado. Although consulting to a couple of other companies, Dr. D'Appolito especially enjoys working with Usher Audio and always finds the tremendous value Usher Audio products represent a delightful surprise in today's High End audio world.

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the screen circuit nor the one that supplies the plate voltage, as they are conventional in all respects and this article is about a new type of output stage. For the same reason I didn't illustrate an input stage, choosing not to blur the focus. Use your favorite capacitor-resistor coupled stage or use transformer interstage coupling.

Dave suggested a 3000Ω load. In the prototype I substituted a 2.5kΩ Hammond 1627SE transformer, which worked fine. For the input I used a .47μF Jupiter beeswax capacitor from Electra-Print with a 100kΩ resistor.

Grid bias is supplied by two 9V batteries. I found it necessary to use DC on the filament of the 807.

Take all necessary safety precautions, including measures to keep the unwary away from the plate cap of the 807 and from the screen power supply, since people won't expect the negative terminal to be hot to ground. All power supplies should be well fused, especially since this is an experimental circuit. You may include switches to suit your needs, but in an experimental circuit the one I like best is pulling the plug from the wall outlet.

RESULTS

I'm very impressed by this amplifier. It just starts to clip at about 3W output, but it's still under the traditional 5% distortion limit, and the distortion is predominately second harmonic. The frequency response is flat within 1dB from 20Hz to 20kHz.

How does it sound? There are so many factors that can color how an amplifier sounds: the music, the source, the construction of the output transformer, the speakers and how their impedance varies with frequency, and so on. But in general, I put this amplifier in the same league as many single-ended 2A3 amplifiers I've heard—not as good as a well-tweaked single-ended '45 but way ahead of other triode-connected 6L6 type amplifiers and with three times the power output. (The value given in the tube handbooks doesn't include losses in the output transformer.) If I had to pick a couple of descriptive words for the sound, they would be "smooth" and "effortless." It's a good-sounding amp. But, wait, there's more!

GOING FURTHER

Not willing to let well enough alone, I decided to see what would happen if I put the auxiliary power supply between the screen and the positive output of the main power supply (Fig. 2.) You



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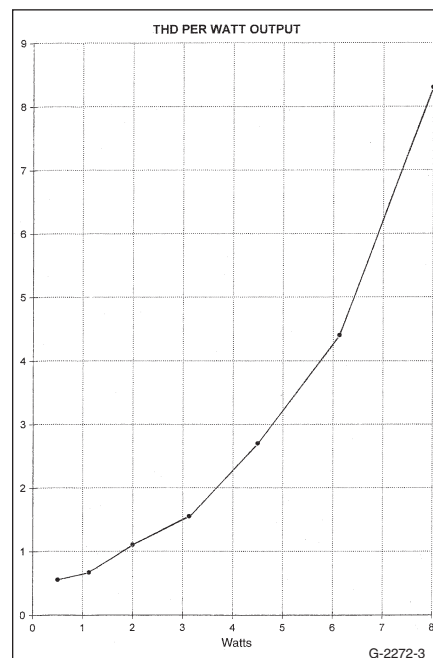


FIGURE 3: Distortion/output for the amplifier in Fig. 2.

might call this circuit a "boosted" beam tetrode!

I was very impressed by the results. It sounded very nice and put out over 6W of audio with less than 5% distortion, again mostly second harmonic. In this circuit the tube has an amplification factor of about 20, so it's remarkably easy to drive.

It does have the tetrode/ pentode characteristic of producing a difference in the levels of distortion as the output impedance varies (for instance, as speaker impedance changes with frequency) but not as much as from a conventional single-ended 6L6/807 beam tetrode. The music also sounds much smoother. I like this configuration very much!

I think these concepts are well worth exploring. They may wind up in the dustbin of audio circuits, along with so many others, or they may prove their worth. Don't be afraid to experiment and try different tubes, output impedances, bias voltages, and so on. See what you can come up with. And credit to Dave Cuthbert and EDN for starting the ball rolling. ♦

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In 1995 developed flat magnet wire, now used in motors and power supplies throughout the world.

Milestones in Audio

1993

GOERTZ™ speaker cables US Patent. 5,393,933

1995

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A Hegeman Subwoofer

Here's an unusual subwoofer design that follows a different path to achieve good low-frequency sound. **By Cornelius Morton**

In 1969 the late A. Stewart Hegeman, of Harman-Kardon Citation fame, introduced a unique speaker bearing his name, the Hegeman Model 1 (*Photo 1*). It consisted of a handmade 8" bass/midrange driver firing upwards into a spherical reflector, resembling a ball cut in half, resulting in a circular horizontal pattern. The dome tweeter was mounted in the flat top of the reflector and fired into a similar smaller reflector mounted to the underside of a metal grille. Because the vertical spacing of the two driver-reflector assemblies was small, the two sources merged into a point source at listening distances greater than 4'.

The inside of the box was even more interesting. Instead of being open, it consisted of six tubes of various lengths opening just under the bass driver with the far end of the tubes closed off so that each tube became a quarter wavelength resonant stub. Each stub presented the driver cone with a high acoustical impedance around the center frequency of the stub. By centering the stub frequencies about the resonance frequency of the driver, the stubs provided a controlled damping to the driver, virtually eliminating the driver resonance peak and associated impedance fluctuations.

Stewart continued producing the Model 1 along with a few Model 2s—a 10" driver—until 1977, when failing health and finances forced him to cease production. At that time he gave Don Morrison, of Toronto, Canada, a six-week course in speaker building along with a truck load of cabinets, driver parts, and so on. Don resumed production in Toronto and continues

to produce a much improved version today. See his website at <http://www.donmorrisonaudio.com/>.

IMPRESSIONS

Several years ago a friend found several Model 1s on eBay and shortly after our audio club auditioned them. The first impression was of very good quality sound reproduction, so we moved on to the sound stage.

I was seated about in line with the left speaker and another member was about 6' away in what should be the sweet spot. A female vocalist was singing and I had her placed just up on a staircase behind the speakers and about 3' to the right of the center line. I asked the member in the sweet spot to point to the vocalist—we both did and it was the same spot! At the time I was using a pair of Magnepans, which were nice but had a very confined sweet spot.

The next impression was of the bass, which was very articulate, with no sense of overhang and no bass boom, just the sound of instruments. I was hooked.

I had some understanding of quarter-wave stubs from a long-term association with radar systems. Quarter-wave waveguide stubs are very similar in function to quarter-wave acoustical stubs. While searching for additional information, I located Don Morrison and explained what I was attempting. Don was very friendly and helpful. After providing history and a ton of information and hints, he commented that only a nitwit and masochist would try to build these things, wished me luck, and said to keep in touch.

The Magnepans are now gone, re-



PHOTO 1: Hegeman Model 1.

placed by what looks like a pair of flying saucers on top of small boxes. But the tight bass response of these clones was what led to thoughts of subwoofers. To date I have built three 12" models and two 10" units. This has been an evolutionary experience with improvements added to each.

One of the 12" versions resides with a friend in Texas, another with the owner of the Hegemans, and I have the third.

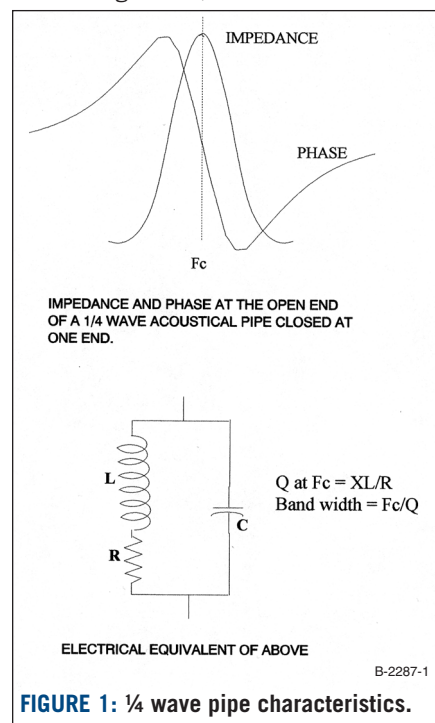


FIGURE 1: 1/4 wave pipe characteristics.

The first 10" model is also gone. The 10" units are the latest and probably the best of the crop in terms of detail. They are also the subject of this construction article.

The drivers are MCM 55-2325 or Audiomobile MASS 2010 devices. The MCM version has an X_{MAX} of 12.75mm and an 8 lb magnet. They also have horrendous impedance peak at f_s . The Audiomobile MASS2010 has an X_{MAX} of 21mm, nearly 2" peak-to-peak and an even more horrendous peak at f_s . Photo 2 shows the subwoofer with the Audiomobile driver installed.



PHOTO 2: Sub with Audiomobile driver.

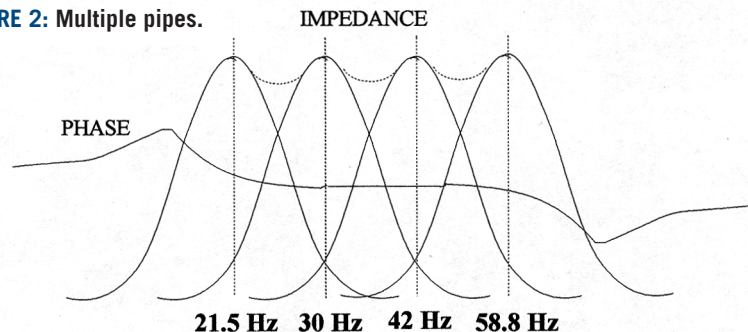
HOW IT WORKS

Most bass and subwoofer speakers depend on the driving amplifier to damp the speaker resonance and control unwanted cone movement. Modern amplifiers very closely approach the concept of a constant-voltage generator. The amplifier sees peaks in the speaker impedance curve as changes in loading, which they are, and it responds by reducing the output current so that the current times impedance remains constant. Note that at the center frequency

of the impedance peak the impedance is purely resistive and the output power is reduced accordingly.

To either side of center the impedance has a reactive component, which the amplifier will try to control, sometimes with interesting results. If an impulse is applied to the speaker, that excites a resonance mode of the driver/cabinet combination, that response is coupled into the voice coil and controlled by the amplifier feedback. For example, an amplifier with 20dB feed-

FIGURE 2: Multiple pipes.



IMPEDANCE AND PHASE CHARACTERISTICS OF THE FOUR QUARTER WAVE PIPES USED IN THE SUB WOOFER. THE DOTTED LINES SHOW THE IMPEDANCE ADDITION OF ADJACENT PIPES. PHASE SHIFT BETWEEN PIPES IS OPPOSITE AND CANCELS.

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resonance is to apply a frequency selective resistance to cone movement over the entire surface of the cone. This would effectively damp the cone resonance, and since the voice coil is firmly

attached to one end of the cone, the voice coil is also damped and the amplifier is presented with a rather benign load. This selective acoustical loading was the secret of the Hegeman Model 1s.

OVERVIEW

Figure 1 illustrates the impedance characteristics at the open end of a quarter-wave pipe closed at one end and the equivalent circuit, a parallel resonance R, L, C combination, where the Q of the circuit is set by R. (See Harry F. Olson's *Elements of Acoustical Engineering* for a more thorough discussion of resonance pipes.) Figure 2 shows the relationship of the four tuned pipes used in this subwoofer. The response of the pipes merges into a bandpass filter response representing the resistance applied to the driver cone. The Q of the individual pipes is adjusted by varying a resistive element placed in the mouth of each pipe.

Standard stuffing materials are not very effective at very low frequencies, but an open cell foam is. The materials used for this sub are a number of utility sponges, such as those sold by Ace

Hardware. Coupling between the pipes and the cone is accomplished with a relatively small plenum into which the rear of the driver projects. Sealing this box is a must.

Figures 3A and 3B show the driver impedance in free air superimposed upon the impedance response of the finished unit for the MCM and Audiomobile drivers. The finished response for the MCM unit indicates a center frequency of about 54Hz and a corresponding bandwidth of 73Hz, resulting in a Q of about 0.74, which results in an excellent transient response. The Q for the Audiomobile driver is 0.78—again, excellent transient response. Now for the “no free lunch” part.

The nominal impedance of the MCM driver is listed as 8Ω and the maximum input power as 175W. The MASS 2010 maximum input is 600W. The impedance curves of Fig. 3 indicate an impedance of approximately 18–20Ω over the operating range. To fully drive these speakers, an amplifier must be able to put out about 200 to 600W into 16Ω. I am using a Hafler DH220 operating in

the bridged mode with good results. A 4Ω driver would result in a better match to lower power amps.

DESCRIPTION

The cabinet is built up of three layers, similar to a triple-decker sandwich. The two outer layers contain the two lower frequency pipes, 21.5Hz and 30Hz. The center layer contains the 42Hz and 58.8Hz pipes. Each pipe is a rectangular tunnel that is folded several times to achieve the proper acoustical length. The acoustical path of the 21.5Hz tunnel is shown in Fig. 4.

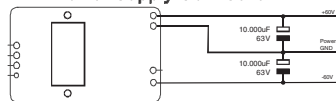
Two walls of the outer layer tunnels are the cabinet sides and the near sides of the separators; the inner sides of the separators provide the same function for the center layer. Seven 3.75” high walls of various lengths, corner pieces, and a stop (acoustical short) define the rest of the tunnel structure in each layer. Figures 5, 6, and 7 show the wall lengths and wall, corner, and stop locations for each layer.

Figure 8 illustrates the layer positions and the location and build-up of the 21.5Hz layer. Note that this layer

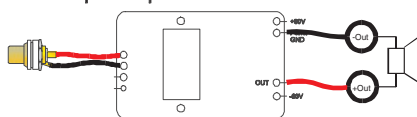
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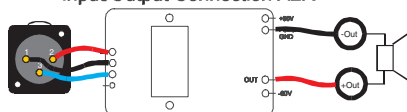
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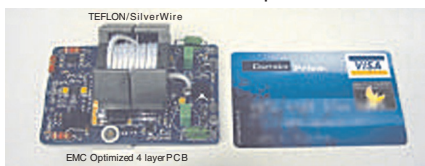
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has seven walls, 12 corners, and one stop. It is the only one that utilizes the maximum available tunnel length; the 30Hz tunnel has three fewer corners and does not use the last two lengths of

the tunnel. The center layer divides the available tunnel into two sections and does not use the last length of the tunnel, leaving space for the lead-in wiring for the speaker.

honeycomb-like structure, which results in an acoustically dead cabinet over the operating frequency range. The open mouth of each tunnel opens under the driver into a small plenum. A divider reduces the plenum volume to improve the coupling between the tunnels and the driver. *Figure 9* details the plenum; the divider is not shown so that the divider support structure may be detailed.

Each layer preserves the same basic structure of seven walls to

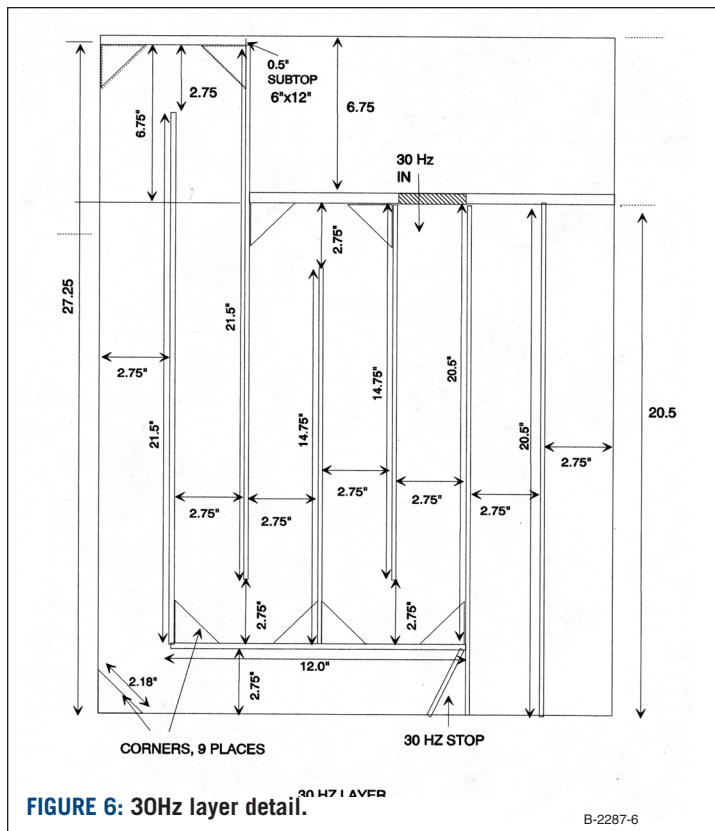


FIGURE 6: 30Hz layer detail.

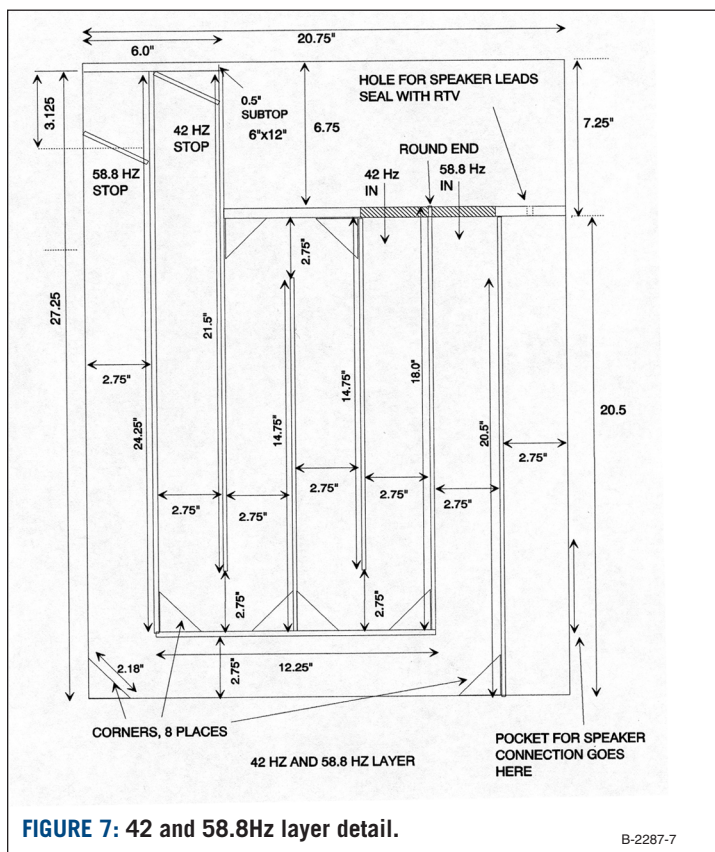


FIGURE 7: 42 and 58.8Hz layer detail.

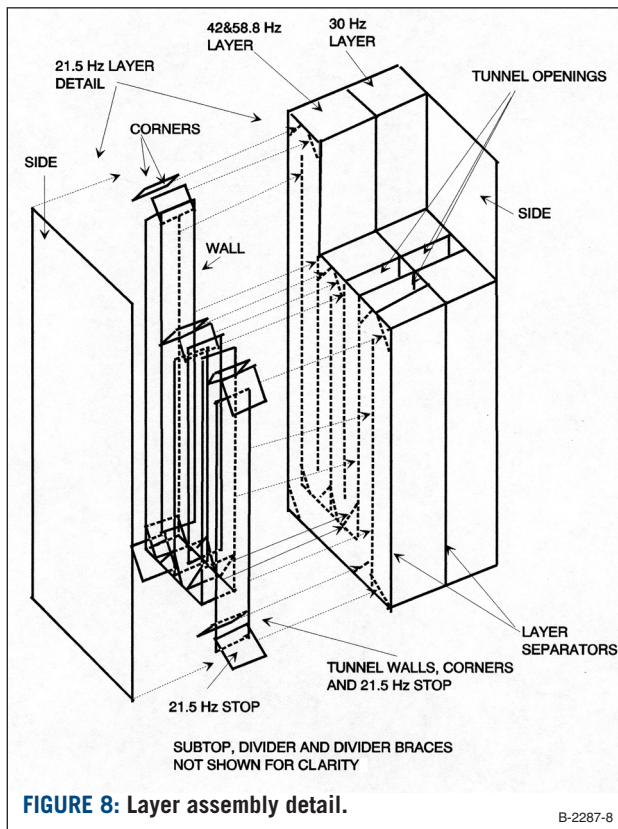


FIGURE 8: Layer assembly detail.

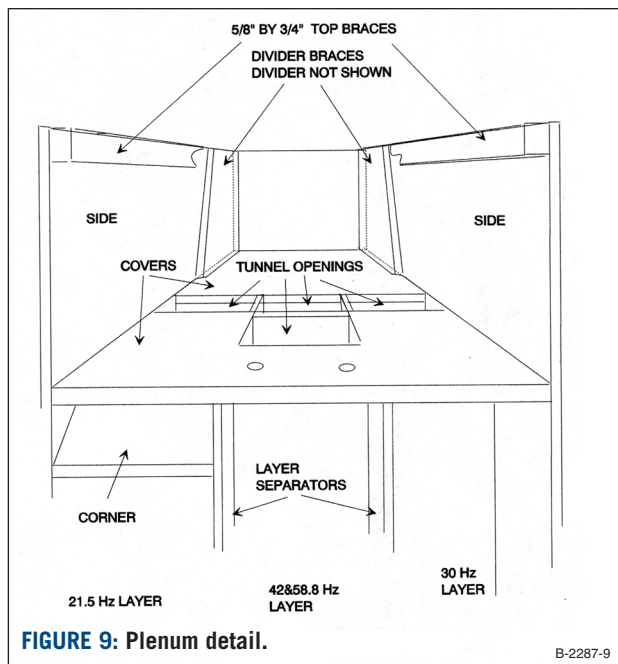


FIGURE 9: Plenum detail.

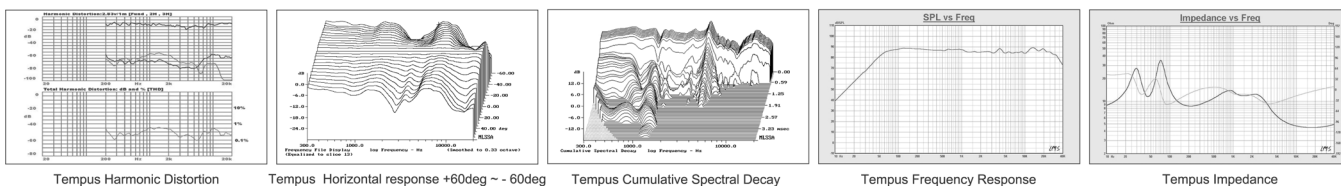
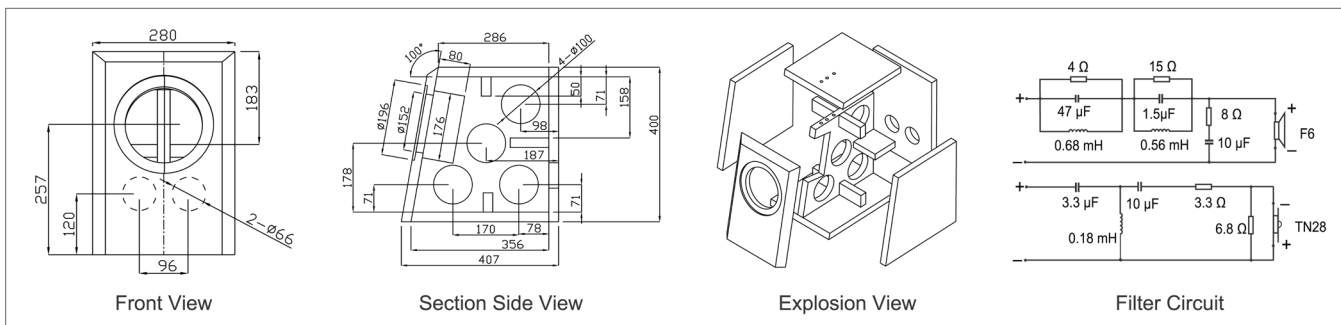
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CONSTRUCTION

Have your supplier cut the two $\frac{3}{4}$ " sides and two $\frac{3}{8}$ " separators to 27.75" by 20.75". You can then cut the separators to their final shape and size on a stan-

dard 10" table saw (Figure 10). Have one 48" by 48" $\frac{1}{4}$ " hardboard cut in half; the two 24" by 48" pieces will make all of the walls, corners, and stops. Stores such as Home Depot will cut these as

part of the material cost. You could cut the front, back, top, and bottom pieces at this time, but because their actual size depends on the build-up of the layers, I like to do those after the three-layer core is complete.

Cut the separators to shape (Figure 10). Then set the table saw to make a 3.75" cut from the fence to the fence by 24" strips of $\frac{1}{4}$ " hardboard, convert-

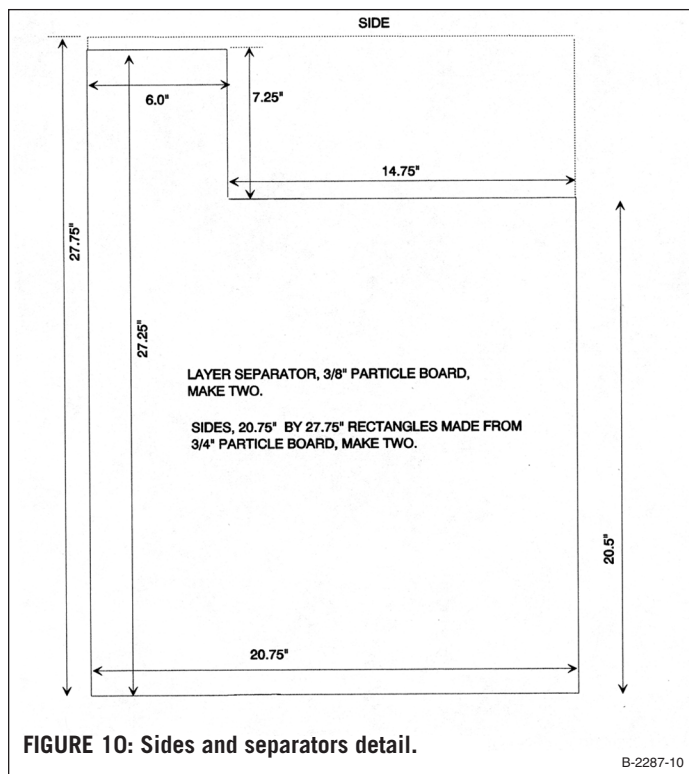


FIGURE 10: Sides and separators detail.

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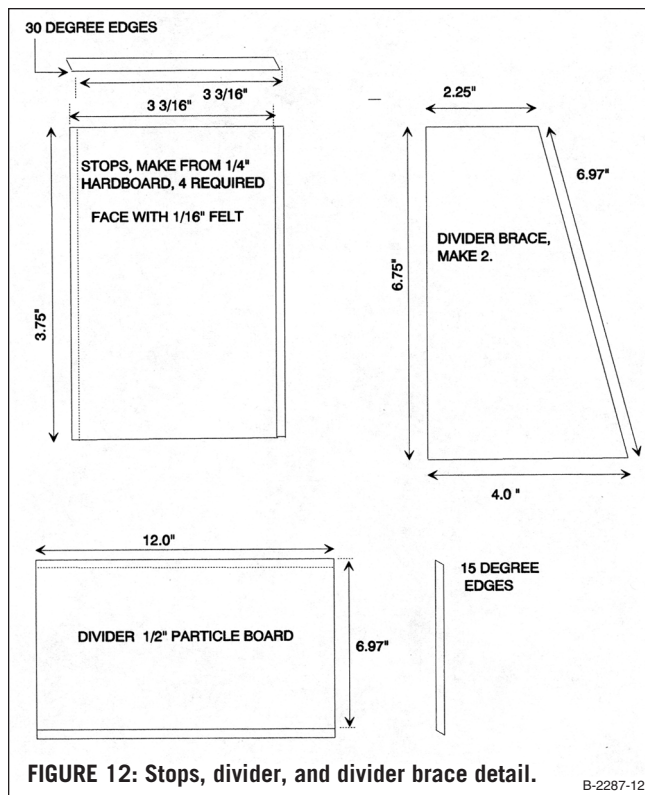


FIGURE 12: Stops, divider, and divider brace detail.

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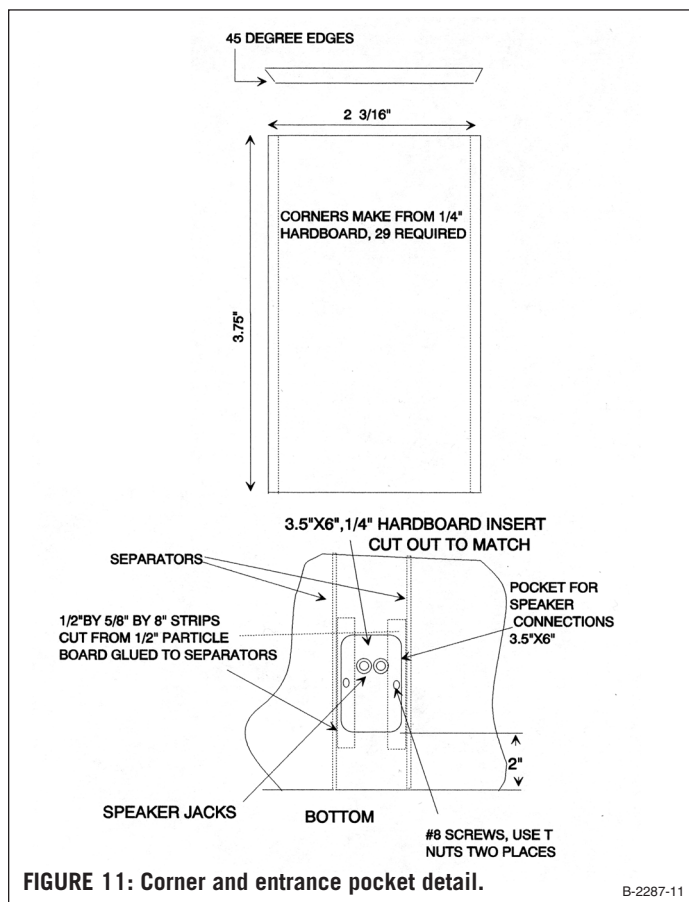


FIGURE 11: Corner and entrance pocket detail.

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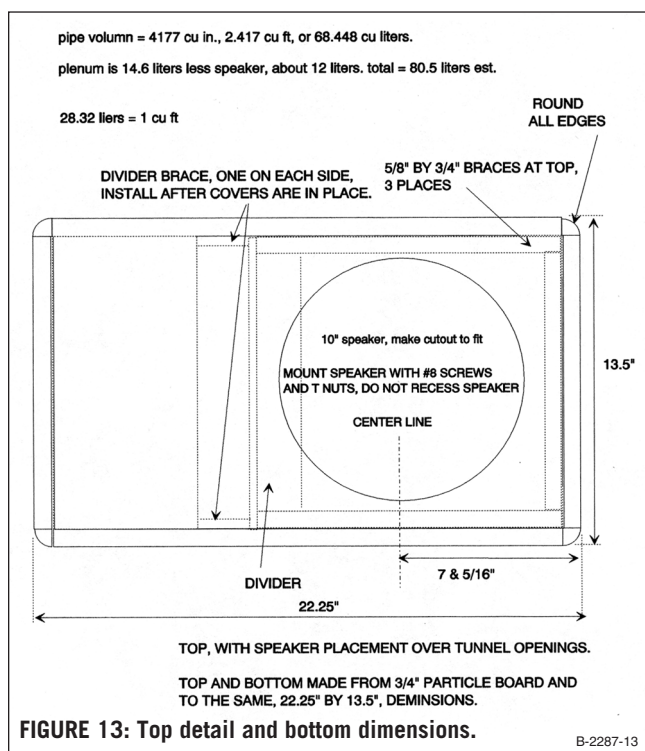


FIGURE 13: Top detail and bottom dimensions.

B-2287-13

ing all of the hardboard to strips. You will cut the walls, corners, and stops from these strips.

Figures 5, 6, and 7 detail the three layers. Starting with Fig. 5, the 21.5Hz layer, cut the seven walls to the lengths shown. I label each one with the layer frequency and wall length. Do the same for the remaining two layers and keep the walls for each layer separate. Note that one wall of the 42/58.8Hz layer is 24.25" long; cut a short length and glue it to the 24" piece to make the full 24.25".

Make the 29 corners as shown in Fig. 11 and the four stops as shown in Fig. 12. Cut the 6" x 12" sub top from 1/2" particleboard. Refer to Fig. 12 and cut the divider and divider braces from 1/2" particleboard. You can find felt for the stops at a local craft store. Attach the felt to the stops with a line of white glue around the edge and a dot in the middle, leaving most of the felt glue free. After the glue has dried, trim the edges with a sanding block.

Note, when cutting the walls, to cut seven for each layer. You must install all seven walls in each layer to ensure the integrity of the box. Leaving out a wall—even though that section of tube is not used—will cause the box to be less rigid and subject to resonance effects.

ADHESION

Photo 3 shows the start of the first layer. I generally begin with the 30Hz layer, which starts out on a 1/4" side. Use a fine point magic marker to draw the outline of the walls and label the length, corners, stops, and, in this case, the sub top.

Photo 3 also shows what I built to aid construction: a right-angle jig that I clamp on the wall to position it during gluing and a larger jig consisting of a 30" x 36" sheet of plywood with four up-rights affixed to it. The up-rights, which are positioned in a right-angle "L" to engage two sides of the core, are about 15" tall and are carefully set to right angles to the base. When adding a separator or the last side to the core you snug the core tightly into the "L" and use the up-rights to align the new piece. Use a good grade of polyurethane glue for construction. This glue expands as it sets and will fill any small gaps.

Be generous with the glue, using large beads, especially when covering a

layer with a separator or side. If you use enough glue, the excess will run down the walls, which will decrease the Q

only a little bit, but the Q will be decreased much more when the system is tuned and there are no leaks.

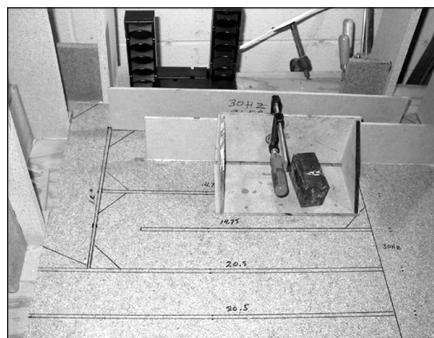


PHOTO 3: Starting the first layer.

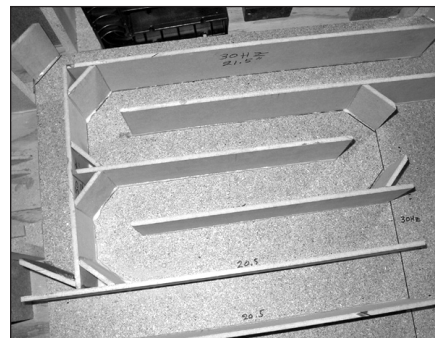
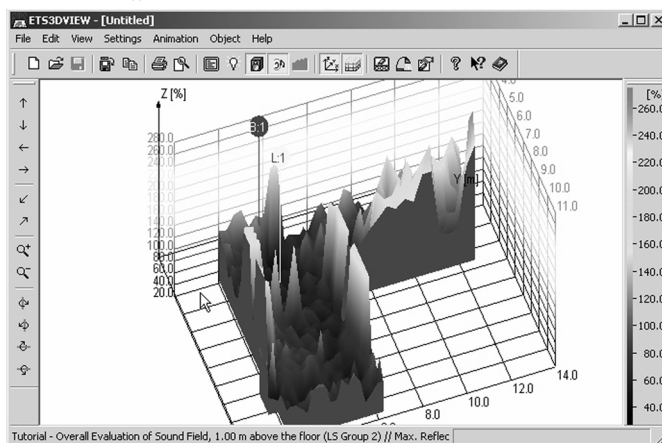


PHOTO 4: 30Hz layer ready for separator.

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Start by gluing the sub top making sure that it forms a right angle with the side. *Photo 3* shows the setup for the second wall. Do not rush—it takes about two hours or so for the glue to set enough to remove the clamp. After the walls are in place, you can glue the corners and stop. The bottom edges of the corners may require trimming to fit the glue bead at the base of the walls. About the time you finish the first layer, you may be wondering why you started this project in the first place (please see Don's comments at the beginning of the article).

Photo 4 shows the completed first layer ready for the separator installation. Note the freestanding corner in the upper left. I made a little jig to mount that with, too. Also, on the freestanding corners I used a small scrap of hardboard about $\frac{5}{8}$ " by 2" as a brace glued to the back so it would remain rigid during handling.

When you reach this point, check to see that everything is at the same height and use lots of glue and install the separator. To ensure a good bond,

use lots of weight to hold the separator in place while the glue sets. Sand bags, gallon cans of paint, or anything else heavy and handy will do. Repeat the preceding for the next two layers.

The next, center layer, is the 42/58.8Hz layer. After you have finished the last layer, with the side on, let the core set overnight to fully cure before handling. See *Figure 11* for the speaker connector pocket details. After you have glued the $\frac{1}{2}$ " $\times$ $\frac{5}{8}$ " $\times$ 8" strips in place, check to ensure that the front, back, top, and bottom openings are flush and without high spots. Cut the top, bottom, front, and back pieces to size (*Figs. 13 and 14*). To make the pocket cutout in the back, I made a template from $\frac{3}{8}$ " material and used a template guide and $\frac{1}{4}$ " straight router bit.

Glue the front, back, and bottom in place using clamps and/or weights to keep the joints tight. Install the covers as shown in *Fig. 15*. Drill the holes for the speaker wires for a tight fit. I used 12-gauge stranded wire for mine. Install the divider braces and divider as shown in *Figs. 9 and 13*. Cut the $\frac{5}{8}$ " by $\frac{3}{4}$ " braces to fit and glue in place, again referring to *Fig. 13*. Note that these should be flush with the top edge.

Make the speaker cutout as shown in *Fig. 13*—9.125" diameter for the MCM

driver or 9.25" diameter for the MASS 2010 driver. Check the fit of the driver and mark the location of the mounting holes. Drill mounting holes for #8 T-nuts and install them. Check to ensure that everything is flush and without high spots, then glue the top in place, using lots of glue.

When everything is well set—ten to 12 hours at least—sand the edges flush and use a router with a $\frac{1}{2}$ " round-over bit to round all edges. Start with the long edges, then you can do the top and bottom by following the edges around. Give the box a final sanding. Install the speaker wires and use an RTV sealant around the wires where they pass through the cover, and your favorite connector on the pocket insert. Leave

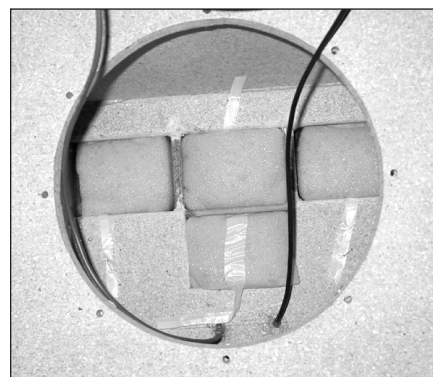
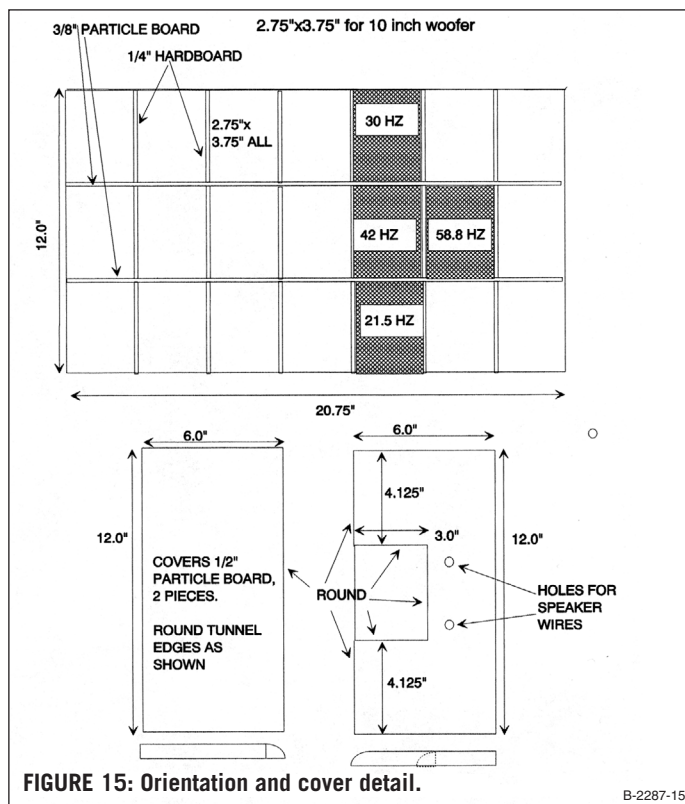
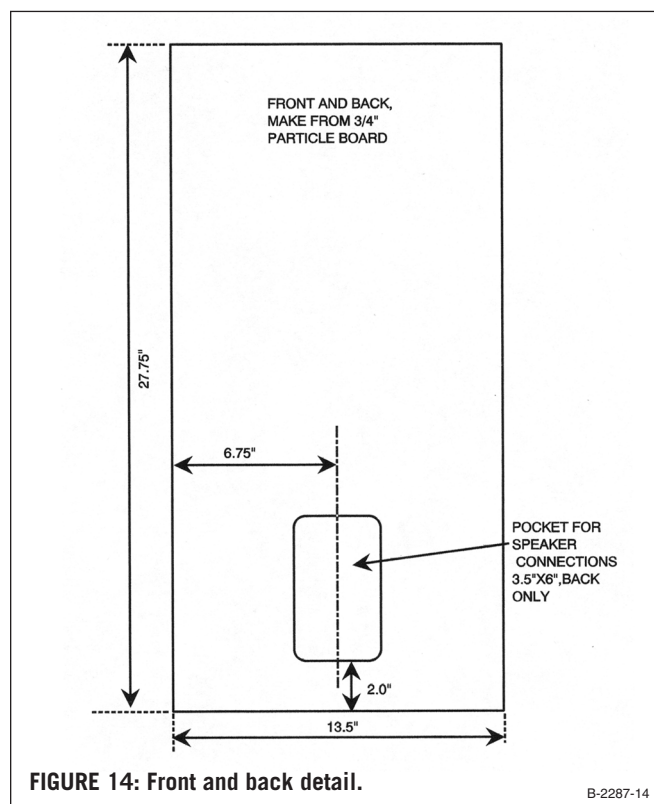


PHOTO 5: Stuffed pipes.



about 15" of wire outside the cover so that you can set the speaker up on the top of the cabinet while connecting or removing the leads.

TUNING

Tuning consists of adjusting the Q of the four pipes so that the impedance of the pipes dissipates the stored energy in the driver around Fs, resulting in a relatively flat impedance curve as shown in Figs. 3A and B. Figure 16 illustrates a simple means of measuring speaker impedance. The little battery-

operated digital VOMs usually have an AC range that is flat to 5kHz or so. My old Radio Shack unit is good beyond 10kHz.

If you use the MCM driver, you must apply a gasket to the bottom of the mounting flange. The Audiomobile driver has a molded rubber mounting gasket that works fine. I used a 3/8" weather strip foam tape from Ace Hardware on my MCM driver. Use masking tape to cover the mounting screw holes to seal the cabinet. Hook up the driver and set it into the cabinet. The driver weight on the gasket will provide an adequate seal.

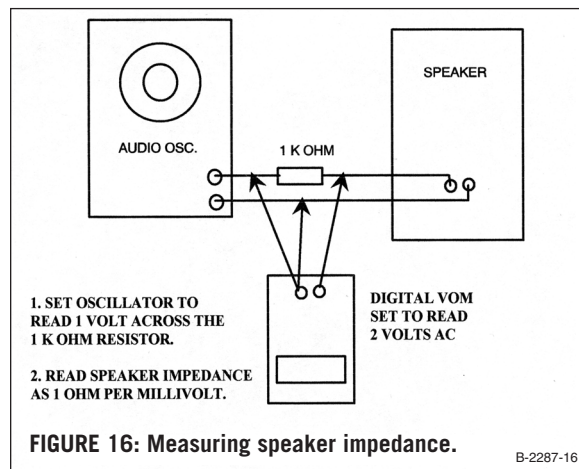
Set the speaker up for test as shown in Fig. 16. Adjust the generator to provide 1V RMS across the 1kΩ resistor and make a test run measuring the voltage across the speaker (1mV = 1Ω), maintaining a constant output level from the signal generator. I used one cycle steps from 15Hz to 30Hz, two cycle steps from 30Hz to 50Hz,

and 5Hz steps beyond. The results will be a bit jagged but will show the effect of the tunnels on the driver response.

I used five 7" by 4.5" by 2.375" polyester utility sponges from Ace Hardware to adjust the Q of the pipes; similar sponges should work as well. Cut two of the sponges in half so that you have four pieces 3.5" by 4.5" by 2.375".

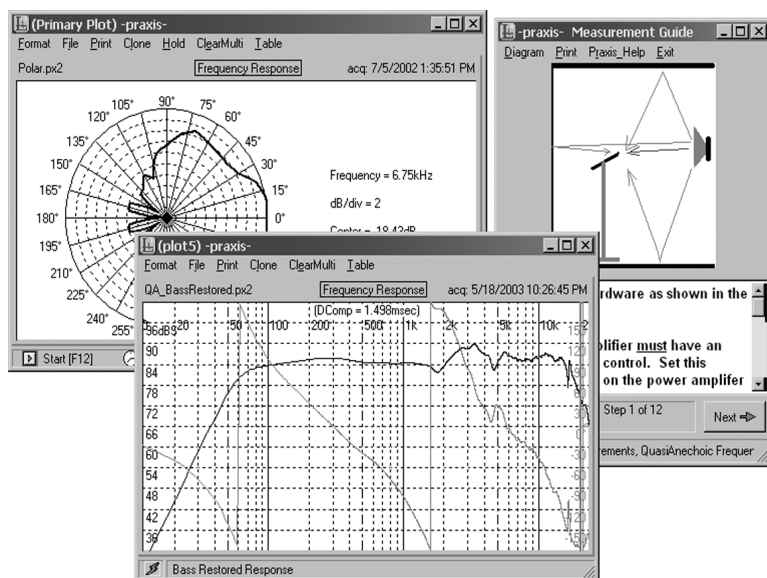
Remove the driver from the cabinet and place it to the rear of the mounting hole. Wrap a strip of 1/2" strapping tape two-thirds around the length of the three whole sponges, centered on the 4.5" sides leaving a 6" tail. Insert the sponges into the 21.5, 30, and 42Hz tunnels with the tails pointing up and the 4.5" sponge width corresponding to the 3.75" width of the tunnel. Place the half sponges into each tunnel so that the 4.5" and the 3.5" dimensions of the sponges correspond to the 3.75" and 2.75" tunnel dimensions (Photo 5). Replace the driver and repeat the impedance measurement, plot it on semi log paper. The plot should look like Figure 3A or 3B, depending on the driver.

You may make minor adjustments by rotating the half sponges by 90°, chang-



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ing the compression of the sponge, or larger changes by adding or subtracting half lengths to the full sponges. Do the adjustments one at a time. Adding sponge material or increasing compression of the sponge in a tunnel will generally increase the measured impedance at the tunnel frequency, and decreasing the sponge material or compression in a tunnel will decrease the measured impedance.

The low frequency tunnels also affect frequency areas where the tunnel is one half wavelength long, twice the tuned frequency. A half wavelength pipe, closed at one end, reflects a closure at the open end, effectively removing the volume of the pipe from the system. The magnitude of this effect is determined by the Q of the pipe. Thus, increasing the Q (removing the sponge) from the 30Hz tunnel will increase the efficiency of the 58.8Hz tunnel.

ASSEMBLY JIGS

Figure 17 illustrates two jigs that I used to ease assembly. Sizes given are approximate. Critical measurements are the 90° angles shown and the height of the layer assembly jig uprights (not less than 15"). The wall-mounting jig or a commercial equivalent is a must. The layer assembly jig makes layer alignment accurate and easy and is highly recommended. A jig for the freestanding corners was mentioned in the text and is nothing more than a mini version of the wall-mounting jig.

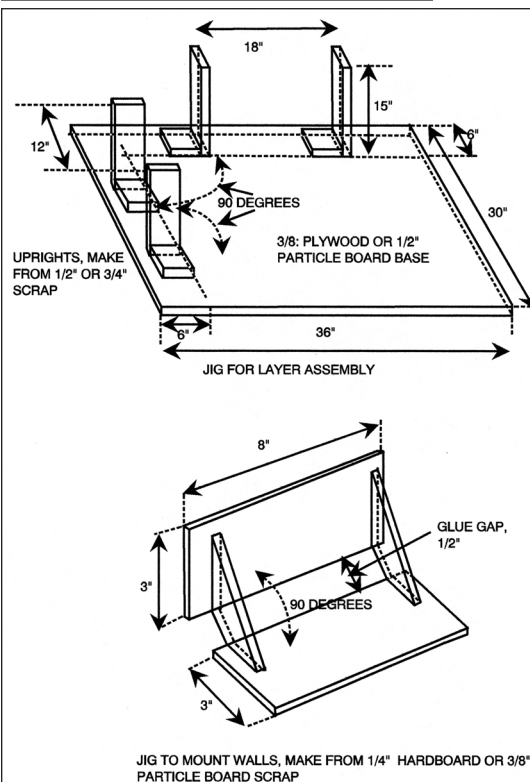


FIGURE 17: Assembly jigs.

Once the tuning is satisfactory, remove the driver, put a tail on the sponge in the 58.8Hz tunnel, and staple the tails to the bottom or sides of the plenum. Loosely fill the plenum with fiberfill, check the connections to the driver, remove the tape over the mounting holes, and screw the driver in place.

FINISH

I had the finished unit sprayed in a bedliner shop. This finish, which has become popular with small bands for their equipment, is extremely durable and easy to care for, and the black crinkle finish looks good. Mine was done by Inyati of Phoenix and ran about \$4.50 per square foot. Lacquer or paint finishes should be applied before tuning.

The bedliner coating only requires that the driver and the connector insert be removed and can be done after tuning. You can stuff the insert inside so you do not need to remove the wires. The shop will cover the holes so that the inside is not sprayed.

SETUP

Set your crossover to sum the low-frequency outputs. Set the crossover frequency in the range of 50-100Hz.

The subwoofer has a sensitivity of 88-89dB. If your stereo pair has a sensitivity of 90-92dB, set the output of each high-frequency channel to 5 or 6dB below the output level of the summed low-frequency channel. For frequencies below 130Hz or so, you will see a 3dB gain from the stereo speakers at your listening location so these settings should result in a channel balance within a few dB. Note that a 12-18dB per octave crossover is recommended.

Center the sub between your stereo pair and the same distance from your listening location; I generally start with the driver pointing up. Put on some music that contains a fair amount of bass and midrange or your favorite

alignment and test CD and try it out.

Because the LF and HF channels of many second- and third-order crossovers are 180° out of phase around the crossover point, you may choose to try switching the phase to the subwoofer for effect. If required, readjust the channel gains so that the subwoofer disappears in the sound stage.

The integration of the subwoofer and the stereo speakers should be seamless; the only noticeable change in sound should be that the low-frequency range has found a lower octave. When set up properly, the low bass may almost sound a little thin but very articulate, just like a live concert!

REFERENCES

Audiomobile,
<http://www.audiomobileinc.com/main.htm>.

MCM,
www.mcmelectronics.com.

Elements of Acoustical Engineering, 2nd Edition, Harry F. Olson, E.E. Ph.D., D. Van Nostrand Co. 1947.

Don Morrison Audio,
<http://www.donmorrisonaudio.com/>.

PARTS LIST

One 4' x 8' sheet of 3/4" particleboard—sides, front, back, top, and bottom.

One 2' x 4' sheet of 1/2" particleboard—covers, divider braces, divider, and subtop.

One 4' x 4' sheet of 3/8" particleboard—separators.

One 4' x 4' sheet of 1/4" hard board—walls, corners, stops, and free corner braces.

16 oz bottle of polyurethane wood glue.

Small bottle of white glue.

1ft² of craft felt.

Ten #8 T-nuts.

Ten #8 cap head or Phillips head screws, 1.25" long.

Ten #8 steel washers.

Two 6' lengths of #12 stranded wire, one red and one black, or your favorite colors.

One dual binding post with 3/4" centers for single or dual banana plugs.

1 3/8" x 1/4" self-adhesive weather proofing tape, MCM driver only.

1ft³ fiberfill.

Five 7" x 4.5" x 2.375" polyester utility sponges from Ace Hardware or equivalent.

MCM 55-2325 or Audiomobile MASS 2010 2/4 driver. If the MASS 2010 series is no longer available the new MASS 2410 2/4 is the replacement and has ±3mm more throw.

The 5/8" x 3/4" braces and the 1/2" x 8" strips are cut from the 3/4" sheet scraps.

NOTES ON DRIVERS

The MCM driver will make a very good subwoofer that will be well worth the time spent for a very reasonable cost. The Audiomobile driver will be outstanding at a higher cost. The following set of distortion measurements are made at a 91dBi level at one meter.

Frequency	MCM	Audiomobile	Adire Audio Brahma 10
40Hz	6%	2.2%	1.5%
30Hz	12%	5.5%	1.75%
25Hz		12%	4.5%

Many other drivers will work in this cabinet; the general requirements are: X_{MAX} = 12mm or greater, Q_{TS} of 0.4 or greater, Q_{ES} of 0.4 or greater, Q_{MS} of 3 to 15, and an f_s between 25Hz and 35Hz. Here's a short list of available drivers (an "*" indicates drivers installed and tested).

Dayton Titanic MKII, X_{MAX} = 16mm and f_s = 28Hz, Parts Express PN 295-412

Audiobahn AW1008Q*, X_{MAX} = 20mm, f_s = 35Hz.

Audiobahn AW1008T (This year's model of the above).

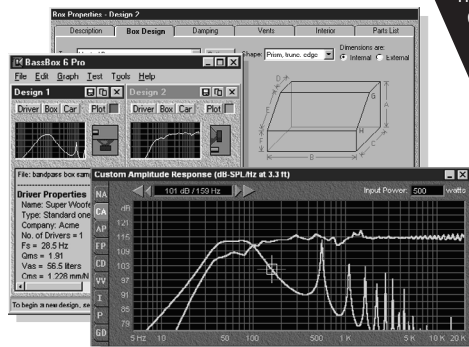
Rockford Fosgate RFR 3110, specs similar to the Audiomobile.

Adire Audio model Brahma 10*, X_{MAX} = 27mm, f_s 35Hz (measured 28Hz). Extremely linear, see URL.

<http://www.acoustic-visions.com/brahmaseries.htm>

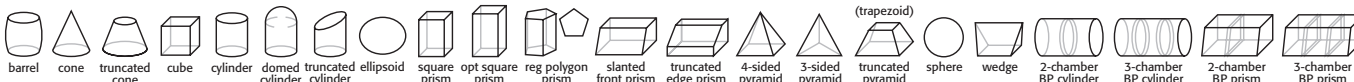
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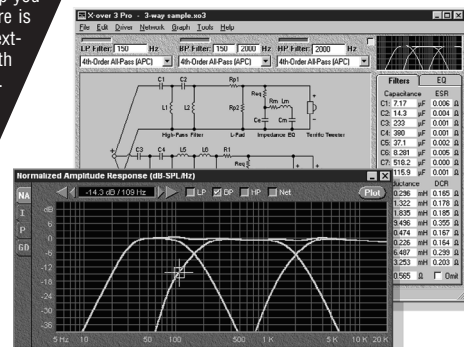
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- Calculate the resistance of parallel or series components.



This article describes the transient response and stability of a simple op-amp circuit, configured to be a real-time analog simulator of a tube power amp I've designed but not yet built. The amp will have adjustable feedback from 0 to 18dB, taken from the output tube plates, rather than the usual transformer secondary. The op amp simulation circuit explores both connections and simulated 10kHz square-wave responses are compared, with various resistive and reactive loads.

SIMULATOR

In Fig. 1, the two-stage op-amp circuit has switchable feedback (FB) from V_S (representing the output tube plate voltage, but scaled to the XFMR, sec. $Z_O = 5\Omega$, and the simulator Z_O scaling = 100:1) to K (input tube cathode); V_i represents the input grid. When discussing feedback here, I mean only that through the switch; each op amp's local feedback is ignored, as they set the gain ($\frac{V_S}{V_i}$) to equal that of the tube amp, 4800 open-

TABLE 1
SIMULATOR FREQUENCY RESPONSES
WITH 5Ω RESISTIVE LOAD

SIMULATED FREQ. (KHZ*)	RESPONSE, DB RE 1KHZ:		
	NO FB	18DB PRI FB	18DB SEC FB
1	0.00	0.00	0.00
5	-0.07	-0.03	0.00
10	-0.12	-0.10	-0.01
20	-0.28	-0.36	-0.05
30	-0.55	-0.78	-0.13
50	-1.5	-2.0	-0.37
100	-7.2	-6.2	-1.0
150	-14.2	-10.3	-0.9
200	-20.3	-13.8	+1.3
255	-26.0	-16.9	+6.2
300	-30.0	-19.1	-1.7
400	-37.4	-22.8	-14.7

*op amp ckt uses 1/10 these frequencies.

loop ($A_{v_{OL}}$). Table 1 shows responses with 18dB feedback_x and no FB.

With (switched-in) feedback, closed-loop gain ($A_{v_{CL}}$) is 610. The ratio

$$\frac{4800}{610} = 7.87 = 17.9\text{dB}$$

is the feedback factor, representing the maximum value selectable in the tube amp (*Fig. 2*). In the tube amp, R_a and R_b are selected to (1) adjust feedback in 3dB steps, 0 to 18dB, and (2) keep the overall gain reasonably constant (*Table 2* and *Fig. 3*).

SCALING

At V_S , the simulator has a (non-FB) Z_o of (close to) 500Ω ; representing 5Ω for the tube amp—referred to the transformer secondary—the impedance scaling factor is 100. Those for L, C, and frequency (F) are shown in *Fig. 1*. I chose 1/10 F scaling to stay within the HF response of

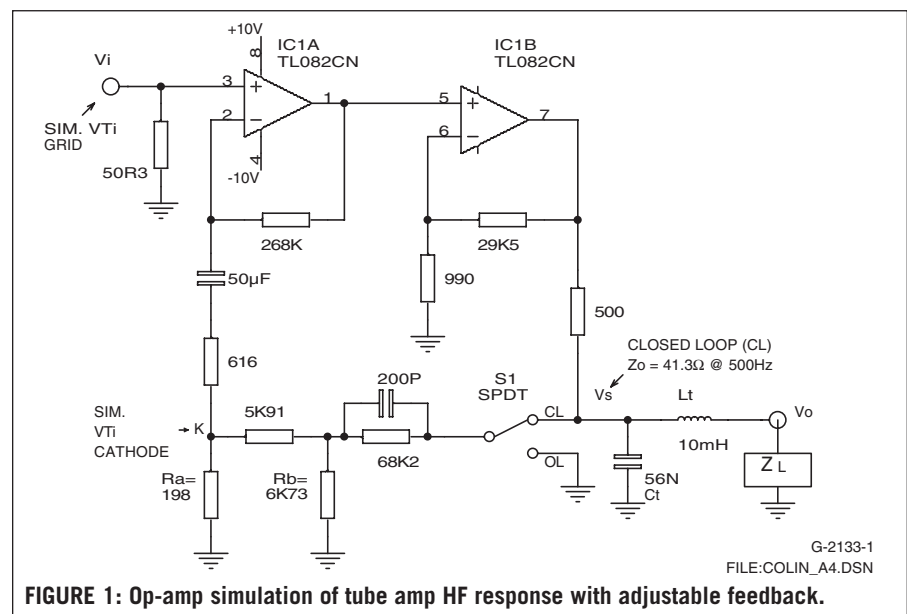
the op amps. Note: the simulator's dominant -6dB/octave rolloff is due to the first stage's high gain reducing the bandwidth to 12kHz , -3dB , F'B switch open (120kHz in the tube amp).

Looking into V_S from the output, V_S represents the open-circuit (no load) transformer secondary voltage in series with a (no-FB) 5Ω resistance (transformed plate resistance). The $0.056\mu\text{F}$ cap (C_T) represents the (transformed and scaled) 1.5nF primary shunt C, and the 10mH (L_p) is for the transformer leakage inductance (4.7mH at primary). These values are roughly typical for a $>150\text{W}$ $2\text{k}\Omega$ p-p to 4Ω XFMR.

(I'm considering the Hammond
1650W, 280W, 1900Ω to 4, 8, 16Ω.)

FEEDBACK

The 200pF cap across the 68k resistor produces an HF rise at 12kHz (+3dB); this with the forward gain rolloff also at 12kHz results in a flat loop response (forward plus FB), except for the loading of C_T . The rolloff due to C_T depends on the load Z_L . But because this is now the only overall rolloff, and this can be capacitive, resistive, and/or inductive,



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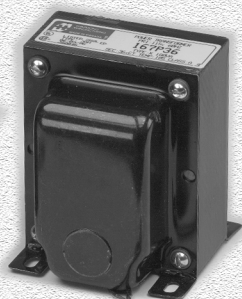


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but never with a phase angle magnitude greater than 90° , the amp will be unconditionally stable. The phase margin (additional loop phase shift needed to cause oscillation) will be at least 90° .

ALTERNATE FEEDBACK

To simulate the usual transformer secondary FB, you can connect the $68k \parallel 200pF$ to V_o . As you will see in the waveform photos, this configuration is unstable with some loads (including no-load). Here, the loop path includes the transformer leakage inductance L_T , which (depending on load) can add up

to an additional 180° of phase shift, causing oscillation.

Admittedly, I did not change the FB network to optimize this configuration. However, even if done for one load, the variability in phase shift with this extra reactance L_T results in only conditional stability. That's why you often see power-wasting resistive or R-C damping with secondary feedback.

DISADVANTAGE TO PRIMARY FEEDBACK?

It would appear desirable to have the FB sense the speaker terminal voltage

directly, so transformer losses, rolloffs, and distortion are "corrected."

Well, first of all, transformers have become very good. Second, the distortion is very low in level and order, probably much lower than that of any tube. But also, in a tightly coupled transformer, magnetic distortion affects the volt/amp relation, but hardly changes the primary/secondary voltage relation at all. So using feedback to reduce distortion at the primary also does so at the secondary.

But the most important advantage of primary FB is the elimination of transformer leakage inductance and its phase shift/time lag from the FB loop.

FEEDBACK "IMMEDIACY" AND SOUND

Feedback itself does not degrade sound quality; feedback with excessive phase shift and delay does. For example, cathode (and emitter) followers inherently have almost 100% degeneration (negative feedback). But cathode followers are accepted as non-degrading; the feedback within the audio range is virtually instantaneous and in-phase.

Of course, FB exacerbates sharp nonlinearities and can cause slew-limiting cutoff in transistors. But I'm construct-

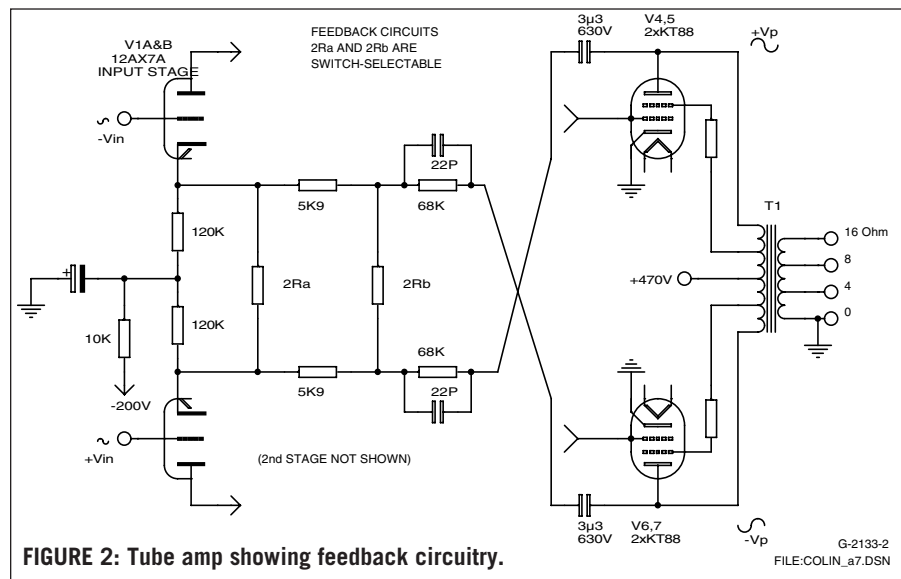


FIGURE 2: Tube amp showing feedback circuitry.

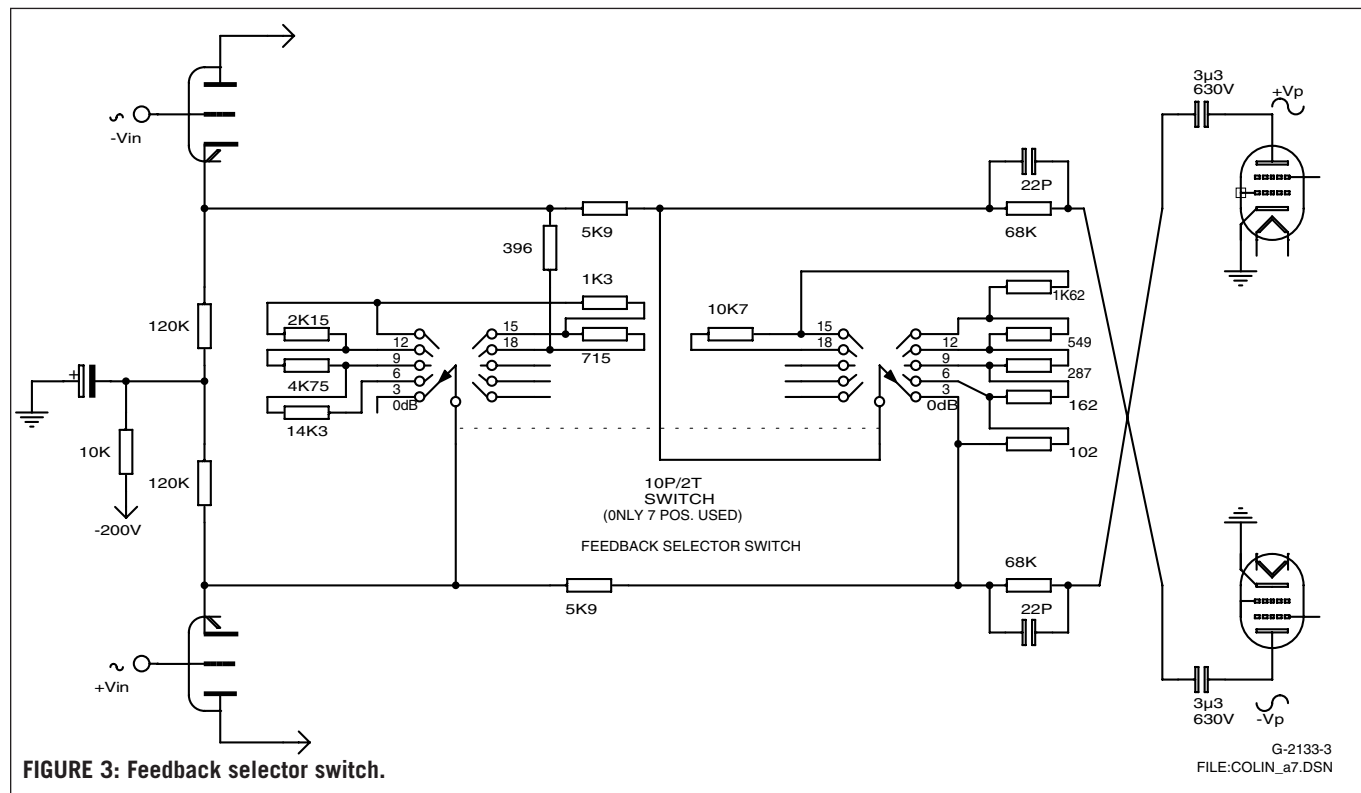


FIGURE 3: Feedback selector switch.

ing a tube amp with smooth transfer function and ample drive for all stages (as is the norm for tube amps).

SQUARE-WAVE RESPONSES

Frequency and load impedances discussed are referenced to the tube amp. In *Photos 1 (a, b, c)*, 2 (a, b, c), and 3 (a, b), upper traces are the simulator V_S , which represents the source voltage driving the transformer (C_T , L_T). This corresponds to the transformer primary (plate signal). Lower traces represent the amplifier output voltage delivered to the load. Plate and output signals are scaled to the same magnitude.

Photo 1 (a, b, c) shows 10kHz square-wave response with a 5 Ω resistive load.

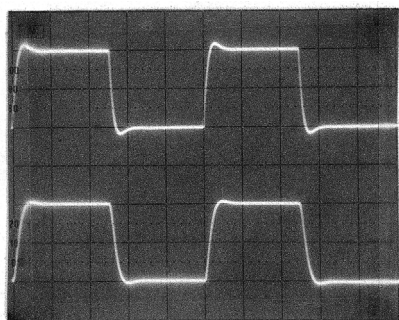


PHOTO 1a: Simulated 10kHz square-wave response with 5 Ω load, no FB. Upper = plate voltage, lower = output voltage.

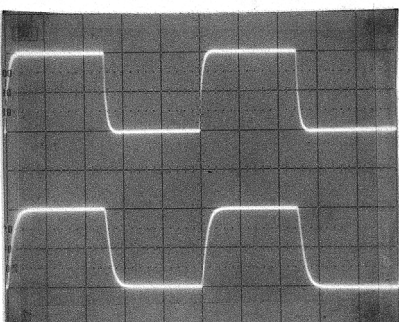


PHOTO 1b: Same except with 18dB of FB from output tube plates.

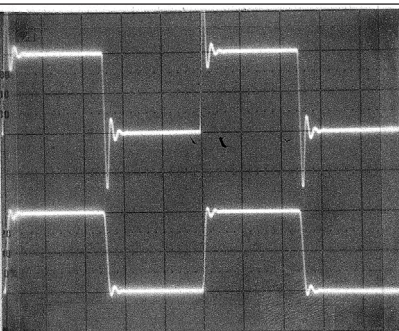


PHOTO 1c: Same except FB taken from transformer secondary output.

1a is with no FB, 1b is with transformer primary (plate) FB, and 1c is with secondary (load) FB. Note the slight overshoot with no FB, while primary FB results in optimum damping. Without FB, the higher plate output R produces less damping of the transformer capacitance/leakage L resonance.

With secondary FB (1c), the output (lower) is very sharp, indicating BW well in excess of the 10kHz square-wave fundamental. But the small amount of ≈ 250 kHz ringing is from a large ($>100\%$) overshoot in the plate (upper) signal; the FB must do this to "correct" for a flat re-

sponse after the (low-pass filtering) transformer, where the FB is sensed.

Of course, no normal signal contains 250kHz to stimulate this overshooting

TABLE 2

VALUES OF R_A AND R_B FOR SELECTED FEEDBACK FACTORS WHILE MAINTAINING OVERALL AMP GAIN AT ≈ 600

FEEDBACK FACTOR	R_A	R_B
0dB	Open	0 Ω
3dB	11.8k	51 Ω
6dB	4.64k	132 Ω
9dB	2.28k	277 Ω
12dB	1.20k	550 Ω
15dB	552 Ω	1.35k
18dB	198 Ω	6.70k



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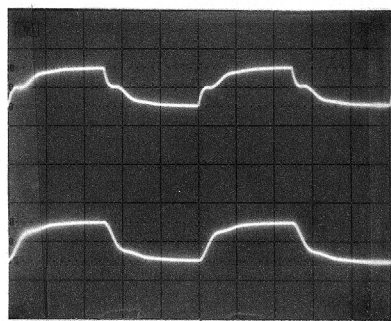


PHOTO 2a: 10kHz square-wave response. Load = $1\mu\text{F}$ series with 1.5Ω , no FB.

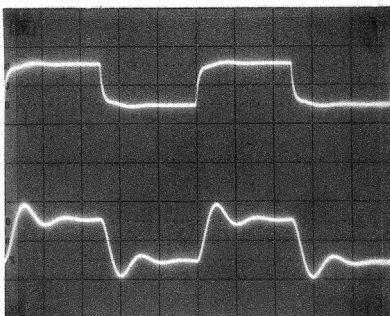


PHOTO 2b: Same except with 18dB plate FB.

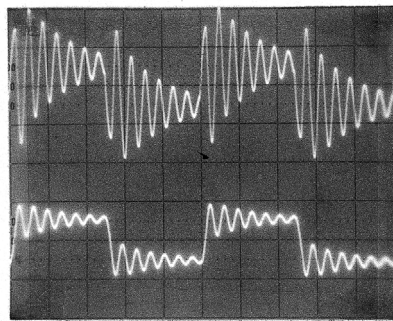


PHOTO 2c: Same except FB from transformer secondary output.

resonance (although clipping will). However, *Photos 1a-c* are with an ideal resistive load, far from the real world of speakers.

Photos 2a-c are with a load of $1\mu\text{F}$ and 1.5Ω in series. Note the severe ringing with secondary FB (2c); decreasing the 1.5Ω load component to 1.4Ω resulted in full-blown oscillation at 130kHz.

With no FB (2a), the response is overdamped and about 3dB down at 20kHz. ("Overdamped" here means excessive HF rolloff, not in relation to speaker "damping factor.") With primary FB, notice that the damped ringing ($\approx 50\text{kHz}$) is almost absent from the plate (upper) signal. The 50kHz resonance is caused not by FB, but by series resonance of transformer leakage L and the $1\mu\text{F}$ load cap.

Unlike *Photos 1a* and *b*, where the only capacitance was the transformer primary, here the resonance is mainly in the output; FB simply lowers the driving resistance, raising the Q of a series resonance. But (1) the 50kHz resonance is inaudible, and (2) the plate signal is well controlled.

Photos 3a and *b* prove the previous assertion that (primary) feedback itself does not cause this resonance: Here, the simulator was not used. The circuitry from C_T through L_T to the load was driven directly from the pulse generator, a high-quality lab unit (HP8116A) with very clean and fast (50MHz) square-wave BW, and precise 50Ω resistive output. The latter is close to the simulator's output R with FB (41Ω actual representing 0.4Ω with reference to the tube amp).

Photo 3b shows the 50Ω generator directly feeding the modeled transformer and load (corresponding to 0.5Ω tube amp Z_O w/ 18dB FB), while in *3a* a 450Ω

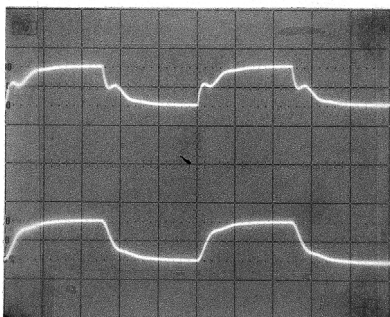


PHOTO 3a: 10kHz simulation (1kHz actual), pulse generator directly driving simulated transformer/load. Driving source $R = 500\Omega$ (compare with 2a).

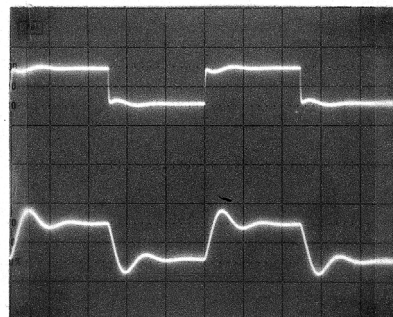


PHOTO 3b: Same except source $R = 50\Omega$ (compare with 2a).

resistor was inserted, producing a 500Ω driving source. The latter value is that of the simulator (actual; 5Ω with reference to the tube amp) with no FB.

Note the almost identical waveforms comparing *Photos 2a* and *3a*, and also *2b* and *3b*. The main difference is the faster rise times of the "plate" signals; this is because the pulse generator doesn't have the first-order 120kHz (with reference to the tube amp) rolloff built into the simulator forward path.

So the 50kHz resonance is not indicative of amp instability, it's simply a passive (harmless) resonance well above audibility, and from an unreasonably high load reactance ($1\mu\text{F}$ in series with only 1.5Ω , and no shunt resistive damping, would be extreme even for speakers, except possibly for some electrostatics). And this is with 18dB of feedback; less could be used with electrostatics.

To further demonstrate stability with primary FB, *Photo 4* shows a pure $1\mu\text{F}$ capacitive load. The output (lower) shows a strong but damped 50kHz resonance, but again this is passive. Notice that the "plate" voltage has much less ringing; that's because the ringing is from the load side, and the low but non-

zero plate (with FB) source resistance is absorbing most (but not all) of the transformer-reflected circulating resonance current.

Photos 5 (a, b) show the output voltage response to a 250Hz square wave. The load is (with reference to the tube amp) a parallel $0.93\text{mH}/47\mu\text{F}$, which is in series with a 5Ω resistor. The overall Q is such that the load impedance reaches a maximum of 26Ω at 761Hz; it falls to 5Ω well away from 761Hz.

This load simulates the crossover input impedance resonance that sometimes occurs even though combined acoustic output may be flat. Notice that with no FB (5a) you can see the 761Hz resonance. The simulated amp, with no FB, has a 5Ω output resistance, so damping factor (as pertaining to the usual speaker terminology) is only one with regard to a 5Ω load.

But with 18dB FB (5b), amp output resistance is low enough to produce a nearly flat signal to this resonant load. Note: the FB was from the primary side, but at this low frequency, secondary FB was very similar (not shown).

SUMMARY

Taking feedback from the output transformer secondary, usually called "global

feedback," introduces an additional reactance (leakage L) into the feedback loop. With primary capacitance, this produces a second-order rolloff even

with a resistive (and/or inductive) load; with capacitive load, the rolloff is third-order. These have phase shifts approaching -180° and -270° , respectively.

With primary feedback (directly from tube plates), as previously described, the rolloff may still be resonant, but its phase shift will be within $\pm 90^\circ$. While secondary FB can be phase-compensated to a degree (no pun intended) for some range of load impedances, the series leakage L introduces much greater net phase variability with actual speaker loads. And while a moderate amount of out-of-phase feedback can be more or less stabilized, one still has, effectively, delayed positive feedback at some fre-

quencies. To say the least, this will not do wonders for distortion-free transient response!

Plate feedback, on the other hand, not only stays reasonably in phase, but can be considered "local feedback" due to its immediacy. Another benefit is that the output transformer is presented with a stable and low driving impedance.

APPLICATION

The amplifier I've designed but not yet built will use four KT88 tubes per channel, in push-pull parallel with 40% ultra-linear screen taps. Power output should be 150W per channel, with this maintained down to 20Hz.

I built the described real-time analog simulator (to investigate feedback stability) for two reasons: (1) I don't have a computer tube simulator, and (2) I think it's much more fun experimenting with a real circuit! Op amps, being the precision and predictable devices they are, are easy to configure to simulate most any forward/feedback frequency/phase response that's mathematically realizable (negative-delay "crystal ball" responses not included). ♦

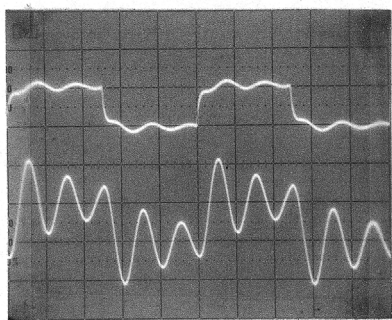


PHOTO 4: 10kHz square-wave response with $1\mu\text{F}$ load, 18dB plate FB.

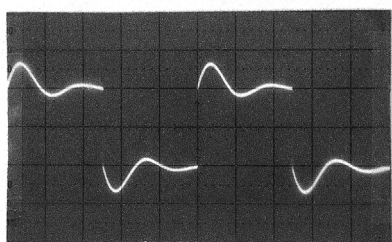


PHOTO 5a: 250Hz square-wave response at output. Load = 5Ω series with paralleled 0.93mH , $47\mu\text{F}$, no FB.

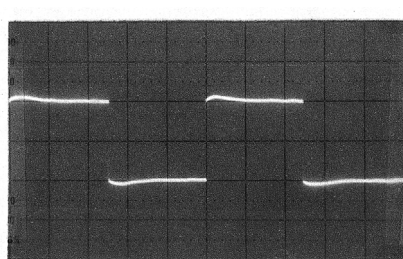


PHOTO 5b: Same except with 18dB plate FB.

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Making Your Own Rubber Surrounds

Extend the life of your speakers with this DIY approach to replacing the surrounds. **By Angel Luis Rivera**

Necessity is the mother of invention, and when the surrounds of my ten precious little 5¼" Peerless polypropylene mid-woofers and my treasured 18" JBL woofer bit the dust, I knew I needed to come up with a solution. I did not want to re-surround with foam surrounds, because the foam would eventually deteriorate again and I'd be back to square one. Not only that, but at \$10–\$25 a pop for each mid-woofer foam surround (either doing the work of replacing the surrounds myself or paying someone to re-foam them for me) plus \$150–\$200 for repairing the 18" (JBL replaces not only the surround but also the cone), the cost was prohibitive.

After much thought, I finally decided to fashion my own molds/forms and make surrounds out of synthetic rubber. But what to make the molds/forms out of? I reasoned that wood was the easiest and the most available material to work with.

NOVEL SOLUTION

Thanks once again to my wonderful woodworking neighbor and friend, Dave Currier, we came up with a novel solution for making the molds/forms. I bought several small boards/sections of hardwood—I believe it was maple, but it might have been oak. It makes no nevermind—the point is to use some form of wood that is not too soft, or susceptible to warping, such as pine or

ABOUT THE AUTHOR

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poplar nor flake like particleboard. I wanted the mold/form surfaces to be nice and smooth.

In much the same way that I imagine a kitchen cutting board is made, we joined the small boards together with a special woodworking clamp, end to end/side to side, gluing them together to form an overall larger composite board, made of hardwood and planed smooth. We then made a second composite board.

Since I had established that I would be making surrounds as large as 18" and 15", we found the center point of each composite board and cut the hardwood boards into two large circular boards—one to accommodate up to 18" size surrounds and the other to accommodate up to 15". We used a band saw, but you could just as easily select a handheld jigsaw or round-saw.

The reason for cutting each composite board into a circular shape was for ease of rotation. When we progressed to working with the router on the router table and to cut the actual mold/form impressions, we preferred to turn the boards with adequate clearance and not worry about corners.

Now, there is no reason why someone experienced with the use of a router could not accomplish the following without need for a router table—much the same way that woofer holes are cut into baffles with a router so that the woofer sits flush with the baffle. All you need is to find the center of the board and a jig, such as a Jasper Audio circle jig, to make perfect circles once you have the appropriate measurements. You could use the same bits described later, and the same choice of



PHOTO 1: 18-12-8" forms/molds.

depth of cuts could apply. However, we thought that we had better control by using a router mounted on a router-table and rotating/spinning the composite circular board, as opposed to moving the router with our hands "free-style" on a stationary composite circular board.

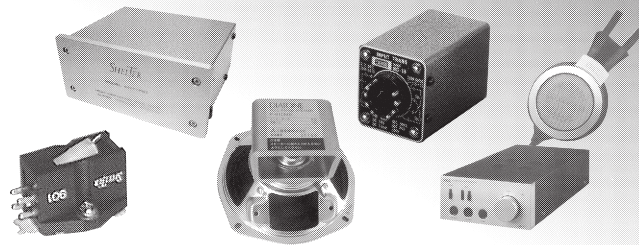
CUTTING OPERATION

Using a table-mounted router, we mounted the router upside down with the cutting blade facing up and drove a nail into a piece of flat scrap board to fit into the center point of each composite circular board. We positioned the board with the nail and clamped it onto the router table so that when the composite circular board was centered on it, it would rotate over the pertinent router blade in a perfect circle. We adjusted the router blade for depth of cut and in this way were able to cut out the "female" mold/form impressions ("humped," curved, "half-round," concave [or convex, depending on from which direction you're looking at the surround]) for the middle portion of a woofer surround. By continuing in this manner, we made alternating concentric circles and made molds/forms for 18", 12", and 8" surrounds on one composite circular board and molds/forms for 15" and 10" surrounds on the other board (*Photos 1 and 2*).

Besides the two large boards, I also made individual surround molds/forms from small pieces of scrap hardwood

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Denon DL-103 (STEREO)	200	Area II \$ 22	Singapore Malaysia Indonesia
Denon DL-103R (STEREO)	250	Area III \$ 27	North America Oceania Europe
Denon DL-103 PRO (STEREO)	350	Area IV \$ 34	Africa South America
Shelter Model 501 II (CROWN JEWEL REFERENCE)	750	These Area I ~ IV are for all products except book.	
Shelter Model 901 (CROWN JEWEL SE)	1,400		

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The Joy of Vintage Tube Amps 1&2 (Tadaatsu Atarashi)	30 each NEW
Direct & Indirect Tube Amps (Kiyokazu Matsunami)	40 NEW
SE Amps by Transmitting Tubes (Kouichi Shishido)	50
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Shelter Model 411	3~15	47	20Hz~50kHz	980	Area I \$ 25 Area II \$ 30 Area III \$ 40 Area IV \$ 50
Jensen JE-34K-DX	3	47	20Hz~20kHz	550	
Peerless 4722	38	50	20Hz~20kHz	300	

■STAX

Model	Price(US\$)
OMEGA II System(SR-007+SRM-007t)	Ask
SRS-5050 System W MK II	
SRS-4040 Signature System II	
SRS-3030 Classic System II	
SRS-2020 Basic System II	
SR-001 MK2(S-001 MK II +SRM-001)	

■Speaker

** Air Economy

Model	Specifications					Price* (US\$)	Postage** (US\$)			
	D (cm)	Ω	Response	db	w		I	II	III	IV
Fostex FE208 Σ	20	8	45Hz~20kHz	96.5	100	296	62	74	120	156
Fostex FE168 Σ	16	8	60Hz~20kHz	94	80	236	42	50	73	98

* Price is for a pair ** Air Economy

■TANGO TRANS (ISO) (40models are available now)

Model	Specifications				Price (US\$)	Postage** (US\$)			
	W	Pri.Imp(kΩ)	Freq Response	Application		I	II	III	IV
XE-20S (SE OPT)	20	2.5, 3.5, 5	20Hz~90kHz	300B,50,2A3	396	47	56	84	113
U-808 (SE OPT)	25	2, 2.5, 3.5, 5	20Hz~65kHz	6L6,50,2A3	242	42	50	73	98
XE-60-5 (PP OPT)	60	5	4Hz~80kHz	300B,KT-88,EL34	620	62	74	115	156
FX-40-5 (PP OPT)	40	5	4Hz~80kHz	2A3,EL34,6L6	320	47	56	84	113
FC-30-3.5S (SE OPT) [XE-60-3.5S]	30	3.5	20Hz~100kHz	300B,50,PX-25	620	62	74	115	156
FC-30-10S (SE OPT) [XE-60-10SNF]	30	10	30Hz~50kHz	211,845	620	62	74	115	156
X-10SF [X-10S]	40	10W/SG Tap	20Hz~55kHz	211,845	1160	90	110	180	251
NC-14 (Interstage)	—	[1+1 : 1+1] 5	25Hz~40kHz	[30mA] 6V6 (T)	264	30	40	50	70
NC-16 (Interstage)	—	[1+1 : 2+2] 7	25Hz~20kHz	[15mA] 6SN7	264	30	40	50	70
NC-20F (NC-20) (Interstage)	—	[1 : 1] 5	18Hz~80kHz	[30mA] 6V6 (T)	640	42	50	73	98
NP-126 (Pre Out)	—	20,10	20Hz~30kHz	[10mA] 6SN7	264	30	40	50	70

Price is for a Pair

■TAMURA TRANS (All models are available)

** Air Economy

F-7002 (Permalloy)	10	3.5	15Hz~50kHz	300B,50	836	60	70	110	145
F-7003 (Permalloy)	10	5	15Hz~50kHz	300B,50	836	60	70	110	145
F-2013	40	10	20Hz~50kHz	211,242	786	70	84	133	181
F-5002 (Amorphous)	8	3	10Hz~100kHz	300B,2A3	1276	65	80	120	160

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for 5¼", 6½", and even 7¾" surrounds (Photo 3). Down the road, I will be making 13–14" surrounds to restore a pair of Avid (not Advent) speakers.

We used a carbide core box router bit for the "half-round" section of the surround. Different router bit sizes are available from outlets such as Sears, Home Depot, Lowe's, ACE Tru-Value Hardware, and whatever local Scotty's hardware stores are still in business. The Sears catalog lists them in ⅜", ½", and ¾" sizes, ranging in price from \$20.99–\$25.99. See also PriceCutter.com (PO Box 1100, Chardon, OH 44024, www.PriceCutter.com). Naturally, you can use the larger sizes for larger-diameter surrounds, and smaller sizes for smaller diameter surrounds but what really dictates the size router bit you use is—listen up, now, this is very important—the distance between the woofer basket edge and the woofer cone edge. You can also control how much depth of cut (which translates to height in the finished surround) you want to give the mold/form and in this way determine how much excursion capability you wish to allot to the surround (Photo 4).

I don't recall whether we used a straight or rabbet router bit for cutting the impressions of the surround sides that would attach to the woofer basket frame on one side and to the woofer cone edge on the other. The straight bits range from ⅛" to ¾" in HSS, industrial, and carbide types; prices range from \$3.99–\$22.99. The rabbet router

bits come in two sizes, ⅜" and ½", both are industrial types and range in price from \$29.99–\$34.99. See Table 1 for speaker surround dimensions and widths (in inches) for each surround size, outer edge, middle (core box), and inner edge.

For each circular path, bear in mind that depth of cut of the surround molds will greatly impact how thick and heavy the final surrounds will be at those points. You really don't want to make the surrounds any thicker or heavier than necessary; don't put any more weight on the speaker cone edges than is necessary, because this will affect your woofer's efficiency. Just think of how thin foam and rubber surrounds are on stock woofers and use that as a guide.

Depth of cut of the surround outer and inner edges is about ⅛". Depth of cut of the middle portion (core box) will really depend on how much excursion you want your woofer to have. For larger woofer surrounds, about ¼"–⅝" depth; for smaller woofer surrounds, ⅜"–⅝" depth. Of course, you are free to make the core box cuts deeper or shallower, if you so desire (Photo 5).

SURROUND SYNTHESIS

Once you have made the wooden molds/forms—before applying any of the materials I'll soon mention—you must spread some form of "mold release" on the wood forms. Car wax is quite popular, effective, and widely available.

I've experimented with silicone (Photo 6), silicone rubber (Photo 7), DAP Alex Plus® (Photo 8), acrylic latex caulk (Photo 9), and liquid latex rubber (Photo 10). Liquid Nails® brand also makes a substance that they claim is superior to silicone, but I haven't experimented with it yet. Take care and precautions when working with/being exposed to chemicals and the like, and these are no exceptions. Adequate ventilation, wearing a mask, and avoiding contact with these materials is a must, particularly with latex, to which you can develop an allergy.

Due to its short shelf life, liquid latex was not profitable in small quantities from the fiberglass and mold outlet where I purchased my original supply, and so it is no longer available in small quart sizes. You must order 25 gallons of it at a time, for \$650 (\$26 per gallon). Under those conditions, it is not practical for the individual amateur, although a group purchase might make it affordable.

In any event, liquid latex requires repeated application of thin layers, allowing it to dry/cure adequately for a day between layers; otherwise, it will literally never dry and will come apart when you attempt to remove it from the mold/form. However, if made too thin, the latex surround will be fragile and have limited life. It may even tear when you remove it from the mold/form. Patiently applying a thin layer each day for two or three days in a row yields one very rubbery and durable latex sur-

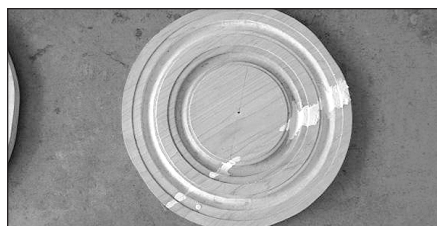


PHOTO 2: 15-10" forms/molds.

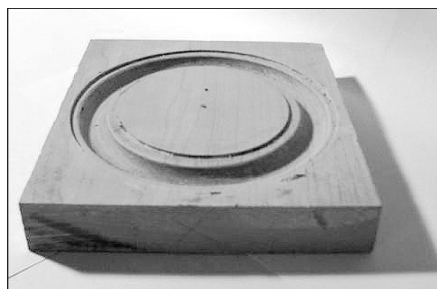


PHOTO 3: Small wood surround form.

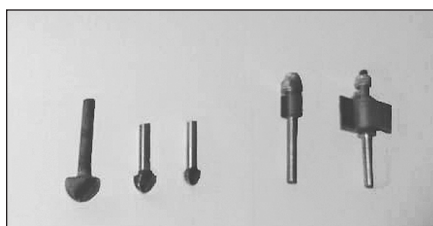


PHOTO 4: Router bits used.

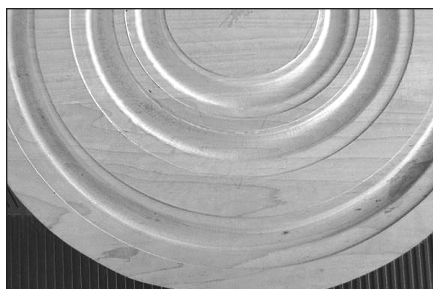


PHOTO 5: Close-up of depth of cuts.

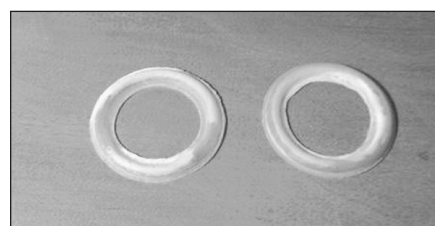


PHOTO 6: Silicone surrounds.



PHOTO 7: AR midrange silicone surround.

round. Practice and experience will teach you how to control the surround's eventual thickness and heaviness.

I dispensed the latex onto, and applied it by using, a tablespoon, slowly spooning it onto the edges of the wooden form. I then tilted the board back and forth to ensure as even a spreading of the latex as possible. I imagine you could also use a medical injection or bulb syringe as an alternative for applying the latex.

Removing the surround from the wooden mold/form on the second or third day requires some care not to unduly stretch and distort the surround. You can simply cut any rough inner or outer edges with scissors.

ADHESION

For those of you unfamiliar or inexperienced with the replacement of woofer surrounds, see my article "Replacing Woofer Surrounds" in the 2/95 issue of *Speaker Builder*. In this article I recommended Elmer's® household cement

(over Duro® household cement), but I now believe that DAP Weldwood® contact cement is far superior and far easier to work with than either of the other two.

The best part is that DAP Weldwood contact cement adheres very well to the latex surround and the woofer basket edge and woofer cone edge. The proper way to use this cement is to apply a layer to each surface to be glued and allow both to dry for about five minutes, long enough to lose its "wetness" and become tacky to the touch. When you press the two surfaces together, it makes for a strong long-lasting bond

that holds the surround firmly in place despite a woofer's repeated and very powerful back and forth excursions.

Use this same technique for gluing formica to wood for making countertops; or even finishing speaker enclosures with formica, for that matter. (As an aside, use this same approach with wood glue when using it to bond wood surfaces together—let each surface dry to a tacky feel before joining them).

After many years, latex will eventually dry out and crack just like an old rubber band, losing its rubbery elasticity, so after installing the surround and let-

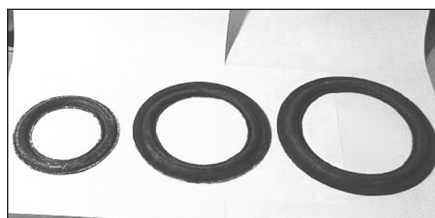


PHOTO 8: Alex Plus surrounds.



PHOTO 9: Acrylic solid surround mold.



PHOTO 10: Latex surround.

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ting the contact cement dry adequately, I coat both sides of the surround—front and back—with a layer of silicone or silicone rubber. Not only does this seal the latex, imparting to it silicone's 35-year life and keeping it rubbery and flexible, but it should prevent microscopic molecules or particles of latex from becoming airborne as the woofer excurses back and forth, and not contribute to any possibility of airborne exposure to latex and possibly developing latex allergy.

OTHER MOLD ALTERNATIVES

You can use other rubbery materials for molds that, unlike latex, require an abundant application of extreme thickness in order to dry and cure properly. That is counter-intuitive to surround characteristics—flexible and strong but thin and light. Those materials are more expensive as well, and since you must use a greater quantity for adequate curing, I have no intention of experimenting with those substances and have no experience with them to report.

One aspect of the liquid latex that I liked very much was its "pourability," if I may coin a phrase (hence my interest in POR-A-MOLD®, discussed later). This obviates the need for a "male" mold/form to "force" the shape of the surround.

Not so with silicone or silicone rubber, which is thick, viscous, and difficult to spread with any degree of consistency. Application of silicone or silicone rubber caulk requires use of a caulking gun. By cutting a small hole in the silicone/silicone rubber tip, you can control how much is dispensed into the mold/form. Another approach is to dispense the silicone/silicone rubber into a medical syringe and apply it onto the mold/form.

Working with the thick, viscous silicone and silicone rubber required my forging "male" molds/forms from Table Top epoxy. Both the Table Top epoxy resin and hardener are in liquid form, and when mixed in equal portions, it dries to a beautiful, clear, solid block of plastic (Photo 11).

A "male" mold/form actually needs only the middle portion of the surround shape in order to force the surround shape. The middle, "half-round" section of the "male" mold/form should not be

as deep as the "female" mold/form, to allow a uniform thickness to the resulting surround. The surround sides for the driver cone edge and driver basket edge that are cut into the "female" mold/form on the front of the hardwood board need not be duplicated on the "male" mold/form, as the "male" mold/form will force the shape of these sides when inserted into the "female" mold/form.

An expedient and practical approach toward making "male" mold/forms is to cut another "female" middle/"half-round" section only on the back side of the hardwood board once you're done cutting the front side. You must avoid cutting so deeply on each side that you end up cutting through the hardwood; so be sure to accurately measure depth of cuts. Of course, you can make "male" mold/forms on separate boards altogether.

For making "male" molds/forms, I even used—are you ready for this?—wood glue, which can harden quite nicely. But I reinforced them with Table Top Epoxy anyway (Photo 12).

I also experimented with Elmer's® wood filler but did not get good results. Mea culpa, because I poured too great a quantity of wood filler at a time and I don't think it dried completely internally. When it came time to release/remove the wood filler cast from its mold, it crumbled and came apart, despite being reinforced by a thick layer of

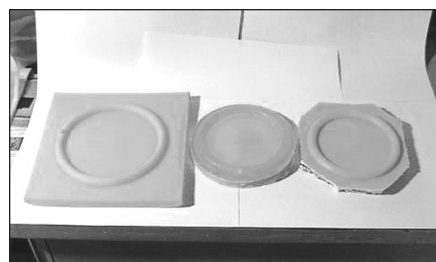


PHOTO 11: Table Top Epoxy—wood glue male holds.



PHOTO 12: Table Top Epoxy-wood glue molds.

Table Top Epoxy. I will likely try again, but next time build up the wood filler a little at a time and give each layer adequate time to dry.

The Table Top Epoxy "male" molds/forms worked well with forcing silicone rubber into the desired mold shape; I made a silicone rubber surround for the midrange driver of a three-way Acoustic Research speaker I gave to my son (Photo 7). I also made 5¼" surrounds out of pure silicone caulk (Photo 6). Silicone rubber caulk is cheaper than pure silicone caulk by a few dollars and so may be more economically practical. You can experiment to see which of the two you prefer to work with and which gives better results.

SILICONE AND ALTERNATIVES

Many years back (*Speaker Builder* 5/91, to be exact), I wrote to the Letters section asking for help: Is there any kind of solvent that silicone can be mixed with so that the silicone can be "liquid" and "pourable?" I received three

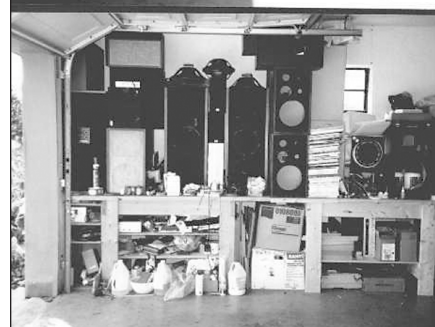
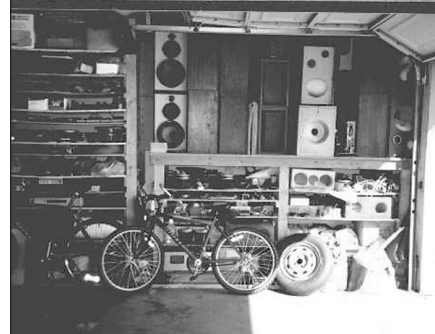


PHOTO 13: A garage full of speakers (and little room for the car).

responses—one from David Meraner, who recommended lacquer thinner; another response from Roy Mallory, who suggested VM&P Naptha; and Greg Szekeres, who suggested isopropyl alcohol for acetic-acid-based silicone. I would greatly appreciate any further suggestions from the *audioXpress* readership regarding any knowledge of silicone solvents.

A nice feature of silicone and silicone rubber is their availability in a multitude of colors: clear, bronze, brown, black, and—as in my son's midrange speaker—white. There is one caveat however: Only one thing that I

know sticks to silicone—and that's silicone! DAP Weldwood contact cement will not help in this case, as it does not adhere to silicone and peels right off the silicone surround. You must thus use silicone or silicone rubber itself to glue either type of silicone surround in order for it to adhere to the woofer cone and basket.

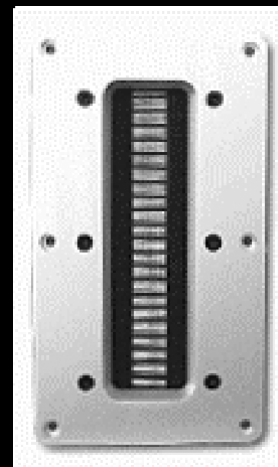
Alternatives to silicone caulk are acrylic caulk and DAP Alex Plus®, which are both water soluble and dissolve easily in water, allowing each to be mixed and poured into any mold, effortlessly taking on the cast/pattern of what it is poured into.

TABLE 1
SURROUND DIMENSIONS AND CUT WIDTHS (IN INCHES)

SURROUND	SIZE OUTER	EDGE MIDDLE (CORE BOX)	INNER EDGE
5¼	¾-¾	½	¾-¾
6½	¾-¾	½	¾-¾
7¾	¾-¾	½	¾-¾
8	¾-¾	10/16-2/16	¾-¾
10	½	¾	¼
12	¾-10/16	¾	¼
15	¾-12/16	¾	¾-5/16
18	¾-2/16	¾	¾-5/16

Cut Width measurements of the outer edges, are not written in stone, because your particular woofer(s) may have different size woofer basket edges and require different width cuts.

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I made a solid "male" mold of acrylic caulk (*Photo 9*). It feels oddly like a combination of cloth and plastic, with a little rubberiness to it. It adheres well with DAP Weldwood contact cement and so is promising. I will be experimenting with this shortly to see whether it is good material for speaker surrounds. After all, for years, cloth surrounds coated with latex or some other rubbery sealant were used on many commercial drivers.

DAP Alex Plus is similar in feel to the acrylic caulk, but it has just enough silicone to prevent adhesion to DAP Weldwood contact cement and is also stiffer and somewhat more fragile as a surround.

My next step will be to make solid "male" molds/forms out of silicone and silicone rubber, as well as DAP Alex Plus®. The goal will be to use these "male" molds/forms to cast more "female" molds/forms made of Table Top Epoxy. I will then make "female" molds/forms out of silicone, silicone rubber, and DAP Alex Plus—that, in turn, will allow me to make other "male" molds/forms out of Table Top

Epoxy. The advantage to using these siliconized materials is that they'll probably release more easily from each "gender" of the wood molds/forms.

Another reason for replacing the wood molds/forms with siliconized materials is that even with adequate mold release/car wax applied to the wood molds/forms, the Table Top Epoxy has a tendency to adhere very tenaciously to the wood molds/forms, at times taking small chunks of wood with it at the time of release. The Table Top Epoxy should release more easily from the silicone, silicone rubber, and DAP Alex Plus molds/forms than from the wood molds/forms.



PHOTO 14: 18" woofer.

Glancing at the pictures of my garage (*Photo 13a, b, and c*), you can see that I am a speaker enthusiast; to say that I have an overabundance of speakers to repair is an understatement. By having multiple molds/forms available, my output of surrounds will increase so that I can make many surrounds simultaneously (instead of cranking out only one at a time) and should speed up completion of all my pending speaker projects.

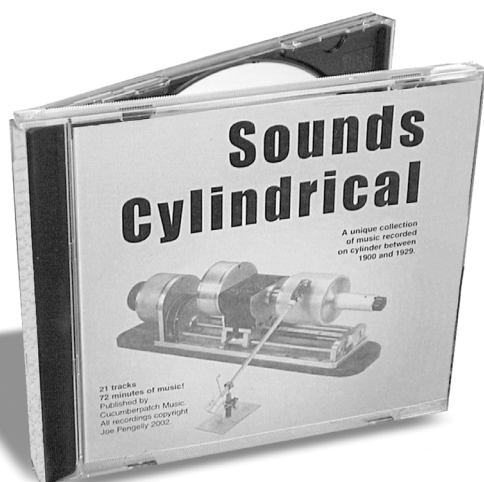
There is another promising product, which I referred to earlier, from a Chattanooga-based company called synair, which makes the POR-A-MOLD line of elastomeric compounds. Their standard POR-A-MOLD comprises three



PHOTO 15: Peerless driver.

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mold types: S111, S333, and S555; softest, medium hardness, and most rigid, respectively. They also have their own brand of mold release called SynLube. Go to their website at <http://www.synair.com> to find out more about their products, prices, and a list of dealers in your area. Click on "Mold Making and Casting" to find out more about POR-A-MOLD.

The fiberglass and mold outlet in my area charges \$23.69 per kit (1 quart each of the resin and hardener, to be mixed in one-to-one ratio) for S111, S333, S555. In gallon size, kit prices are \$71.08, \$77.54, and \$71.08, respectively. For what it's worth, colors are tan, blue, and pink, respectively. Work

life is 20 minutes.

I have not had any experience with POR-A-MOLD yet, including what type adhesive will work with surrounds made from it, although the salesman at my local outlet thinks it will adhere well with contact cement. It is inevitable that I will try it out and I will report on my results when I do so. At essentially \$12 per quart, it is not prohibitively expensive and will more than pay for itself if you fashion many surrounds from it; certainly it is far cheaper than paying for just one pair of foam surrounds.

CONCLUSION

I have already repaired a number of

woofers for friends, my son, as well as myself, granting new and extended life to speaker systems that would otherwise have been destined for foam replacement surrounds. All the owners of these resuscitated speaker systems are quite happy with the sound quality and how the surrounds are holding up.

Pictured are my 18" JBL woofer, a pair of 15" woofers, the ten 5 1/4" Peerless midwoofers (Photos 14, 15, and 16), and dual 10" woofers on an ESS speaker from the 1970s (Photo 17). As you can see, the process worked quite well for my purposes. These surrounds should last through my lifetime and beyond.

CREDITS

Many thanks my friend, Dave Currier, for his invaluable help in the making of the wooden molds for this project. Also to my son, Arjuna Rivera, for the digital photos, and to my daughter-in-law, Kristan Rivera, for image editing of the photos of router bits. ♦

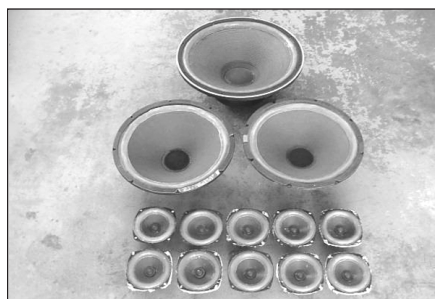


PHOTO 16: Repaired woofers.

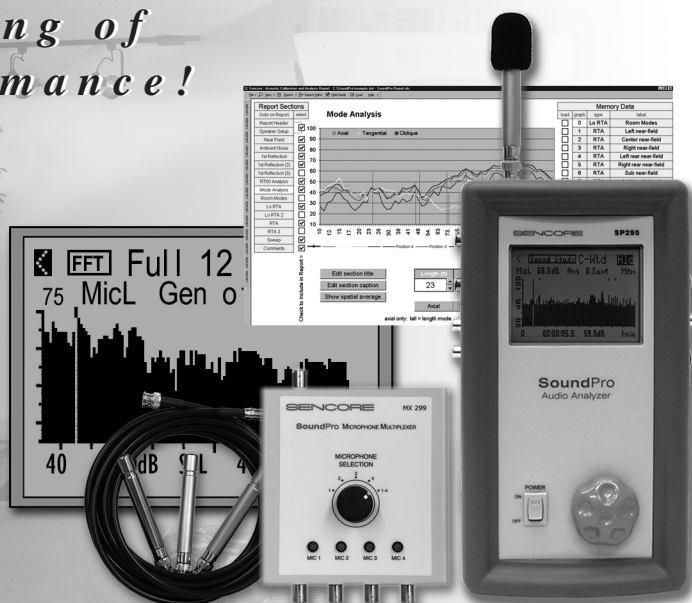


PHOTO 17: ESS speaker.

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Why Speakers Have Slanted Fronts, Part 1

Is it just for appearance, or do slanted speaker fronts serve a purpose?

This four-part article provides the answer. **By G. R. Koonce**

I'm sure readers have noted many speaker articles and commercial speakers show floor-standing enclosures with the front panel tipped back from vertical. Other enclosures provide a similar effect by using a stepped front panel with the drivers at various distances from the box front. Some reasons why you might tip back the front panel are:

1. The challenge of construction with a tipped front panel.
2. To time-adjust the outputs of the various drivers.
3. Enclosures look better with the tipped-back front panel.
4. To break up standing waves that might occur between the front panel and the back of the cabinet.

I believe there is some validity to all these reasons. Tipping the front panel will help in the time coherence of a two-way system, but generally with a three-way or more system a stepped front panel would be required. Having non-parallel opposing walls is also helpful.

I'm sure appearance of the finished enclosure enters into many commercial designs. However, there is a more fundamental reason why so many enclosures have a tipped front panel. This article shows why this occurs and offers some help in designing such enclosures.

All speaker systems have a response that varies somewhat with listening angle relative to the front panel. For multi-way systems using the conventional alignment of drivers, in a near-vertical array, the system response will vary more with vertical angle than with horizontal angle. It has been demon-

strated that for a listener perception of a flat frequency response the system direct (first arrival) sound should have a flat frequency response. It is thus important that the listener be on a vertical angle that offers a nearly flat frequency response.

For good imaging it has been demonstrated that the speaker's response should degrade smoothly with changing horizontal angle. This is why the vertical array of drivers is so common. The discussion in this article is limited to speaker systems that have all the drivers mounted on the enclosure front panel.

Many people believe that placing the tweeter at ear height is always optimum, but this is not correct. You will see why this occurs with real-world drivers and crossovers. This work shows how I establish the optimum listener angle for a speaker system design and how you can relate this to the position of a seated listener. This involves the proper front panel tip angle for floor-standing boxes or the proper stand height for stand-mounted boxes.

Finally, I will show some of the approaches I have used to simplify construction of boxes with tipped front panels. I hate the complication of building with the front panel tipped, but to date have found no other way to build a good-sounding floor-standing box.

THE DREADED POLAR PLOT

The polar plot is a rather simple one. For a given frequency it plots the system acoustic re-

sponse at various angles relative to a reference line within a plane. Simple or not, I find that the polar plot can be deceptive. If you fail to look at a plot for some critical frequency, you may get a distorted view of what the system is doing. This happens because you lack advanced knowledge of all the frequencies that may be critical.

I believe a better plot format exists for establishing the system's off-axis performance and will discuss it shortly. However, the polar plot is ideal for showing some of the real-world effects on speaker design. I'm sure most readers have seen polar plots in articles on crossover design. Generally such plots assume "ideal" drivers.

THE IDEAL DRIVER

The ideal driver does not really exist. If it did there would be no reason for anyone to design crossovers. This theoretic-

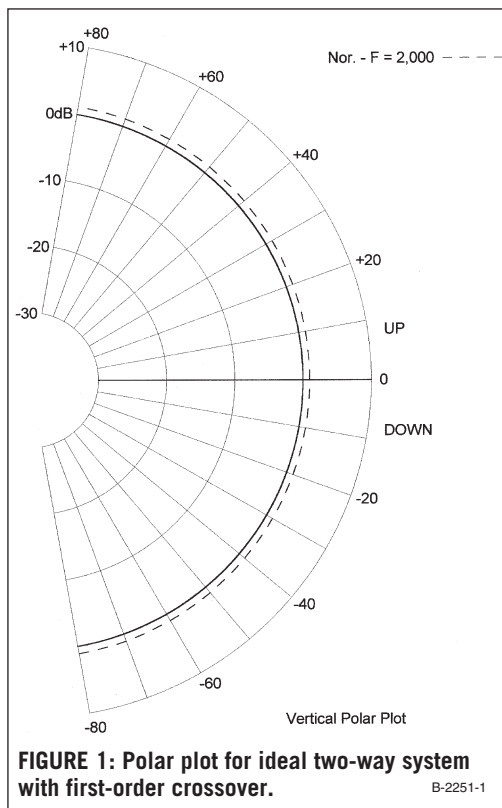


FIGURE 1: Polar plot for ideal two-way system with first-order crossover.

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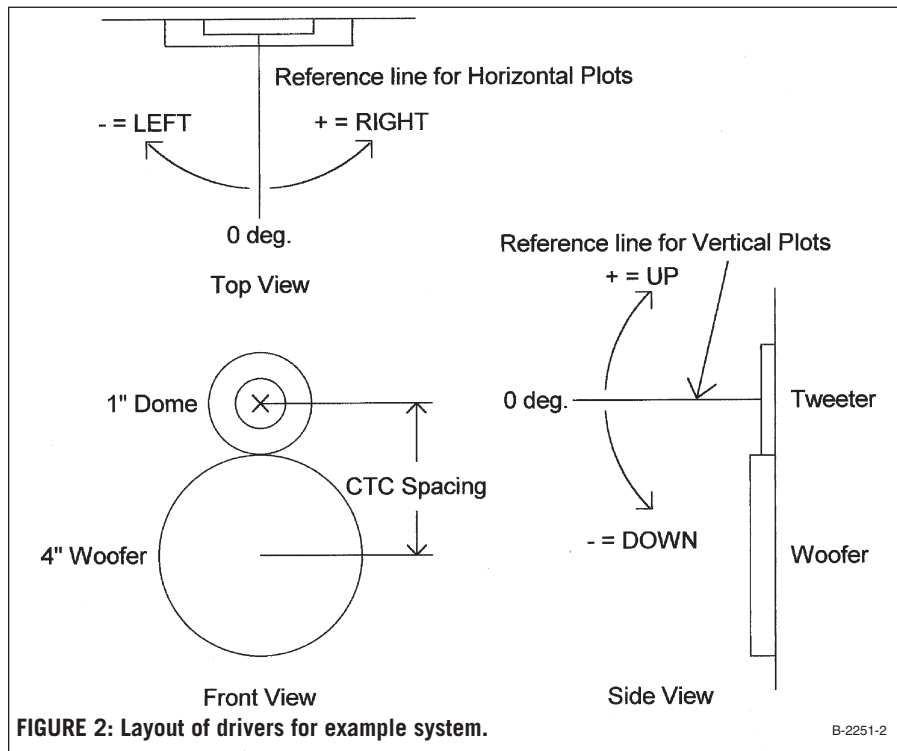
cal driver has a flat frequency response and constant input resistance over the audio band (20–20kHz). The ideal driver radiates equally in all directions; i.e., it is an omnidirectional “point source.” It

has no internal time delay and thus zero phase shift at all frequencies. The acoustic output radiates from the plane where the ideal driver mounts on the front panel. It

REAL DRIVERS

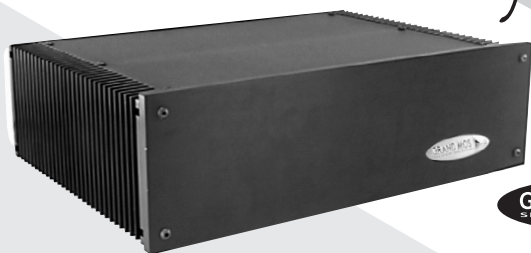
Here are some of the ways that real drivers differ from the ideal driver defined previously:

1. Frequency response—no driver has a flat frequency response over the entire audio band. Woofers are usable over the lower portion of the audio band and tweeters over the upper portion. Drivers defined as a midrange normally have a bandpass response making them useful over the middle portion of the band but unacceptable as a woofer or a tweeter. A recently developed class of small “full range” drivers has a response usable from about 100–20kHz for use in one-way system satellite speakers.
2. Phase shift—real drivers have a phase shift that varies with frequency.
3. Input impedance—real drivers have an input impedance that varies in both magnitude and phase angle over their useful frequency range. These variations will interact with a passive crossover (CO) to produce response changes. The active CO will avoid this particular problem.



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4. Directivity—real drivers do not radiate equally in all directions over their full useful frequency range. At the lower end of their range the driver may be nearly omnidirectional, but at the upper end the response will fall as you move off the driver's axis.
5. Acoustic center—real drivers do not have their source of acoustic radiation located at the point where they mount to the front panel. The source of the acoustic radiation is generally behind the mounting point—the larger the driver, usually the farther behind the mounting plane. This causes differences in the time it takes for the radiated sound from various drivers to reach the listener. In the steady-state case these represent a phase difference, and in the transient case a time delay difference.

The topic of the driver acoustic center is complex and beyond the scope of this article. For information on the driver acoustic center and ways to measure or compensate for it, see references 1–10. The point to remember is that any CO designed ignoring the relative locations of the driver acoustic centers will not perform as you expect.

DEVELOPING REAL SYSTEMS

When developing a real speaker system, you must take into account all of the mentioned limitations of real drivers. Ignoring any of them may result in a system response other than what you wanted. In addition, unless you are using a manufactured coaxial driver, you will need to space the drivers out on your front panel to avoid physical interference. The geometry of the driver placement will have a major influence on the system performance.

EXAMINATION VIA POLAR PLOTS

I will use polar plots to demonstrate some of the most common crossover functions when used with ideal drivers spaced about the front panel. Then, you can see what happens when you take a couple of CO types and factor in the characteristics of real drivers. The example system is a two-way, with a CO frequency of 2kHz and a small woofer to limit spacing between drivers. While these parameters may not fit practical systems, they keep the polar plots simple enough to be easily understood.

The polar plot for a system using a real CO with ideal drivers having their acoustic radiation centers located at

the same point in space is a circle. The dB value of this circle is that of the on-axis response of the CO at the frequency used for the polar plot. *Figure 1* shows such a plot for a first-order Butterworth (B1) CO with the ideal drivers.

The gain of each driver in *Fig. 1* has been increased 1dB to raise the dashed system response plot above the 0dB circle for clarity. For this system the response is a circle (at +1dB) for both the vertical and horizontal planes. Also, the response stays a circle for the tweeter (top driver) wired with either the same polarity as the woofer (normal) or with reversed polarity (inverted).

The plot covers only $\pm 80^\circ$ of arc relative to a line perpendicular to the driver-mounting plane (front panel). This article concerns only effects over this restricted range of angles. You will see that with real systems it is difficult to get a "good" polar response in both the horizontal and vertical planes over even a portion of this restricted angle range.

Clearly, a speaker system has numerous planes about which you can generate the polar plot. Normally, you study plots only in the vertical and horizontal planes. For the more common placements of drivers, the response in planes

at angles between horizontal and vertical will be somewhere between responses in these two plots.

As soon as the two drivers do not have their acoustic centers located at the same point, things become more interesting. The transit time from each driver to the point of interest is no longer the same. This introduces additional phase shift, and the polar plot is no longer a circle.

Consider the example two-way system as using a 1" dome tweeter that has a small faceplate of 2" diameter and a woofer 4" in diameter. The drivers are mounted with the tweeter above the woofer at the minimum possible 3" vertical center-to-center (CTC) spacing between the drivers (*Fig. 2*). Note that the 0° reference for all these polar plots is a line perpendicular to the front panel and through the center of the top driver, the tweeter.

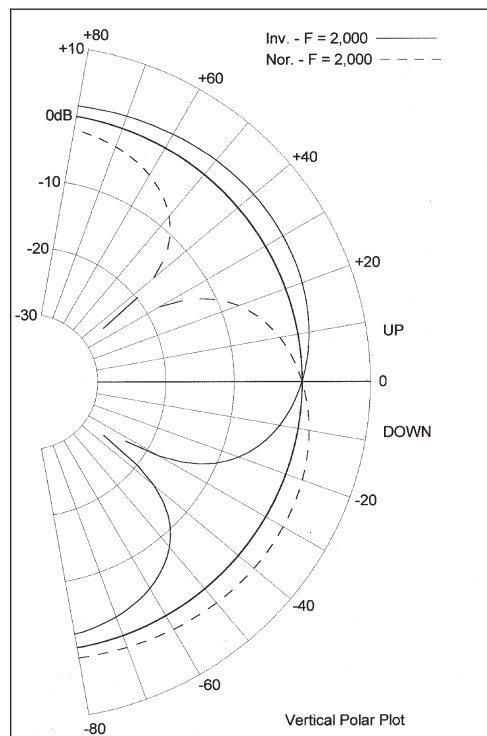


FIGURE 3: Ideal first-order Butterworth CO—solid curve is inverted tweeter polarity; dashed curve is normal tweeter polarity.

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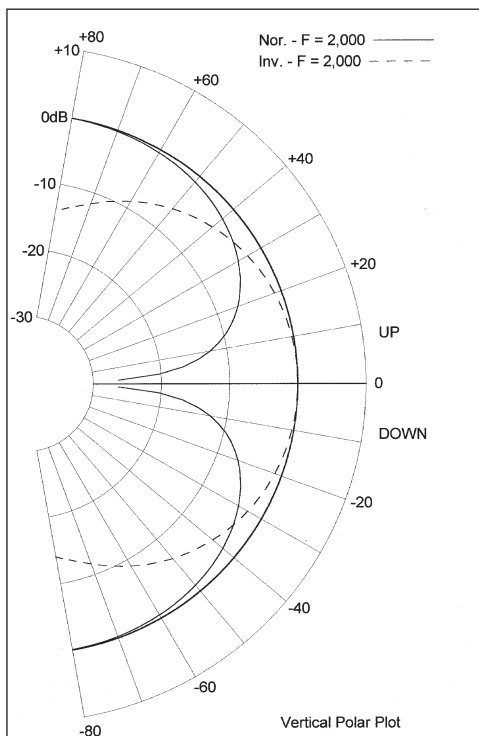


FIGURE 4: Ideal second-order Linkwitz-Riley CO—solid curve is normal tweeter polarity; dashed curve is inverted tweeter polarity.

B-2251-4

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POLAR PLOTS FOR IDEAL SYSTEMS

Figures 3 and 4 show the vertical polar plots for four common CO functions with this pair of spaced ideal drivers, which radiate in all directions a perfectly flat frequency response, and both have their acoustic radiation center located in the plane of the front panel. These are the plots you might see in CO design articles and thus represent taking the outputs of the high-pass (HP) and low-pass (LP) crossover networks and vector summing them while correcting for the difference in transit time between the two drivers to the point of interest. Normally the acoustic summation is taken to occur at infinity. This means both drivers radiate along a line at the angle shown in the polar plot. Note that with these ideal drivers aligned vertically, the horizontal polar plot will still be a circle.

Figure 3 is the vertical polar plot for the first-order Butterworth (B1) CO at the CO frequency. Note that the 1dB gain used on each driver in *Fig. 1* has been removed. Rather than the circle you had with no CTC spacing between the drivers, you now have a polar response that nulls at some angle. Where this null occurs depends on the tweeter wiring polarity.

While the system response is still 0dB on the tweeter's axis, the angle for maximum system response is shifted above or below the tweeter axis (0°). This shift in maximum response off the 0° axis is typical for odd-order COs. The horizontal polar plot is still a circle at 0dB.

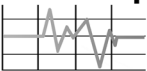
Figure 4 is the vertical polar plot for the second-order Linkwitz-Riley (LR2) CO at the CO frequency. Here the infamous null on-axis that occurs with a second-order CO with both drivers

wired with the same polarity is clearly visible. For the second-order CO, wiring the tweeter inverted polarity is clearly correct for ideal drivers.

Note that the response with inverted tweeter polarity is a wide lobe symmetrical about the 0° line, and with the LR2 CO the on-axis system response is 0dB. This symmetrical lobe is typical of even-order COs. With the inverted tweeter polarity the horizontal polar plot is still a circle at 0dB.

Next month, in Part 2, we'll continue our look at system response by examining more polar plots. ♦

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NEW RECTIFIERS

We begin Part 2 by replacing the rectifier diodes and snubbers and adding a DC common-mode choke to the raw DC supply (Fig. 2, Part 1, and *Photo 12*).

- Remove the four rectifier diodes D907–D910 (save the diodes—you'll need two of them later).
- Remove the four rectifier snubber capacitors C901–C904. These are in parallel with the rectifier diodes. In some versions of the 565 preamp these four caps were not used. Instead, there is one R/C snubber across the rectifier bridge, labeled R901 and C901. Remove R901 and C901 if your preamp has them.
- Replace D907–D910 with International Rectifier HFA08TB60 ultra-fast, soft-recovery HexFred diodes. Carefully observe polarity! Pin 1—the “h”-shaped lead—is the cathode. Put $\frac{3}{8}$ ” heat-shrink tubing on D907 and D909 (*Photo 12*). You do not need to heat the tubing—it should be a tight enough fit without heating to keep it from slipping off the diodes.
- Replace the snubbers with four series R/C snubbers (Fig. 2—47.5 Ω , 1/2W in series with 0.47 μ F, 100V). If you use the Vishay-Dale non-magnetic resistors, the Xicon capacitors listed in the parts list complement them nicely. These metallized box-type capacitors are non-inductive, and have tinned copper leads. The new capacitors and resistors are designated C901–C904 and R901–R904. The new R/C snubbers will fit the existing C901–C904 footprint if you stand the

components on end (*Photo 12*). To the best of my knowledge, all versions of the Adcom PC board have locations for C901–C904, even if this snubber arrangement was not used. Note that the series order of the resistor and capacitor in each R/C snubber does not matter.

As Fig. 2 shows, the modified power supply contains a Panasonic V-Series Line Filter common-mode choke between the rectifier bridge and the raw DC filter capacitors.

- Mount the 56mH Panasonic V-series Line Filter on a piece of Circuit Spe-

cialists Prototyping board (*Photo 9*, Part 1). The board should be 1 $\frac{1}{8}$ by 3 $\frac{3}{8}$ ”. Attach 14AWG, stranded leads as shown in *Photo 9*—these will be attached to the main PC board shortly.

- Make a pair of “L”-shaped mounting brackets out of 0.064 $\times$ $\frac{1}{2}$ ” brass stock, available from most hardware stores and hobby shops. *Photo 13* shows the dimensions of the brackets and approximate locations of the various mounting holes.
- *Photo 13* shows an extra pair of holes in the brackets, tapped for 4-40 machine screws. These are optional, and allow you to bolt the bottom plate to the bracket to secure the bracket assembly. You'll need to drill a pair of holes in the bottom plate to line up with the tapped holes in the brackets.

This is necessary only if you intend to ship the preamp. In most cases, you can leave them out. Normally, the GFP-565 preamps were shipped with aluminum bottom plates. How-

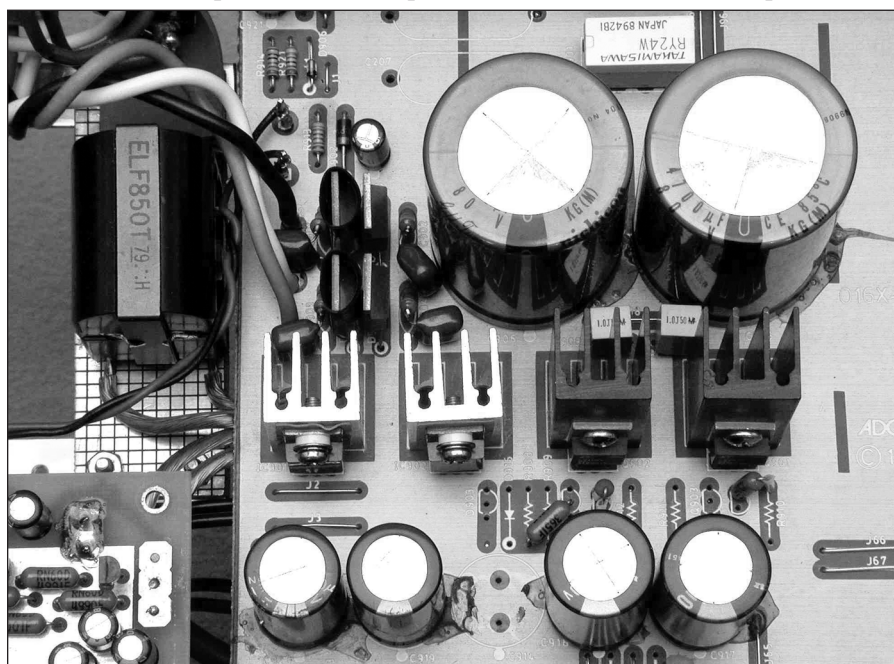


PHOTO 12: New HexFred rectifier diodes and R/C snubbers are installed in the existing Adcom footprints. This photo also shows the pre-regulators mounted on new heatsinks, along with three of the divider resistors.

ever, Victor Campos tells me that steel bottom plates were offered to customers who experienced hum problems in the phono preamp due to fact that aluminum does not provide sufficient shielding.

See Photo 10, Part 1.

- Fasten the filter-board assembly to the brackets with 4-40 hardware, and

bolt the bracket/filter assembly to the side of the chassis using the hardware and mounting holes previously used to mount the original power transformer. The "L"-shaped mounting bracket fits right into the "L"-shaped corner of the chassis. Route the leads under the main PC board.

If you space everything as shown in Photo 10, the old transformer mounting holes will line up in the

center of the mounting bracket stock. When you are finished, there should be at least $\frac{1}{8}$ " clearance between the filter choke and the main PC board.

- You must interrupt the PC traces between the + and - rectifier outputs and the C905/C906 raw-DC filter capacitors by cutting two traces on the main PC board. The locations of the cut traces are shown in *Photo 14*. Make the cuts a good $\frac{1}{4}$ " wide, and be sure that you remove all copper material.
- Solder the leads from the filter choke to the PC board as shown in *Photo 14*, trimming the leads to the required length. Here, and during the regulator installation later, you will need to scrape enough enamel off the PC trace to provide a good soldering surface. After scraping the enamel, be sure that the exposed copper is clean, and tin the surface with solder. Then, solder the lead to the prepared surface.
- Photo 10 shows an insulator made with $\frac{1}{16}$ ", rubber-gasket material between the fuse-holder and the filter-choke assembly. There should be plenty of clearance between the

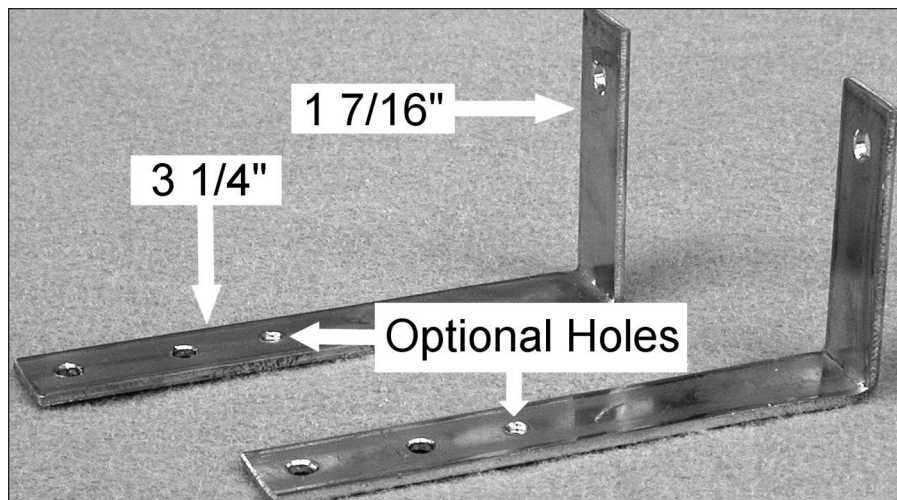


PHOTO 13: Mounting brackets for the DC common-mode choke assembly, with long and short dimensions. The brackets are fabricated from $0.064 \times \frac{1}{2}$ " brass stock.

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choke assembly and the fuse holder, but I suggest adding the insulator as a safety precaution. You can fasten the insulator to the bottom of the fuse holder with a nylon cable tie (Photo 10). The insulator should be long enough to overhang the fuse holder by about 3/4".

The muting circuit does not have symmetrical current drain from the power supply. The current drains from the raw supply rails feeding the 78M15 and 79M15 regulators (IC901 and IC902) are 21mA from the positive rail and 18mA from the negative. This is only a difference of 3mA, but the choke won't function as a true common-mode device if the currents through the two coils are mismatched. There's enough of a difference in voltage drops across the two coils in the common-mode choke to produce a raw supply difference of about 1V between the positive and negative supplies. The easy solution is to pull another 3mA of current from the raw negative supply by adding to a shunt resistor:

- Solder an 8.25k 1/2W resistor from the raw negative supply to ground. This is R905 in Fig. 2. This resistor was added after I took the photos. Solder it across C905 on the bottom of the PC board.

At this point, power up the preamp and check the raw- and regulated-supply voltages. The raw DC voltages at C905 and C906 will be around $\pm 26V$ DC, and the regulated voltages still should be at $\pm 17.5V$ DC. Put the covers on and listen to the preamp, if you like. Everything done so far should yield a noticeable sonic improvement.

NEW ELECTROLYTICS

Before removing and replacing the Adcom power-supply regulators, replace all of the power-supply electrolytic capacitors and local film bypassing that affect the audio circuitry. Adcom used Panasonic TSNH-series electrolytic caps for raw-DC filtering (C905 and C906), and Panasonic HF-series electrolytics for local bypassing (C917, C918, C121, C122, C121B, C122B, C401 and C403). Panasonic film capacitors were used for high-frequency bypassing

of most of these electrolytics.

One of the goals of this project was to eliminate steel leads on passive components wherever possible, especially post-regulator. This is not possible to do with the improved regulator due to limitations in the PC board layout, but in the post-regulator it is quite feasible. The Nichicon and Mallory caps used to replace the Panasonic originals for local-supply bypassing have copper leads. These Nichicon electrolytics have also been designed specifically for audio applications, and perform extremely well. Walt Jung and I found that higher DC voltage ratings on electrolytic power-supply capacitors are sonically beneficial, so I have used what I believe is a good balance between adequate voltage and capacitance values, without exceeding the

available physical space.

Some readers may wonder why I have not used the Black Gate caps, considered by many to be the best electrolytics available. The reason is that they are extremely expensive, and they will be a tight fit in the physical spaces available on the Adcom PC board. See Fig. 4.

- Replace C905 and C906 with 4700 μ F, 80V DC Nichicon KG-Gold electrolytic capacitors. Observe polarity!
- Replace C917, C918, C121, C122, C121B, C122B, C401, and C403 with 1000 μ F, 50V Nichicon KZ electrolytic capacitors. Observe polarity!
- Replace C119, C120, C121A, C122A, C402, C404, C907, and C908 with 1.0 μ F, 50V Mallory 168-series film capacitors.

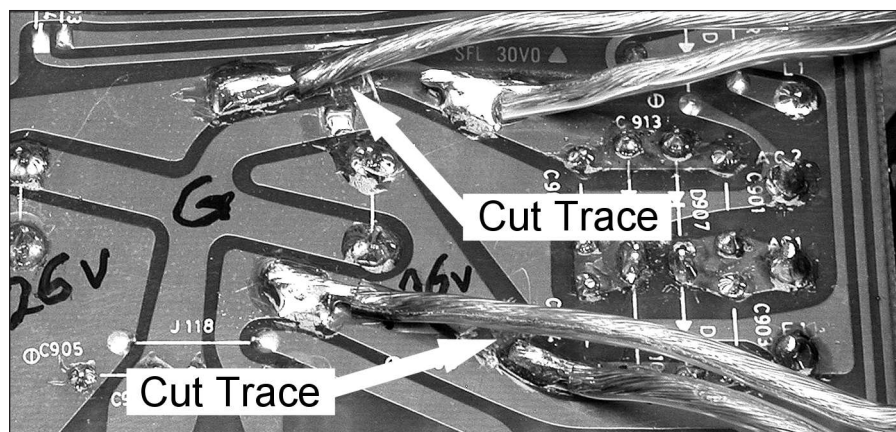


PHOTO 14: Two traces must be cut on the main PC board to insert the DC common-mode choke between the rectifiers and the raw-DC filter capacitors. The photo shows the locations of the cut traces, and the connections to the choke.

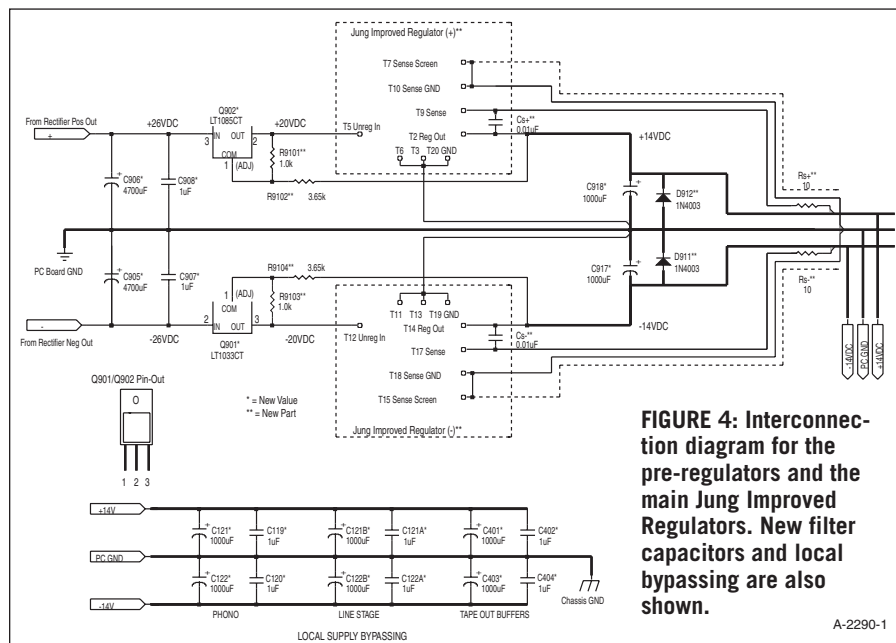


FIGURE 4: Interconnection diagram for the pre-regulators and the main Jung Improved Regulators. New filter capacitors and local bypassing are also shown.

Power up the preamp and re-check the raw and regulated supply voltages.

The Nichicon KG-Gold capacitors are the same height as the Panasonic TSNH caps, which means that they can actually touch the inside of the preamp's metal cover. Although the tops of the original Panasonic capacitors were completely insulated, I found that repeated removal and replacement of the cover

began to wear through the plastic insulation on the capacitors. The Nichicon caps have exposed metal in the center, so it is imperative that the metal cover be insulated from these capacitors.

I contact-cemented a 6" square piece of 1/16" gasket material, available at any hardware store, to the inside of the cover. Position the gasket material so that it is 1 1/2" from the rear edge of the cover, and 3/8" from the left edge. An alternative to the gasket material is the tray from a CD jewel case, with the edges cut off with a band saw. *This insulator is not an option! It is mandatory for safe and proper operation of the preamplifier!*

PRE-REGULATOR INSTALLATION

Now you're ready to remove the original Adcom power-supply regulators and install

the Jung Improved Regulators, complete with the floating pre-regulators shown in Fig. 4 of Walt's 4/00 article. Fortunately, the Adcom PC layout allows the installation of the pre-regulators in the original regulator footprint by cutting three PC traces and adding one jumper. Note that you will replace only the main positive and negative regulators. The ±15V regulators that power the muting relays—IC901 and IC902 and associated components—are retained. These regulators have no effect on the sound, so there's no need to replace them (they were also used to power the headphone amplifier, now removed).

Begin by removing all of the Adcom regulator components and cutting the traces:

- Remove Q901, Q902, Q903, and Q904. Save the four mounting screws used for the Q901 and Q902 heatsinks.
- Remove D903, D913, D914, and D915.
- Remove R908, R909, R910, R911, and R912.
- Remove C914.

See Photo 15.

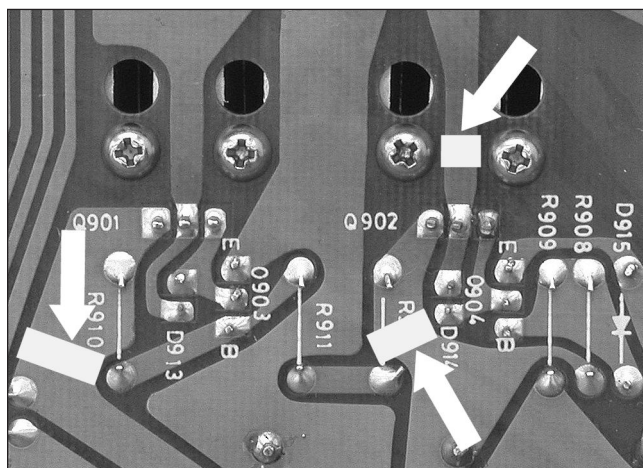


PHOTO 15: Three traces must be cut near the Q901 and Q902 footprints to facilitate installation of the pre-regulators. This photo was taken before the removal of the old Adcom regulator components.

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- Cut the three PC traces as shown in *Photo 15*. Be sure that you remove *all* copper material and that the PC board is completely clean when you are finished. (Note that *Photo 15* was taken before the removal of the Adcom supply components).

Figure 4 shows the power-supply pre-regulator and main-regulator connections. I have set the pre-regulators at $\pm 6V$, which puts the input to the main regulators (the Jung Improved Regulators) at $\pm 20V$, half-way between the raw DC voltages of $\pm 26V$ and the main-regulator outputs of $\pm 14V$. This ensures more-or-less equal heat dissipation by the pre-regulators and the pass transistors of the main regulators. With this scheme, the pre-regulators drop out of regulation with a line voltage of about 105V AC; the dropout point for the main regulators is considerably lower.

Now you can install the pre-regulator components. I originally used the 1" Adcom heatsinks for the pre-regulators, but they ran a bit warmer than I liked so I decided to replace them with 1½" Wakefield 634-15ABP types (or Aavid 581102B00000). I admit that I am being conservative here—the original Adcom heatsinks are probably adequate, but I did not wish to take any chances on long-term reliability. You can use National's LM317T and LM337T devices recommended by Walt Jung for the pre-regulators, but I prefer the Linear Technology LT1085CT and LT1033CT types for their lower dropout characteristics and higher dynamic current capability.

Linear Technology's website notes that the LT1033CT is not recommended for new designs, so they may be planning to discontinue this item. As long as it remains available from Digi-Key, I see no reason not to use it. If it does become unavailable, I suggest the LM317T/337T pair, or Linear Technology's LT1086AT/LT337AT combo. I don't recommend a "mix and match" approach to picking the + and - pre-regulators; always use a complementary pair—LM317T/337T, LT1086AT/337AT, or LT1085CT/1033CT.

See *Photo 12*.

- If the heatsinks you purchased have mounting pins, remove them. This

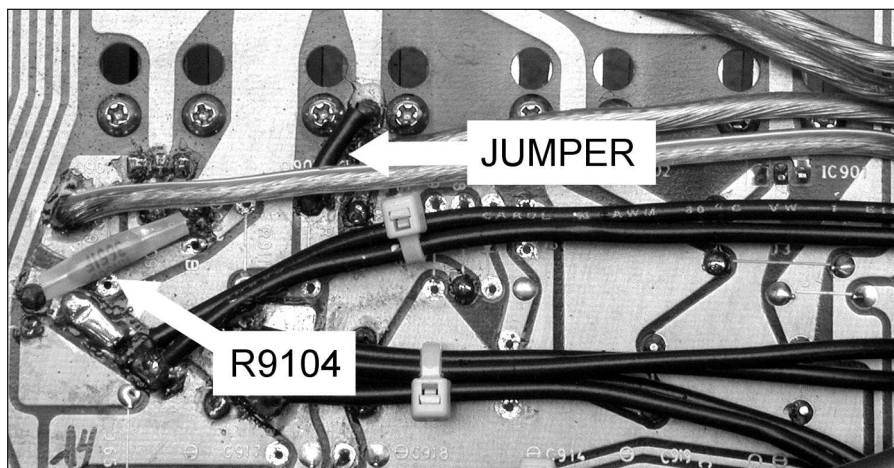


PHOTO 16: Close-up of the pre-regulators, bottom view, showing the locations of R9104 and the jumper.

may take a bit of effort, because the pins are usually very tight. I suggest clamping the pin in a vise and twisting the heatsink back and forth until it comes loose. The Aavid type should not have pins.

- Mount the Linear Technology LT1085CT and LT1033CT regulators on the new Wakefield heatsinks with ¼", 6-32 machine screws. You can use the original Adcom silicone insulating pads to facilitate heat transfer, or use white thermal compound (my preference). Don't use clear silicone grease; real thermal compound contains metal oxide, necessary for efficient heat transfer. Although the Adcom pads are an electrical insulator, this is unnecessary since the heatsinks don't make electrical contact with anything. Since the Aavid and Wakefield heatsinks are tapped for a 6-32 machine screw, you can't use insulating washers with the TO220 regulators anyway.
- Install the LT1033CT negative-regulator assembly in the Q901 footprint. Use the old Adcom mounting screws to secure the heatsinks to the PC board, then solder the three regulator leads to the board.
- Install the LT1085CT positive-regula-

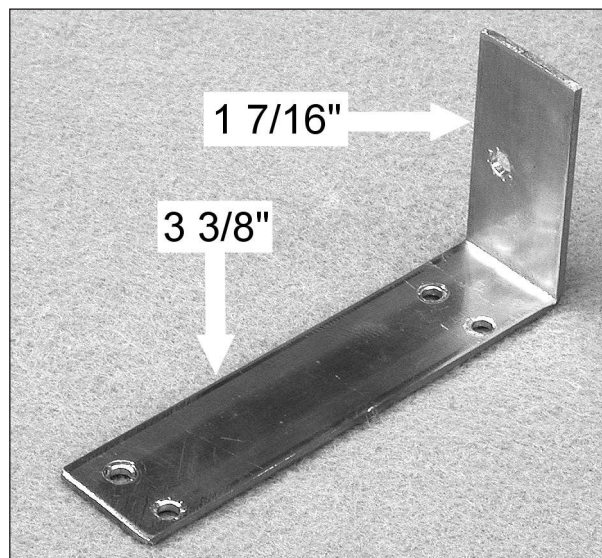


PHOTO 17: The regulator-board bracket with its long and short dimensions. The bracket is fabricated from a piece of 0.064 × ¾" brass stock.

tor assembly in the Q902 footprint. Use the old Adcom mounting screws to secure the heatsinks to the PC board, then solder the three regulator leads to the board.

You can mount three of the voltage-divider resistors for the pre-regulators in existing PC holes on the component side of the Adcom board. See *Fig. 4* and *Photo 12*.

- Install R9103 (1.0k) in the rear-most holes previously occupied by D913 and R910. This resistor will stand on end—use sleeving on the longer lead.
- Install R9101 (1.0k) in the holes previously occupied by D914. This resistor will stand on end—use sleeving on the longer lead.

- Install R9102 (3.65k) between the holes previously occupied by the collector (center pin) of Q904 and the forward-most hole previously occupied by R908.

You should mount the remaining resistor, plus a jumper, on the bottom of the PC board (*Photo 16*).

- Install R9104 (3.65k) between the pad occupied by J66 and the hole previously occupied by the center pin (collector) of Q903. J66 is not removed—the resistor shares this PC pad with this jumper. Use clear sleeving over this resistor.
- Install an insulated 16AWG jumper between the +26V raw supply trace—scraping enough enamel off the PC trace to allow a good connection—and the rear-most hole previously occupied by R912. This connects the raw-DC supply to the LT1085CT input (pin 3).

MAIN REGULATOR MOUNTING

At this point you should assemble and test the Jung Improved Regulators. Follow the instructions in *AE 4/00*, plus the testing procedure in *TAA 4/95*, with a few clarifications. The heatsinks for each pass transistor should include a Digi-Key HA113-ND 2W extender along with the recommended HA112-ND. Use the AD825AR opamp for X1 and X2.

I strongly recommend using a good SOIC-to-DIP adapter for mounting the AD825 on the 8-pin DIP footprint of the Didden PC boards,

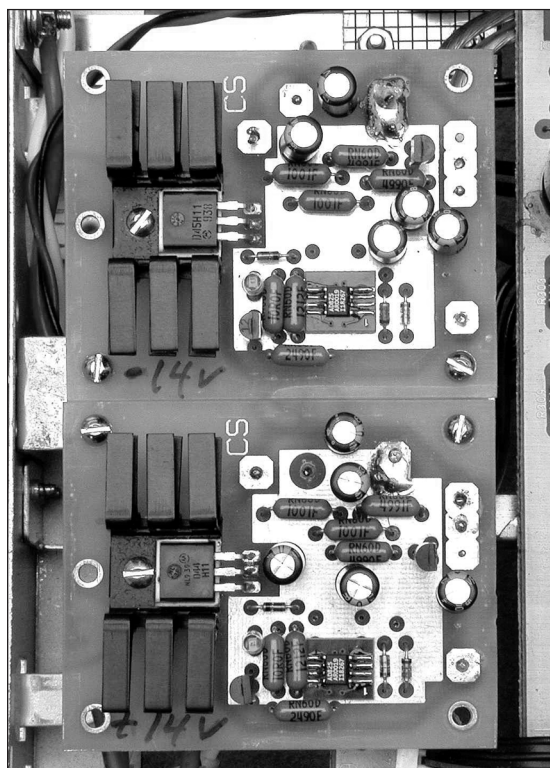


PHOTO 18: Top view of the Jung Improved Regulators installed in the preamp. The mounting bracket sits tight against the brass support for the main PC board.

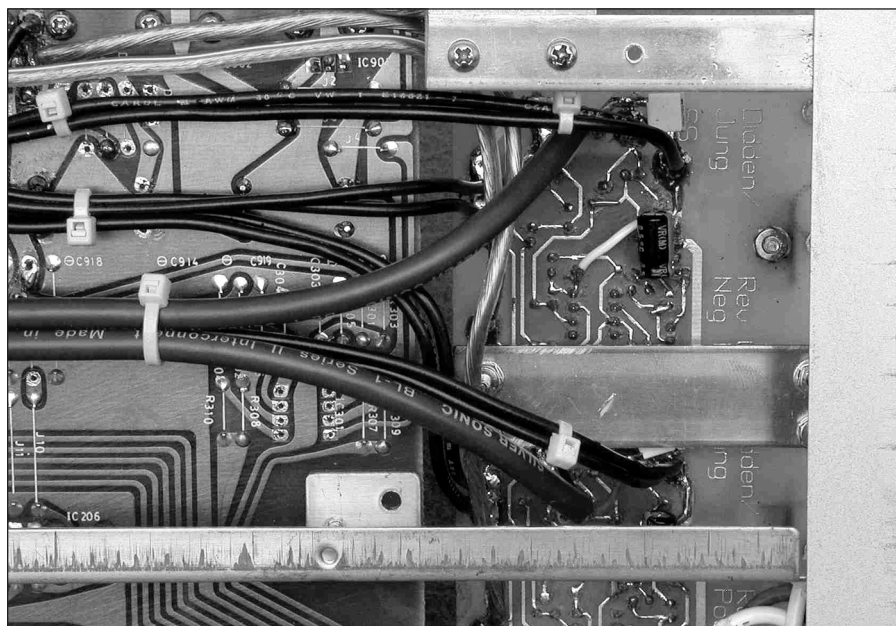


PHOTO 19: Bottom view of the Jung Improved Regulators. All connections are made to the bottom of the regulator PC boards.

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rather than attempting to solder the AD825 to a header. The Aries adapter listed in the Jung parts list is fine, as is the Accutek Microcircuit #AK08D-NSO mentioned in the parts list for this article. Many aX readers may not be familiar with Accutek Microcircuit; they manufacture a sizable assortment of adapters for IC mounting. I haven't found any need to implement the stability/RFI option described in Walt's side-

bar (AE 4/00, p. 16).

Walt has found that the electrolytic capacitors in the regulators also benefit from higher voltage ratings, and the Panasonic HFQ series he originally recommended has been discontinued. At his suggestion, all of the 120 μ F/25V Panasonic HFQ electrolytic capacitors are replaced with 47 μ F/63V Nichicon UVR series. I suggest cleaning the Jung regulator boards with Caig CaiKleen

TRP DG7S-6 spray when you are finished with the assembly and testing to remove all excess flux. CaiKleen TRP is a low-residue, citrus-based degreaser and flux remover, and my personal favorite for PC board cleaning.

The Roederstein/Resista MK3 resistors have also been discontinued, though some dealers still have ample stocks. In the interest of eliminating magnetic materials wherever possible, Walt suggested replacing these with Vishay-Dale CMF Type RN60D, which is a military type. All Vishay-Dale RN60D resistors have solder-coated copper leads, and all of the ones I've received from Mouser have non-ferrous end caps. However, Vishay does not guarantee that these resistors will be entirely non-ferrous, and I have heard reports of some parts coming through with steel end caps.

The "D" in the RN60 designator refers to the temperature coefficient, which is a mil spec of +200/-500ppm. But, Vishay claims that they supply ± 100 ppm parts for characteristic "D." Since we are using 1/2W resistors where, for the most part, 1/4W types would be adequate, a temperature coefficient of ± 100 ppm shouldn't be a problem. Mouser lists the RN60D resistors as 1/4W, but that is the military rating. For non-military applications, these are 1/2W resistors.

Holsworthy Electronics, makers of the highly regarded Holco non-ferrous resistors, merged with Meggitt Electronics a while back, and Tyco has subsequently taken over Meggitt/Holsworthy. The Holco resistors have been made with steel end caps since the merger with Meggitt. You can easily identify the new resistors, since they are completely cylindrical in shape, in contrast to the "dog-bone" style of the old all-copper Holcos. Holcos are no longer the perfectionist audio resistor that they once were.

Once you have built the Improved Regulators, it is imperative that you test them as I outlined in TAA 4/95. You need to be absolutely sure that the regulators are working properly before installing them in the preamp.

Use the remote sense de-coupling that I described in Part 4 of the 1995 regulator series. The 0.01 μ F capacitors, Cs+ and Cs-, are soldered to the bottom

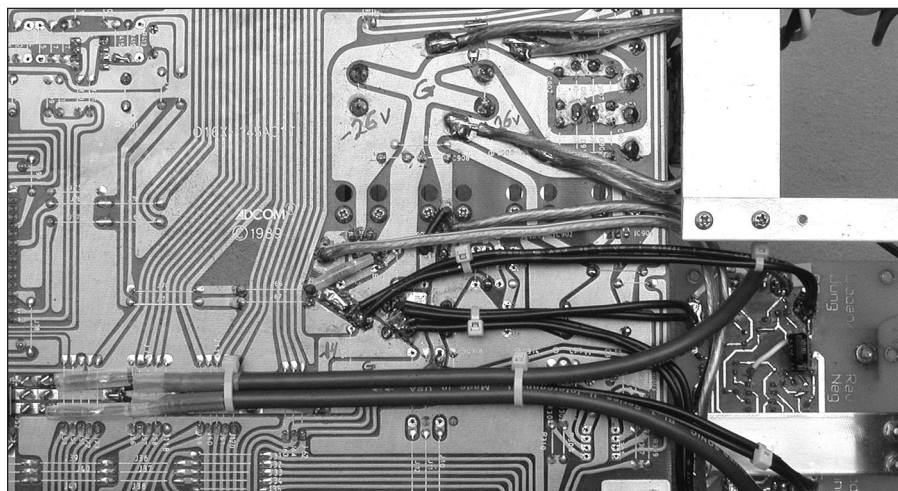


PHOTO 20: Large view of the main PC board showing connections to the Jung Improved Regulators.



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side of the regulator boards. These should be Mallory 168-series, as shown in the parts list. Installation of the 10Ω resistors, Rs+ and Rs-, will be described later.

Mount the regulator boards on a bracket made from 0.064 × 3/4" brass stock. *Photo 17* shows the bracket dimensions and locations of the mounting holes. You must drill four holes to accommodate the Jung regulator boards. Note that these four mounting holes are not centered on the regulator bracket, but rather are offset so the positive regulator mounting holes are close to the edge of the bracket. This is necessary in order to make connections to the bottom side (underside) of the positive regulator board.

Photo 18 is the top view of the assembled regulator boards, mounted on the brass bracket. Use 5/8" 4-40 machine screws, 1/4" nylon spacers, lock washers, and nuts to mount the regulator boards on the brackets. The bracket sits against the main brass chassis support (*Photo 18*). A single 1/2" 6-32 machine screw, lock washer, and nut holds the bracket in place, using an existing hole in the preamp chassis side rail. When installed, the right-angle bend in the brass regulator board bracket will be flush with the top edge of the chassis side rail, and the cover will fit on the preamp with at least 1/2" clearance between the pass transistor heatsinks and the preamp's metal cover.

WIRING THE REGULATOR

The reverse-polarity protection diodes D911 and D912 in *Fig. 4* are also shown in the Adcom schematic and PC board layout. However, I have never actually seen these diodes in a GFP-565 preamp, and none of the production Adcom PC boards I've seen have a footprint for them. I've designated these as new parts in *Fig. 4*. I suggest putting them in if your preamp does not have them.

- Install D911 and D912 as shown in *Fig. 4*. Use two of the 1N4003 diodes removed when you replaced the rectifier bridge. You can solder these anywhere along the main power-supply bus—use the pads where the brass rails are soldered in place. *Carefully observe diode polarity.*

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CUSTOM WORK

Make all connections to the Jung/Didden regulator boards to the pads on the bottom side of the board (Photo 19). I used 14AWG, stranded wire for the connections from the pre-regulators to the main-regulator inputs, and double-runs of 16AWG insulated solid bus wire for the main-regulator output and ground connections. To make the connections to the main PC board, prepare soldering surfaces on the PC traces as necessary.

See Photos 19 and 20, and Fig. 4.

- Solder 14AWG, stranded wires between the pre-regulator outputs on the main PC board and the input pads on the main-regulator boards. The output terminal on the positive LT1085CT pre-regulator is pin 2. The output terminal on the negative LT1033CT pre-regulator is pin 3.
- Connect the ground pads of both regulators to the ground bus on the main PC board. Use double-runs of 16AWG insulated, solid bus-wire for each regulator. As Photo 20 shows, there is a large ground area on the Adcom PC board which will provide

plenty of space for soldering the four solid wires (two in parallel for each regulator).

- Connect the negative output of the main regulator to the negative bus on the Adcom PC board. Use a double-run of 16AWG insulated, solid bus-wire.
- Similarly, connect the positive output of the main regulator to the positive bus on the Adcom PC board.

All that remains is to connect the remote sense lines for the main regula-

tors (Fig. 4 and Photos 19, 20, and 21). The remote sense lines require a two-conductor shielded cable, allowing a ground connection on both ends, with a floating shield at the sense point. I suggest D.H. Labs Silver Sonic BL-1 interconnect cable for these connections. The remote sense will give best performance if the sense point is close to the load.

Since the phono preamp and line stage are physically separated, I decided to make the sense point roughly equidistant from the two circuits, just

PARTS LIST

Rectifiers and Filter Caps:

- (4) International Rectifier HFA08TB60 HexFred Diodes, Digi-Key HFA08TB60-ND (D907-D910)
- (4) 47.5Ω, 1/2W resistor, Vishay-Dale CMF Type RN60, Mouser 71-RN60D-F 47.5; or Roederstein Resista MK3 (R901-R904)
- (4) 0.47μF, 100VDC capacitor, Xicon MEB, Mouser 1430-1474; or Panasonic V-series, Digi-Key P4733-ND (C901-C904)
- Panasonic V-series Line Filter, 56mH, 1.1A, Digi-Key PLK1017-(L001)
- (1) 8.25k, 1/2W resistor, Vishay-Dale CMF Type RN60, Mouser 71-RN60D-F-8.25k or Roederstein Resista MK3 (R905)
- (2) 4700μF, 80VDC Nichicon KG-Gold, Michael Percy Audio (C905, C906)
- (8) 1000μF, 50VDC Nichicon KZ, Michael Percy Audio (C917, C918, C121, C122, C121B, C122B, C401, C403)
- (8) 1.0μF, 50VDC Mallory 168-series, Newark 89F1692 (C119, C120, C121A, C122A, C402, C404, C907, C908)
- (2) 1N4003 Diodes (use discarded Adcom rectifiers) (D911, D912)

Miscellaneous

- 3/8" heat-shrink tubing for rectifiers (Radio Shack)
- Prototyping Board, Circuit Specialists IF-RFB
- 0.064 x 1/2" brass stock (local hardware or hobby store)
- 1/16" rubber gasket material (local hardware store)

Power Supply Regulators:

- Linear Technology LT1085CT 3A, 3-terminal positive regulator, Digi-Key LT1085CT-ND (Q902)
- Linear Technology LT1033CT 3A, 3-terminal negative regulator, Digi-Key LT1033CT-ND (Q901)
- Wakefield 634-15ABP 1 1/2" Heat Sink, Newark 91F3674 or Aavid 581102B00000, Digi-Key HS303-ND
- (2) 1.0k, 1/2W 1% Metal-Film Resistor (R9101, R9103)*
- (2) 3.65k, 1/2W 1% Metal-Film Resistor (R9102, R9104)*
- (2) 10Ω, 1/2W 1% Metal-Film Resistor (Rs+, Rs-)*

*Suitable resistors include Vishay-Dale CMF Type RN60, Mouser 71-RN60D F-Value; or Roederstein Resista MK-3 (Discontinued, but many values still available from Michael Percy Audio).

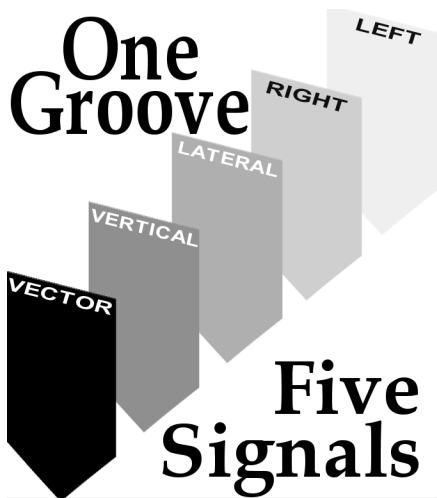
- (2) 0.01μF, 100VDC Mallory 168-series, Newark 46F3689 (Cs+, Cs-)
- (1 ±Pair) Jung Improved Positive/Negative Regulators built on Didden PC Board. All parts are as per Walt Jung's 4/2002 *Audio Electronics* article, P.11, with the following changes/clarifications:
- All 120μF, 25V Panasonic HFQ capacitors are changed to Nichicon UVR-series, 47μF, 63V, Mouser 647-UVR1J470MEA

- All resistors may be changed to Vishay-Dale CMF Type RN60D, Mouser 71-RN60D-F-Value
- Use Digi-Key HS113-ND 2W Heat Sink Extenders along with the recommended HS112-ND
- Use the AD825AR Op-Amp for X1 and X2, Analog Devices AD825AR, Newark 83F3403
- Use Aries 8-pin SOIC/DIP Adapters for the AD825AR Op-Amp, Digi-Key A724-ND, or Accutek Microcircuit AK08D300-NSO

Miscellaneous

- Chemtronics Heat Sink Grease, Digi-Key CT40-5-ND 0.064 x 3/4" brass stock (local hardware or hobby store)
- 1/4" nylon spacers for #4 machine screw, Digi-Key 876K-ND D.H. Labs BL-1 Cable
- 16 AWG insulated solid bus wire, Digi-Key A3057B-100-ND
- 14AWG insulated stranded wire
- Caig CiaKleen TRP DG7S-6 Cleaner, MCM Electronics 200-095 or Caig Laboratories DG7S-6
- Nylon Cable Ties (Radio Shack)

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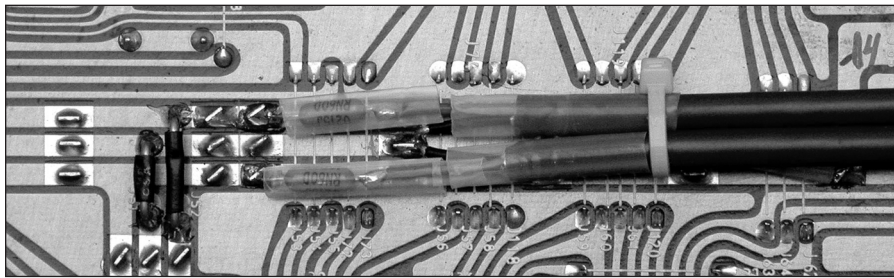


PHOTO 21: Close-up of the remote sense connections to the main power-supply buses, through the 10Ω de-coupling resistors. The 16AWG replacement jumpers for the supply bus are on the left.

ahead of where the main-supply buses branch off to the line stage. This is also right next to the 16AWG, solid jumper wires installed in Part 1. *Photo 21* shows this location.

- Install a remote sense cable for the negative supply using D.H. Labs BL-1 cable. Solder the shield drain wire to the T15 sense screen pad on the Jung regulator board. Use sleeving on the drain wire. Solder the black ground wire to the T18 sense GND pad. Both wires should go through to the top side of the board where they are also soldered to the regulator-board ground plane. These are the only wires that also require soldering to the component side of the regulator board. Solder the red wire to the T17 sense pad.
- *Photo 21* shows a close-up of the remote sense connections to the main-supply bus, through the 10Ω decoupling resistors. The drain wire of the BL-1 cable is not connected on this end, so the shield floats. Solder the black wire to the ground bus on the Adcom PC board. You can solder the red wire to the 10Ω resistor by bending a hook in the wire and the resistor lead, crimping them together, and then soldering. Use plenty of clear sleeving over everything. Solder the resistor to one of the pads supporting the brass supply-bus rails.
- Install a remote sense cable for the positive supply using D.H. Labs BL-1 cable. Solder the shield drain-wire to the T7 sense screen pad on the Jung regulator board. Use sleeving on the drain wire. Solder the black ground wire to the T10 sense GND pad. Both wires should go through to the top side of the board where they are also soldered to the regulator board

ground plane. These are the only wires that also require soldering to the component side of the regulator board. Solder the red wire to the T9 sense pad.

- Connect the BL-1 positive remote sense cable and 10Ω decoupling resistor following the procedure outlined previously for the negative supply.
- Use some small nylon cable ties to bundle the wiring neatly (*Photos 19, 20 and 21*).

Check all wiring very carefully against the *Fig. 4* schematic diagram and the photographs. When you are absolutely sure that all wiring is correct, connect the outboard transformer to the preamp and turn the power on. Use a variable AC transformer if you have one—monitor the main supply rails and make sure that the positive and negative supplies are headed in the right direction as you raise the line voltage from zero to 117V AC.

Check all supply voltages shown in *Fig. 4*. The raw-DC voltages should be $\pm 26V$ DC. There should be $\pm 20V$ DC at the input terminals to the main Jung regulator boards (T5+ and T12-). There should also be $\pm 14V$ at the main-regulator outputs and on the main-supply buses (or the brass supply-bus rails) on the Adcom PC board.

You should also use an oscilloscope to check for oscillations on the pre-regulator outputs and the main-supply rails. I have built three of these preamps and have not experienced even a hint of supply instability. Clean the entire Adcom PC board with Caig Caikleen TRP to remove all excess flux.

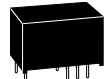
Part 3 will describe an entirely new line stage. In the meantime, enjoy the sonic benefits of the improved power supply in your GFP-565 preamplifier. ♦

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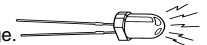
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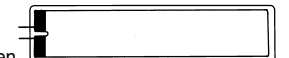
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Product Review

Onkyo DV-SP800 SACD & DVD Audio Video Player

By Gary Galo

Onkyo DV-SP800 SACD & DVD Audio/Video Player. Onkyo U.S.A. Corporation, 18 Park Way, Upper Saddle River, NJ 07458; 201-785-2600, FAX 201-785-2650, www.onkyousa.com.

Since the beginning of sound recording, the audio (and later video) industry has loved format wars. First it was cylinder vs. disc, then laterally-cut discs vs. the vertically-cut minority from Pathé and Edison. The 78-rpm era was brought to a close with Columbia and RCA Victor battling it out over 33 1/3-rpm vs. 45. The 1970s brought us the battles that killed quadraphonic audio, at least on LP—the Sony/Columbia SQ system fought the JVC/RCA Victor CD4 and Sansui QS systems for market domination; there were no winners.

Then came the Mother of All Format Battles—Beta vs. VHS, with the technically superior Beta format ultimately losing to VHS. The early and rapid standardization of the Compact Disc gave us a 20-year break from incompatibilities, but in recent years the industry has started all over again with two incompatible, high-resolution digital audio formats: Sony's SACD (Super Audio Compact Disc) and DVD-Audio.

DVD-AUDIO

DVD-Audio is a 24-bit, linear PCM system that employs a data packing/unpacking system developed by Meridian known as MLP, for Meridian Lossless Packing. In a nutshell, the Meridian system is the audio equivalent of a ZIP file—when the file is unpacked in playback, all of the original data is restored. This is a sharp contrast to lossy digital compression systems, such as that used for the MiniDisc, in which data reduction takes place during recording, and the missing data is not recoverable during playback. Meridian Lossless Packing increases the amount of data that can be recorded on a DVD without compromising the integrity of the original datastream.



PHOTO 1: Onkyo's new DV-SP800 multi-format DVD player, which is compatible with SACD, DVD-Audio, plus virtually every other silver-disc format.

The DVD-Audio standard allows 2-channel stereo at sampling frequencies as high as 192kHz, and 6-channel recording as high as 96kHz. But, there's no law that says manufacturers can't use lower sampling rates. All standard sampling frequencies are available to DVD-Audio manufacturers, including 44.1, 48, 88.2, 96, 176.4, and 192kHz, though anything above 96kHz must be 2-channel only. Lower bit-rates—16 and 20—are also possible.

As with all PCM digital recording systems, the usable frequency response is just under half the chosen sampling frequency, and the dynamic range is roughly 6dB per bit of resolution. You can find a good overview of the DVD-Audio standard on the Disctronics web site: http://www.disctronics.co.uk/technology/dvdaudio/dvdaud_intro.htm.

SACD

Sony's SACD format is based on their DSD (Direct Stream Digital) recording system. DSD is a 1-bit system that can also be described as "variable-density" recording system. DSD operates at a sampling frequency of 2.82MHz, and has a frequency response of 100kHz and a dynamic range of 120dB.

One of the alleged advantages of DSD is the elimination of decimation and interpolation filters used in PCM systems. The DSD/SACD system requires only one simple analog, low-pass filter, in playback only. The system operates at only one mode of resolution, and its performance is, therefore, not subject to the whims of record companies who care more about making money than high-quality audio.

SACD is capable of 2-channel stereo and multi-channel performance with up to six-channels (five plus subwoofer), all at the same resolution. In addition, the SACD specification includes dual-layer capability, and manufacturers can also produce a hybrid disc that includes a CD layer, making the SACD backward-compatible. In a conventional CD player, the shorter-wavelength SACD layer is transparent to the CD laser beam. If the original DSD recording is multi-channel, the SACD can contain a 2-channel stereo SACD mix, a multi-channel SACD mix, along with a 2-channel CD layer.

Sony has developed a system called Super Bit Mapping Direct for conversion of DSD recordings to the CD standard. There's an SACD tutorial on the

Sony Web site: <http://interprod5.imgusa.com/son-637/technology.asp>, and the Disctronics site also has an excellent SACD overview.

The DVD-Audio PCM system and SACD have completely different datastreams, but the incompatibility isn't nearly as bad as Beta vs. VHS, in which the tape cassettes weren't even the same physical size. Fortunately, both DVD-Audio and SACD use the same physical disc—a standard DVD. As the Disctronics site notes, "The SACD specification is contained in the Scarlet Book. SACD discs are DVD discs in that they use the same sector size, error correction and modulation as DVD discs and the same file system (UDF plus ISO 9660)."

All that is necessary to play both formats is the proper electronics for decoding of the two formats. This isn't quite as simple as it sounds—until fairly recently, designing a player to handle both formats was prohibitively expensive. Fortunately, that has now changed.

With street prices of around \$900, the Onkyo DV-SP800 represents a bit of a breakthrough. It is one of the first reasonably affordable DVD players that will

handle both DVD-Audio and SACD (Denon recently introduced their own multi-format player, the DVD-2900, which is comparably priced to the Onkyo, and Marantz has just announced their second higher-end machine, the DV8400, which sells for around \$1500).

TECHNICAL DETAILS

Nearly all DVD players are designed—first and foremost—with video in mind, and nearly all have switching power supplies. The Onkyo DV-SP800 is a refreshing departure from this cost-saving approach. A hefty conventional power transformer feeds four encapsulated bridge rectifiers. The player has a total of seven fixed, 3-terminal IC regulators. Onkyo is obviously aware of the sonic problems associated with switching supplies, and I applaud their decision not to use them.

Although I requested a service manual for the DV-SP800, I never received one, but I can offer a few additional circuit details. The player uses three Cirrus Logic CS4392 DACs, which are complete stereo converter chips, including the digital interpolation filter, D/A conver-

sion, and analog output filtering. The chip accepts PCM data at sampling frequencies up to 192kHz, and word lengths up to 24-bit, making it fully compatible with the DVD-Audio standard. It also accepts the SACD datastream.

Cirrus notes that patented mixed-signal technologies are used in the CS4392, including a proprietary delta-sigma modulator architecture and analog switched-capacitor filters. The chip has a dynamic range of 114dB, with THD+noise levels of -100dB. The ability of one converter chip to handle both the SACD and PCM datastreams is probably *the* major factor in making dual-format DVD players affordable. The DV-SP800 also has a separate SACD decoder board, ahead of the CS4392. The heart of this board is Sony's own CXD2753R DSD decoder chip.

The DV-SP800 uses IC op amps manufactured by JRC for the analog circuitry, including six NJM2068 and seven NJM4565. The NJM2068 is a low-noise dual op amp with a 6V/ μ s slew rate and a 27MHz unity-gain bandwidth (UGB). The NJM4565 has a slew rate of 4V/ μ s with a UGB of 4MHz. Both devices are bipolar and are cost-effective rather than state-of-the-art.

It would appear that the NJM2068 devices are used for gain; the NJM4565 chips appear to be output buffers for the 14 separate audio outputs on the player. One additional NJM4565 is also used for the headphone amplifier. All of the audio outputs are capacitor-coupled, with Nichicon VX-series, 47 μ F/50V. Ac-



PHOTO 2: Rear panel of the DV-SP800. The player has 14 analog output channels, and both S/PDIF coax and Toslink optical digital outputs. On the video end, the player outputs component video, S-video, and standard NTSC composite.

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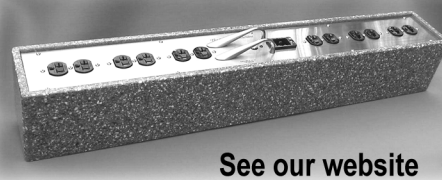
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cording to the Nichicon web site, the VX-types are general-purpose, rather than audio-grade, electrolytic capacitors.

On the video end, the player uses a Pioneer PM0033A video decoder and an Analog Devices ADV7300A video encoder. According to Analog Devices' web site, the AD chip contains six 12-bit, 108MHz NSV Precision Video™ DACs for multiple video outputs, plus 2×, 4×, and 8× over-sampling for high-definition, progressive scan, and standard definition video.

OPERATION

The DV-SP800 is equipped with a proliferation of operational features, too numerous to list here. You'll be hard-pressed to find anything missing, from an operational standpoint. Most of the player's functions are accessed with the remote control, which I found very easy to use. The remote is also fairly non-directional; point it nearly anywhere in the room and it works just fine.

As mentioned, the player has 14 separate audio outputs. Included are two

pairs of L&R stereo outputs, which appear to be individually buffered. The surround channels have the usual left and right front and rear outputs, center channel, and subwoofer. There is also an additional pair of outputs called Surround 2, which is used only when connecting the player to a 7.1-compatible surround system—a rear-panel switch enables this mode of operation.

When I bought my first DVD player a few years ago, I chose the Pioneer DV-525 because it was the only player I

SACD VS. DVD-AUDIO: THE BATTLE FOR SONIC SUPERIORITY

For this review, Editor and Publisher Ed Dell asked me to try to draw some conclusions regarding the SACD vs. DVD-Audio debate. I'm afraid that's impossible at this time. Unfortunately, the material currently available simply doesn't allow meaningful comparisons.

What we really need are identical recordings issued in both formats. These could be either brand new recordings, made with the mixing consoles feeding both DSD and DVD-Audio recording systems, or recordings transferred from the analog era—classics from the Mercury, RCA Victor Living Stereo, and Decca/London catalogs—to both formats. No recording company has done either, and none shows any signs of doing so. Telarc's DVD-Audio version of their *1812 Overture* re-make seemed promising, but the DVD-Audio version was not made as a separate recording at the original sessions. Instead, the original DSD recording was converted to DVD-Audio format, and not even at the highest resolution the format is capable of.

If you read my review of SACDmods.com's modified Sony SCD-CE775 SACD player in the Dec. 2002 issue of *aX*, you will recall my enthusiasm for the SACD format. I continue to be enormously impressed with SACD—the recordings I have heard have convinced me that it is a perfectionist audio format, far superior to the CD. Telarc's SACD recordings of the *1812* and Benjamin Zander's thought-provoking performance of Mahler's 5th Symphony are simply stunning. From a purist audio point of view, the fact that SACD offers only one extremely high mode of resolution is especially appealing. I also like the hybrid approach, ensuring backward compatibility, and eliminating the need to issue two different versions of the same recording.

SACD SHORTCOMINGS

A few record companies are failing to take advantage of the ability to include a CD layer on SACD discs. Sony Classical is one of the guilty parties, which is strange since the parent company invented the format! Perhaps they are trying to conceal the fact that many of their SACD reissues of analog material from the Columbia catalog have not been transferred to the new format particularly well.

A case in point is *Bernstein Conducts Bernstein* (listed with my reference recordings). When Sony Classical transferred this material to CD back in 1997, they were in the midst of a short-lived period of excellence in the re-issue field. The CD transfer was done using the original multi-track analog tapes, with excellent results (this was part of Sony's *Bernstein Century* series, SMK 63085). The SACD transfer sounds as though it was done from production tapes used for LP cutting, with results inferior to the CD, even with the Onkyo used as a stand-alone CD player. The SACD sounds somewhat harsh and trashy; the CD is smoother and more detailed, cleaner and more spacious, and the soundstage has greater depth and width.

If Sony Classical had put the CD transfer as a separate layer on the SACD disc, the inferiority of the SACD transfer might have been cause for embarrassment. Could this be why they decided to issue this and many other SACD reissues in single-layer format?

The SACD is so revealing that a bad transfer of older material is really a "garbage-in, garbage-out" situation. But, when SACD is done properly, it is stellar.

DVD DOWNFALLS

I wish that I could be as enthusiastic about DVD-Audio. The problem is not with the format itself, but with the fact that it is nearly impossible to find material that takes advantage of the full resolution of the format, especially classical. The EMI discs in the list accompanying this review don't even come close.

Though all are 24-bit, the Strauss and Ravel re-issues (from excellent 1970s-vintage analog tapes) are at 48kHz, and Simon Rattle's less-than-coherent performance of Mahler's reconstructed 10th is at 44.1kHz. The choice of sampling rate for the Rattle is truly puzzling, since this all-digital recording was made in 1999. EMI seems interested in using the storage capability of the DVD to cram as many formats as possible onto each disc, rather than offer music lovers the best possible sound.

The EMI discs are two-sided. One side has both 2-channel and multi-channel DVD-Audio mixes. The flip side offers the same recordings in Dolby Digital AC3-encoded 5.1 surround, and straight 24-bit, 2-channel PCM. Since the straight PCM program is at the same sampling rate and bit rate as the DVD-Audio version, they are essentially identical in sound quality. What an idiotic waste of disc space!

Even Telarc has fallen into the trap. They apparently opted for a sampling rate of 88.2kHz for the DVD-Audio version of the *1812* in order to make disc space available for other formats. The 2-channel stereo mix is 24-bit, but the surround mix is only 20-bit (A Data Conversions Systems 972 Interface was used for the DSD to DVD-Audio conversion). The flip side has DTS Surround and 48kHz/16-bit stereo programs (the tray card says there's a Dolby Audio program, but it doesn't appear on the menu). There's even an MP3 version!

Many DVD-Audio discs are set up in such a way that it is difficult—or impossible—to select the program you desire without using the disc's on-screen menu. You must turn on your television in order to listen to music, a decided nuisance. With SACD discs, you set up your player to select either the 2-channel or surround programs. You do this one time, with the player's on-screen setup menu. Once you've made the right choice for your playback system, all SACD discs automatically play in that format. There's no further need to use your TV to play music, and tracks are selected just like a conventional CD.

The DVD-Audio discs I purchased for this article don't even approach the sound quality of the best SACD discs I own. Until the record companies decide to exploit the full available resolution of the DVD-Audio format, rather than using it to offer as many versions of the same program as possible, it will be of little use to audiophiles. If the present trend continues, SACD will deserve a victory in this format contest.

could find with a 96kHz digital output (most automatically down-sampled 96kHz datastreams to 48kHz). Fortunately, that situation has changed, and there are now a large number of DVD players that will output 96kHz/24-bit via the S/PDIF output. Onkyo has made the S/PDIF digital output extremely versatile. Both coax and Toslink output are included. The default is a 48kHz, down-sampled output.

If you are using a newer outboard digital processor that's compatible with 96kHz datastreams, you make a simple change in one of the on-screen setup menus. You can also use the on-screen setup to choose other configurations for the digital output, including Dolby Digital, Dolby Digital/DTS, Dolby Digital/MPEG, Dolby Digital/DTS/MPEG, or straight PCM, depending on the type of outboard processor you own. Select the PCM setting for 2-channel applications with outboard digital processors designed for audio use (as opposed to home-theater use). You can also use the setup menu to convert all other formats—Dolby Digital, DTS, and MPEG—to conventional PCM.

When you play an SACD disc, the digital output automatically mutes. This is because the SACD datastream is completely incompatible with the PCM stream for which the S/PDIF interface was designed. But, the digital output is alive and well when you play DVD-Audio discs. The playback processing of the Meridian Lossless Packing system "unpacks" the missing data ahead of the S/PDIF output, so you have a fully restored PCM datastream available at the digital output for DVD-Audio discs. If the sampling rate on a DVD-Audio disc is 192 or 176.4kHz, the digital output is automatically down-sampled to 96 or 88.2kHz, respectively (or, 48 or 44.1kHz if you've told the player not to output higher sampling rates).

The DV-SP800 has a "CD Digital Direct" menu setting that allows you to bypass audio circuits that are only required for DTS-encoded discs. Unless you are using DTS discs, you should enable this direct mode for the best sound quality. The player also has a front-panel button—duplicated on the remote control—that allows you to turn off the video portion of the player. This results in an audible improvement in

sound quality, since the video circuits don't radiate any digital noise that can compromise audio performance.

The video circuits should always be turned off for critical audio listening. Unfortunately, some DVD-Audio discs require the use of the on-screen menu

for program selection, so you need to select the program and turn the video off after the playback has commenced. This is one feature of DVD-Audio I find really annoying.

The DV-SP800 is equipped with two composite video connectors, two S-

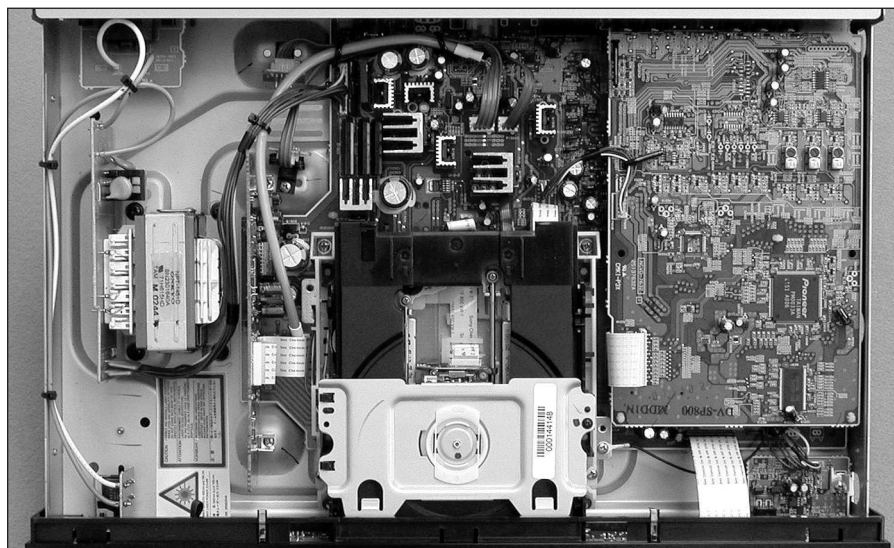


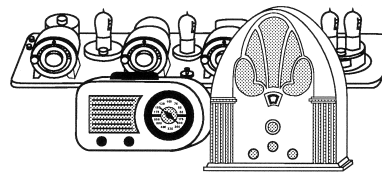
PHOTO 3: Inside the DV-SP800. This solidly constructed player boasts conventional, non-switching power supplies. The upper PC board on the right houses the video processing circuitry. Most of the audio circuitry, including the D/A converters, are on the lower PC board, underneath the video board. A separate SACD decoder board is mounted vertically on the left, between the mechanism and the power transformer.

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The first sample I received of the DV-SP800 had an intermittent SACD decoding problem. Sometimes SACD playback would be accompanied by a broadband background noise, much like low-level white noise. The problem was not consistent. Ejecting the disc and reloading would often cure the problem, but it might reappear the next time the same disc was played. Onkyo replaced the

first review sample with another player, and I've had no problems with the second sample.

THE SOUND

All of my evaluations of the DV-SP800 were done on my 2-channel stereo system. My reference for SACD playback, at least in my own system, is SACDmods' modified Sony SCD-CE775 SACD player I reviewed in the Dec. 2002 issue of *aX*. That player really made a strong case for the virtues of SACD, whereas I thought that the stock Sony player did not.

The audio performance of the Onkyo DV-SP800 is decidedly superior to the stock Sony player, but not quite in the same league as the SACDmods version. On Telarc's new recording of the *1812 Overture*, the Onkyo player reveals many of this recording's virtues, including the very warm and palpable string and choral sound at the beginning of the piece. The excellent soundstaging captured by Telarc is quite convincing on the Onkyo player, and the dynamics and impact of the bass drum and canons are very impressive.

Compared to my recollection of the SACDmods player, the Onkyo imparts just a bit of texture in the midrange, which is particularly evident in the choral passages, and a slight hardness in the treble. One of the virtues of SACD is how it captures the air and openness of a live musical event. The Onkyo doesn't reproduce those qualities to the same degree as the SACDmods player. Though the bass is impressive, the SACDmods player had more weight and better definition. Overall, the SACD performance of the Onkyo is quite respectable, making a good case for the format, but not revealing SACD's virtues to their fullest.

Given the lack of good DVD-Audio source material (as noted in the sidebar), it is difficult to offer an absolute assessment of the Onkyo's DVD-Audio performance. All of the EMI DVD-Audio discs I used in this review lack midrange smoothness and are somewhat tizzy in the treble. The air and openness of the Telarc SACD discs just isn't there on these DVD-Audio recordings. Telarc's DVD-Audio version of the *1812* is the best of the DVD-Audio discs I own, and is much smoother and cleaner than the EMI discs. I'm sure that the

higher sampling rate chosen by Telarc is a major factor here, though the full potential of DVD-Audio is still not evident.

Classic Records' 96kHz/24-bit DVD transfer of the Rachmaninoff *Symphonic Dances* remains one of the best recordings I own in any format (this is a straight PCM disc, not DVD-Audio). This recording sounded much better on the Onkyo than any of the DVD-Audio discs I own. The incredible dynamics of this recording were quite convincing on the Onkyo. The lateral image was precise, though depth perspective fell somewhat short. As is the case with the SACD discs, the bass is a bit weak, and the treble slightly tizzy compared to a reference-quality playback system (for this disc, my reference is my DVD player feeding my outboard upsampler and D/A converter).

The performance of the Onkyo player is certainly good enough to reveal the essential differences between CD, SACD, and DVD-Audio. Despite the shortcomings of the EMI DVD-Audio discs, the Strauss and Ravel re-masterings were clearly superior to their CD

(continued on page 72)

RECORDINGS USED FOR THIS REVIEW:

SACD:

Beethoven: Symphonies Nos. 5 and 7. Vienna Philharmonic Orchestra, Carlos Kleiber, conductor. Deutsche Grammophon 471 630-2. (Hybrid SACD/CD; transfers of analog tapes.)

Bernstein Conducts Bernstein: Overture to *Candide*, Symphonic Dances from *West Side Story*, Symphonic Suite from *On the Waterfront*, *Fancy Free Ballet*. New York Philharmonic, Leonard Bernstein, conductor. Sony Classical SS 89043. (SACD only, single-layer; DSD transfers of analog tapes.)

Mahler: Symphony No. 5. Philharmonia Orchestra, Benjamin Zander, conductor. Telarc 2SACD-60569. (Hybrid SACD/CD; original DSD recording.)

Stravinsky: *The Firebird*—Suite. Atlanta Symphony Orchestra, Robert Shaw, conductor. Telarc SACD-60039. (Hybrid SACD/CD; DSD conversion of original Soundstream recording.)

Stravinsky: *The Rite of Spring*. Cleveland Orchestra, Lorin Maazel, conductor. Telarc SACD 60563. (Hybrid SACD/CD; DSD conversion of original Soundstream recording.)

Tchaikovsky: *1812 Overture*. Cincinnati Pops Orchestra, Erich Kunzel, conductor. Telarc SACD-60541. (Hybrid SACD/CD; original DSD recording.)

DVD-Audio:

Mahler: Symphony No. 10 (Reconstruction by Deryck Cook, Berthold Goldschmidt, Colin Matthews, and David Matthews). Berlin Philharmonic, Simon Rattle, conductor. EMI 4 92394 9. (44.1kHz, 24-bit.)

Ravel: *Daphis et Chloé* (Complete Ballet), *La Valse*, *Boléro*. Orchestra de Paris, Jean Martinon, conductor. EMI 4 92395 9. (48kHz, 24-bit transfers of analog tapes.)

Strauss: *Ein Alpensinfonie*, Op. 64, *Also Sprach Zarathustra*, Op. 30. Staatskapelle Dresden, Rudolf Kempe, conductor. EMI 4 92396 9. (48kHz, 24-bit transfers of analog tapes.)

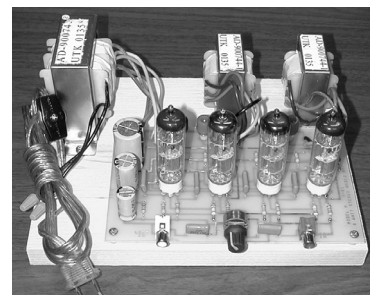
Tchaikovsky: *1812 Overture*. Cincinnati Pops Orchestra, Erich Kunzel, conductor. Telarc DVD-A-70541. (88.2kHz, 24-bit conversion of DSD original listed previously.)

Sonic Boom! DVD-Audio Demonstration Disc—Classical and Jazz Selections. Denon CDZ 17156. (96kHz, 24-bit; many recordings are older digital originals upsampled to 96kHz.)

DVD (PCM):

Rachmaninoff: *Symphonic Dances*, Op. 45. Dallas Symphony Orchestra, Donald Johanos, conductor. Classic Records DAD 1004. (96kHz, 24-bit PCM transfer of 30-ips analog tape engineered by David Hancock.)

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Xpress Mail

8417 PROS AND CONS

 In regard to Mr. Pettis' letter ("Overlooked Tube," July '03 Xpress Mail, p. 65) I would like to share my experience with the 8417 beam-power tube. Back in the late 1970s, I built a 120W power amp with four of these tubes operating in Class AB1, pentode connection with 465 anode volts and regulated screen volts of 300. I set the idle current of each tube at 35mA. The tubes, manufactured by Sylvania, were fan-cooled.

This was a good-sounding amp and, for the most part, caused little trouble. However, the 8417 tubes did have a tendency to go into "runaway" and self-destruct upon reaching maximum power. The screen grids would glow red, and sometimes the tubes would become gassy, then short out and blow the fuse in the anode/screen grid supply. The tubes would sometimes develop failure conditions without warning, including cracked base seals from excess heat. (I finally changed my design to Tung-Sol 6550s.)

Since the 8417 is high gain, its grids

are wound close together with little spacing between windings. It appears the screen grid had problems dissipating its normal heat load, with the resultant overheating of the control grid, which is already quite hot from being near the cathode. This would lead to "runaway" conditions, and sometimes severe failure. If the grids are not properly aligned, one overheated screen winding can cause a "creeping" of excess cathode current with "runaway" the result.

From looking at the internal structure of the tube, I imagine this type of design would have benefited from a larger glass bulb (such as the 6550/KT88 type) and the use of large heatsink radiators mounted on both the control grid and the screen grid side rods. An excellent example of this construction is the Sylvania 6BG6GA "clear-top" with side getters horizontal sweep television tube—a rugged member of the 6L6 family of beam power tubes, with which I have yet to have a failure in any of my lower powered amplifiers (40–50W).

However, any power tube can give

unreliable performance when run at its maximum ratings for an extended period of time. Severe overdriving ("clipping") of the amplifier will reduce tube life, but some types handle this better than others—many design factors figure into this as well.

I will agree with the responding comments of Mr. J.L. Markwalter, and Mr. Joseph N. Still in that the 8417 would be quite satisfactory for triode operation, if the tubes are not over driven. I also agree with the operating conditions he described for Class AB1 triode conditions.

With the tubes high mu, little drive would be needed.

I found the comments from all involved quite informative. I hope my experience with the 8417 will help other vacuum tube audio builders.

Joseph K. Risher
Sounds Great! Enterprises
Stone Mountain, Ga.

Edwin Pettis responds:

Mr. Risher has largely confirmed my state-

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ments about the 8417 from his experience with them. His amplifier, operating at a very conservative plate voltage of 465V and 35mA with a fan (a very good addition) illustrates the fact that 8417 tubes did not need to be run at maximum ratings to cause failures. His idle power of 16.275W per plate was well below the 35W capacity of the 8417.

The main problem with the 8417 was its grids, in particular the screen. Its design maximum rating was 5W, according to Sylvania, and grid no. 2's dissipation could reach 8W (a 60% overload condition) during higher speech and music levels. This did not require the tube to be running anywhere near design maximum plate readings for this condition; it could just as easily occur with a plate voltage of only 400V and 275V screen. The tube's screen grid was something of a current hog, which was bad for it. Its very close proximity to the cathode only added to its heat problem.

Mr. Risher covers the failure modes quite well and seems to have experienced just about all of them. The 7591A tended to fare a little better, because its G_M was only 10,200 vs. the 8417's 23,000, allowing for a little more spacing. Unfortunately, it could experience just about all of the failure modes that the 8417 could due to its construction.

I quite agree with Mr. Risher's appraisal of the 8417's lack of good construction; a bigger bulb and better heat radiators would have helped. However, given the necessity of the grid structures for such high G_M , I think the tube still would have suffered from continued problems, but at perhaps a lower rate of failure. The 7581A from the 6L6 family—also rated at 35W plate—never had any of these problems, even running at near maximum ratings frequently. The 6BG6GA is indeed a 6L6 in sheep's clothing. It is very well built and, given the plate cap connection, could handle higher plate voltages.

Since Mr. Risher mentioned the 6BG6, I would like to add that back in the 80s, Sylvania produced a large quantity of 6BG6GAs for the military that actually contained 7581As inside (the construction was identical). They can run continuously at 35W without any problems. Internally, they do appear differently than a stock 20W 6BG6GA, which cannot operate in a like manner without self-destruction. No one else produced this "super" version of the 6BG6GA, so don't bother with anything but a Sylvania.

In the more common power output tubes such as 6CA7, 6L6, 6550, EL34, KT66, KT88, and the like, running them at or near

maximum ratings generally only shortened their life spans with no catastrophic failures. Exceeding a tube's maximum ratings runs the risk of a catastrophic failure. I have seen amplifier designs with tubes running in excess of their maximum ratings without catastrophic failure, but very short life spans are the penalty, which must be due to very good tube designs. I do not recommend this practice. Like any component, overstressing them has consequences, which are often bad.

Triode operation of the 7591A and 8417 does get around the screen grid problem to some degree, but will not eliminate it. Operating the tube at a conservative level will help ensure the tube's longevity. It is a pity that none of the manufacturers came out with an 8417A that fixed most of its flaws, but the grid problems would have been difficult to eliminate altogether.

I urge anyone considering using either the 7591A or 8417 to include circuit protection to preclude major circuitry damage. A runaway tube can cause much damage before the line fuse decides to do something about it. As output transformers and other components have become quite expensive, an ounce of prevention may save you many pounds of destruction.

These two tube types had a lot of potential; unfortunately, manufacturers failed to expend the effort to make them reliable. I surmise that they could see the writing on the wall: large-volume tube production was nearing its end and such effort would not be justified. Careful design will help minimize these problems, so if you have amplifiers that use these tubes, take some steps to partially correct these failure modes, addressed on an individual basis.

TUNER TIPS

 Regarding the article "Improving Dynaco's FM-5 and AF-6 Tuners," by Daniel Dufresne (August 2003), I have a small suggestion regarding the ripple on the DC line. If you consider Fig. 2, C238/C86 is left with the resistor R241/R95 in series, which is equivalent to a fairly poor capacitor! Just replacing this resistor with a short will increase the filter capacitance by quite a fair amount, diminish the ripple on the DC line, and may further improve the hum level.

Philippe Trolliet
Montréal, Canada

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Daniel Dufresne responds:

Yes, the modification you suggest will lower the ripple voltage, by approximately 50%, at minimum cost. I did consider doing so but decided against it. I wanted to compare the original circuit against the regulator without adding capacitance to the raw DC supply.

In Mr. Dufresne's article on improving Dynaco tuners, he references replacing the stereo decoders. I also have an older tuner, a Fisher 90-X, which has a multiplex outlet but no multiplexer. Are there parts I can purchase to make a multiplexer or any way to buy a multiplexer?

This is a very good tuner that I don't use because of the lack of stereo, so any advice would be appreciated.

Rick Heyke

rheyke@winston.com

Daniel Dufresne responds:

I am sorry I cannot answer you on this with specific details. I remember seeing multiplexer kits years ago, but I have not seen any lately. Surely a search on the World Wide Web should give results. My quick search revealed nothing. Maybe you will have better luck.

Another solution is to find a discarded FM stereo tuner or receiver—even an old car radio—locating the appropriate circuits to cut that part off, and use that as your decoder. A real hack job.

TUBE SOURCES

 I picked up your magazine last weekend and enjoyed it. I'm thinking of putting together "The DC Revenge E182CC Amplifier" (7/03 aX, p. 20). Can you recommend a location where I can purchase all the necessary parts?

Joe Guerra

Jguerra@stc.ca

Mauri Pännäri responds:

I am pleased Mr. Guerra has shown an interest in my amplifier. I must say I don't recommend this amp as a project for first-timers. This is because of the DC-coupled gain block and its high bandwidth. For a first project, available tube amp kits are maybe a better solution because they also solve the problem

Mr. Guerra presents here (of course, I have no way of knowing the tube skills/knowledge of Mr. Guerra).

For obtaining tube parts, you don't typically easily find quality OP-transformers and NOS tubes from the same supplier. Of course, your best source for tube supplies are the advertisers in this magazine. But here's a list of some specific tube sources:

Angela Instruments

<http://www.angela.com>

Hammond end transformers: try 125ESE (inexpensive), or, for quality level, use 1627SE.

Hammond mains transformers: use one cheap 269JX for each channel (CT with two diodes) for double mono; one 270CBX might just suffice for both channels, I'm not sure.

Tube sockets, components, and also for tubes (use 12AT7 for 33A/101K)

K&K Audio

<http://www.kandkaudio.com>

Lundahl end transformers: LL1623/60 mA for best possible quality, wired for 1.6kW (recommended) or 3kW.

Lundahl mains transformer: LL1683, a new model, which is an exact fit here and works with 115 or 230V mains. The Lundahl transformers are quite ugly individuals and need a cover. For their full data, see also <http://www.lundahl.se>

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PROJECTS FOR FIRST-TIMERS

Just wanted to share my appreciation for *audioXpress* in the form of a few comments on projects from the magazine's pages that I've recently tried. First, hats-off to aX and Pete Millet for the ingenious, easy-to-build, safe, and fun hybrid tube headphone amp project (aX 11/02, p. 20). This was just the sort of project for someone like me, who has considerable experience building kits but no scratch-building experience. Plus, it sounds good, as a headphone amp and also as a preamp!

Thanks also to Kevin Haskins (www.diy cable.com) for making the

PCB available. This "lowered the activation energy" quite a bit for a DIY neophyte like me to actually tackle this project.

Second, I'd like to thank aX and Jim Forte for Jim's article on "Fixing a Ho-Hum Crossover" (aX 10/01). Jim discovered a diamond in the rough in the Cambridge SoundWorks Model Six two-way bookshelf speaker. Again, his article was clear and simple enough (and the components cheap enough!) to convince someone like me to tackle it.

The crossover Jim designed dramatically improves the "reality" of the presentation by the little CSWs, but stays true to the "voicing" that Henry Kloss gave these little bookshelves. My daughter was looking for a stereo for her dorm room, and this fall she'll be enjoying a semi-home-made system consisting of the S-5 Electronics pp tube amp (also reviewed in aX) and the Forte-modified CSW Model Sixes. Thanks again and keep up the good work.

Mark R. Hardy
Harvard, Mass.

Jim Forte responds:

I would like to thank Mr. Hardy for his kind words and I am pleased that he found my article to be useful. Basic projects such as this one are perfect for "first timers" and will, I hope, inspire them to tackle more advanced projects in the future. audioXpress should continue to publish articles on all skill levels to attract the widest audience possible.

POWER REQUIREMENTS

K What is the background for the decision to provide unbalanced 120V AC power ("The AC Power Line and Audio Equipment," aX 9/01, 10/01, 2/02)? Does it go back to Westinghouse/Tesla days?

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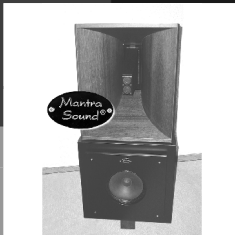
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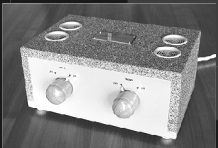
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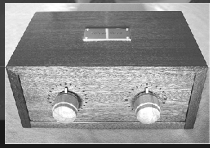


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power. Are there other solutions?

Aaron Shipow
San Jose, Calif.

Charles Hansen responds:

When 60Hz alternating current electric service first became widely available, it was used for "110V" lighting circuits, replacing the gas lighting then in use. The average fuse box had three 10A lighting circuits with knob and tube wiring. Once the power required for larger appliances (water heaters, electric ranges) exceeded 20A, the utilities began to furnish center-grounded, unbalanced "220V" (110v-0-110v) in order to service the higher power appliances and still maintain compatibility with the existing lighting circuits.

As to the number of additional solutions for audio power conditioning, a search on the Internet should provide the readers with the available products.

MAGNETIC SHIELDING

In Mr. Ferguson's article on a center channel speaker (aX 9/03, p. 24), he is forced into the situation of having to shield his drivers to prevent magnetic interference with the nearby TV. While most interference problems in electronics are due to magnetic coupling, rather than pure electrostatic coupling, the topic of magnetic shielding is one not normally studied by most technical people. While introducing a grounded plate between an interfering source and the bothered receiver can remove electrical coupling, it will not stop magnetic coupling.

I remember a dramatic demonstration of this many years ago. We had two cables in proximity that were showing crosstalk via magnetic coupling in the audio frequency range. Nearby was a scrap sheet of 3/4" thick steel, which we slid between the two offending cables, certain that this would annihilate any magnetic coupling. The shock came when the instrumentation showed the magnetic coupling greatly increased! This convinced us we needed a better understanding of magnet coupling.

I have listed two excellent books I found on the subject of shielding. Since I used them for many years and have now been retired for over a decade, I'm sure there are more recent editions available.

Staying with the very basics, the only way to obtain magnet shielding is to fully enclose either the source or receiver of the magnetic interference with a magnetic material. A good example is the shielded power transformer fully wrapped in a steel shell with as few penetrations as possible. When you stand a single plane of magnetic material between the interfering source and receiver it tends to just gather the flux and make the problem worse, as with our thick steel plate.

In Mr. Ferguson's case, placing the offending drivers in "cups" of magnetic material (Photo 4) is the proper approach. These cups should be as complete as possible with a minimum of openings. Deterioration of the shielding depends on the largest dimension of any opening, so a round hole or series of small holes is much better than any long, narrow slit. I must assume the drivers close the front of these cups to complete the magnetic enclosure.

I believe the bottom shielding shown in Mr. Ferguson's Photo 5 will be totally ineffective and may even be harmful. Since Mr. Ferguson points out this bottom shielding is the most expensive, I support his comment of building without the bottom shielding.

I compliment Mr. Ferguson on an interesting and informative article on developing a center speaker.

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GR Koonce
Liverpool, N.Y.

Dan Ferguson responds:

As a long-time reader of your numerous contributions in Speaker Builder, it is an honor to receive your favorable comments concerning my center channel speaker article.

Regarding your recommendation on the effectiveness of the bottom shield, I admit that I did not test this either before or after installing it in the cabinet. I was merely following the recommendations of the literature published by the material distributor.

I used three different alloys in my center

channel speaker. Each of them is purported to have a specific purpose. The bottom plate, called Mag-Stop®, is shown in the literature as being applied to a section of wall adjacent to a personal computer, which is supposedly shielding the PC from an electrical distribution panel on the other side of the wall. As shown, it does not encapsulate the electrical box, and the application is similar to how I applied it. Beyond that, I certainly make no claims as to its effectiveness.

The only reason I used this particular piece was that the location of the woofer magnet was so close to the picture tube yoke that I was concerned that any stray magnetism might cause a problem. Perhaps a more effective way to provide additional shielding to the woofer (which is probably not needed anyway) is to apply the shielding directly to the woofer magnet shield.

Again, thanks for your interest.

HELP WANTED

I have a Hafler DH 220 with a bad power transistor—a 2SK134 or a 2SJ49. I've tried some electronics parts companies mentioned in *audioXpress* but have had no luck. Lots of obsolete tubes, but no FETs. I'd hate to toss this amp on account of just one bad transistor, so I was wondering whether any readers could help me locate these transistors.

Bill Wallace
881 Sergeantsville Rd.
Stockton, NJ 08559
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(609) 397-9527

Shottky diodes appeared on the scene after I completed my courses in semiconductor physics and electronics, so I must admit I know nothing about them. I'd much appreciate a brief account of Shottky diodes relating their salient features and applications. I note that the Hagerman Bugle preamp power supply uses them throughout and that those in the bridge rectifier have no snubbers. ♦

A.J. Steen
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Readers with information on these topics are encouraged to respond directly to the letter writers at the addresses provided.—Eds

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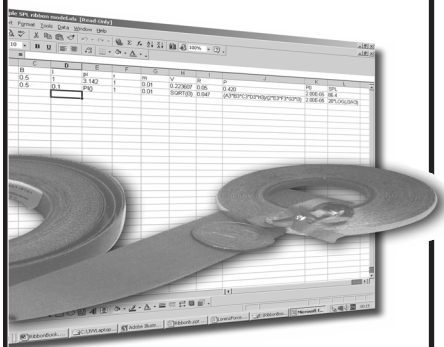


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2003 *audioXpress* Index Subject

ACOUSTICS

- "Acoustic Diffraction: Does it Matter?," James Moriyasu, February, p. 12.
- "Acoustical Shrinkage of Large into Small Rooms," Stephen Harner, July, p. 28.

AC-POWER

- "System Power Control," Frank S. Thomas III, August, p. 46.

AMPLIFIERS

- "Odyssey of a Line Stage, Part 1," David Davenport, February, p. 20.
- "Odyssey of a Line Stage, Part 2," David Davenport, March, p. 22.
- "A 6AS7/6080 Circlotron Amp," Monny Nisel, April, p. 32.
- "The SPP Amplifier," Helmut Otte, May, p. 4.
- "A MOSFET Update of the Forte 1A Amplifier, Part 1," Joe Berry, May, p. 10.
- "Showcase: A Headphone Amp," Klaus Noll, May, p. 52.
- "A MOSFET Update of the Forte 1A Amplifier, Part 2," Joe Berry, June, p. 60.
- "60W Triode/100W UL Control Amplifier," Joseph Norwood Still, June, p. 16.
- "An SE Class A Headphone Amp," Aren Van Waarde, June, p. 30.
- "Hybrid Solid-State Power Amplifiers," Charles Hansen, July, p. 6.
- "The DC Revenge E182CC Amplifier," Mauri Pännäri, July, p. 20.
- "Line-Transformer-Driven SV300B SE Amplifier," Satoru Kobayashi, July, p. 32.
- "Amplification Without Distortion, Recreating a 1920s Amplifier," Larry Lisle, July, p. 54.
- "Matt's Big Class A Amplifier," Matt Tucker, September, p. 6.
- "Showcase: Building Rozenblit's 80W OTL," Ignatius Chen, September, p. 69.
- "Zen Variations, Part 5, The Complimentary Zen," Nelson Pass, October, p. 6.
- "Modifying Peavey's TKO 80 Bass Amp, Part 1," Charles Hansen and G.R. Koonce, October, p. 16.
- "Amplifier Burst Testing," John L. Stewart, November, p. 30.
- "Restoration of Peavey TKO 80 Bass Amp, Part 2," Charles Hansen and G.R. Koonce, November, p. 40.
- "Build a Boosted Triode Amplifier," Larry Lisle, December, p. 8.

AUDIO AIDS

- "A Balanced Op-Amp Driver," A.J. van Doorn, March, p. 72.
- "A 1¢ Diffraction Detector," Mark Hotchkiss, April, p. 69.
- "Current-Regulated Heater Supplies," Michael Kornacker, April, p. 72.

BASS

- "Optimizing Frequency Response in the Bass Range," Marc Bacon, February, p. 36.
- "Bass in Small Places," Dick Pierce, March, p. 32.

BOOK REVIEWS

- Master Handbook of Acoustics, Fourth Edition*, Duncan MacArthur, April, p. 67.
- Loudspeaker and Headphone Handbook*, Richard Honeycutt, May, p. 68.
- Opamps for Everyone*, Jan Didden, July, p. 72.
- Pro Audio Reference*, Bill Fitzmaurice, September, p. 68.

CD PLAYERS

- "A De-Emphasis Fix for the D2D-1," Gary Galo, January, p. 46.
- "Upgrade Rotel's 970BX CD Player," Charles Hansen, February, p. 26.

COMPUTER MODELING AND DESIGN

- "Easy Layouts and Other CAD Tricks," Patrick M. Brunner, January, p. 36.

CROSSEOVERS

- "Tube-Based Crossovers," John R. Broskie, September, p. 16.

EDUCATION/INFO

- "The ABCs of Filters, Part 1," Richard Honeycutt, September, p. 38.
- "The Soap Factor," Benjamin L. Poehland, October, p. 28.
- "The ABCs of Filters, Part 2," Richard Honeycutt, October, p. 50.

ELECTRONICS TIPS AND TECHNIQUES

- "Tools, Tips, and Techniques: Quick Desoldering," Paul Whiteman, January, p. 72.
- "Techniques and Gadgets for Audio Experimenters," Larry Lisle, March, p. 48.
- "Audio Uses of Transformers," Peter Buddee, May, p. 50.

"Faster, Straighter, Nicer," Hilary Paprocki, July, p. 48.
 "DC Protection and Switch-On Delay for Power Amps," Jenoe Keceli, September, p. 34.
 "Tools, Tips, and Techniques: Free Filament and Bias Voltage," Patrick M. Brunner, October, p. 68.

HORNS

"The DR15A Horn," Bill Fitzmaurice, January, p. 16.
 "The DR5 Horn," Bill Fitzmaurice, July, p. 10.
 "Extending the 30" Tractrix Horn," Robert Roggeveen, August, p. 20.

LOUDSPEAKERS

"Build a Plasma Tweeter," Colin Joye, April, p. 4.
 "The Legend of El Pipe-O," Kent English and Nelson Pass, May, p. 22.
 "Simple Satellites, Part 1," G.R. Koonce and R.O. Wright, Jr., May, p. 32.
 "An Affordable Full-Range Speaker Project," Peter Millett, June, p. 6.
 "Simple Satellites, Part 2," G.R. Koonce and R.O. Wright, Jr., June, p. 44.
 "Care and Maintenance of Dukane Ionovac Tweeters," Daniel Schoo, August, p. 50.
 "Showcase: An Italian THOR," Atto Rinaldo, August, p. 58.
 "A Center Channel Speaker: A Different Approach," Daniel L. Ferguson, September, p. 24.
 "An Unorthodox Two-Way, Part 1," Jon Mark Hancock, September, p. 46.
 "An Unorthodox Two-Way, Part 2," Jon Mark Hancock, October, p. 40.
 "A Servo Dual Voice Coil Subwoofer," Daniel L. Ferguson, November, p. 18.
 "An Unorthodox Two-Way, Part 3," Jon Mark Hancock, November, p. 50.
 "Ask aX: Box Design," G.R. Koonce, November, p. 68.
 "A Hageman Subwoofer," Cornelius Morton, December, p. 12.
 "Why Speakers Have Slanted Fronts," G.R. Koonce, December, p. 38.

MISCELLANEOUS

"A 6-Channel Volume/Balance Control," Dennis Colin, February, p. 6.
 "Inductive RIAA Compensation," Darcy E. Staggs, February, p. 40.
 "A Hybrid Stereo \$90 Control," Joseph Norwood Still, April, p. 22.
 "Make a Panel-Cutting Jig," Bill Fitzmaurice, April, p. 38.
 "Guest Editorial: Detrashing Television," Darcy E. Staggs, June, p. 4.

"Digital Measurements of the Thiele/Small Parameters," Oliver H. McDaniel, June, p. 24.
 "Flared Ports," Hilary Paprocki, November, p. 28.
 "Making Your Own Rubber Surrounds," Angel Luis Rivera, December, p. 30.
 "Glass Shards: Four Unusual Electro-Voice Amps," Lance Cochrane, December, p. 69.

NEW CHIPS ON THE BLOCK

BY CHARLES HANSEN

"AKM AK4363 and AK4364," May, p. 67.
 "AK4358," June, p. 72.
 "AKM AK4395 and AK4554," August, p. 72.
 "TI 1394a-2000, TSB43CA43A, and AD 1896," September, p. 72.
 "PMD-200 and AKD1833/AD1836," October, p. 72.
 "AD 1959 and Weber Copper Caps," November, p. 69.

PREAMPLIFIERS

"Passive Phono Preamps: Design Constraints," Paul J. Stamler, March, p. 38.
 "A Tube Preamp for Computer Soundcards," Graham Dicker, June, p. 36.
 "Borbely's RIAA Preamp with Tubes," Joe Tritschler, October, p. 36.
 "Adcom's GFP-565 Preamplifier, Part 1," Gary Galo, November, p. 6.
 "Adcom's GFP-565 Preamplifier, Part 2," Gary Galo, December, p. 42.

PRODUCT REVIEWS

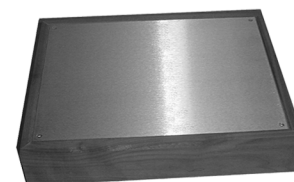
"Monarchy DIP Upsampler," Gary Galo, January, p. 56.
 "Building Adire's HE10.1 High Efficiency Coaxial," Edward T. Dell, Jr., February, p. 42.
 "Building Adire's HE10.1, Listening Critique," Dennis Colin, February, p. 46.
 "Building Adire's HE10.1, Test Report," Joseph D'Appolito, February, p. 46.
 "Behringer DSP8024," Charles Hansen, February, p. 52.
 "Behringer DSP8024, Critique," Bill Fitzmaurice, February, p. 54.
 "Beyond Thiele/Small—Dumax and Klippel Driver Measurement Systems," Thomas Perazella, March, p. 50.
 "Constructing the SEAS Froy MK3," Edward T. Dell, Jr., March, p. 60.
 "Testing the SEAS Froy MK3," Joseph D'Appolito, April, p. 57.
 "SEAS Froy MK3, Listening Critique," Dennis Colin, April, p. 58.
 "Budget Phono Preamps," Charles Hansen, April, p. 40.



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"Budget Phono Preamps, Listening Critique,"

John and Sandra Schubel, April, p. 52.

"Marchand PM48 Computer Amp," Charles Hansen, July, p. 58.

"Marchand PM48 Computer Amp, Listening Critique," Duncan and Nancy MacArthur, July, p. 60.

"DACT CT 102 Power Supply," Charles Hansen, October, p. 56.

"Onkyo DV-SP8000 SACD and DVD Audio Video Player," Gary Galo, December, p. 52.

TEST EQUIPMENT

"A Digital POOGIE for HP's 339A Test Set," Charles Hansen, March, p. 16.

"Capacitor ESR Tester—the Good, the Bad, and the Leaky . . .," Flemming Jensen, April, p. 14.

"Budget Milliohmometer Bridge," Charles Hansen, May, p. 18.

"Build a Reactive Load," Dick Crawford, August, p. 48.

TRANSMISSION LINES

"A Small Reflex TL," Matt Hills, March, p. 6.

"Alpha Transmission Lines," Rick Schultz, August, p. 34.

TUBES

"Direct Heaters: A Guided Tour," Mark Kelly, January, p. 28.

"High G_M Smart Power Tubes, Part 3," Stefano Perugini, January, p. 48.

"JJ Electronics' ECC99: A New Power Triode Driver," Hans Bubeck, February, p. 32.

"Vintage Glass: Neglected Power Tube," J.L. Markwalter, February, p. 72.

"Disposable Camera = Tube Power," Graham Dicker, May, p. 46.

"Phase Inverter Design," Adriaan Hammer, September, p. 56.

"More on Heater Problems, Tube Flash, and Electron Emission," Bernard Magers, November, p. 34.

"Glass Shard: Mu Stage Split-Load Phase Inverter," courtesy of D.G. Wilson, November, p. 72.

"Considering Negative Feedback," Dennis Colin, December, p. 24.

TUNERS

"A Simple, High Quality AM Tube Receiver," Scott K. Reynolds, August, p. 6.

"Improving Dynaco's FM-5 and AF-6 Tuners," Daniel Dufresne, August, p. 28.

TURNTABLES

"The LP Terminator," Raymond A. Futrell, January, p. 8.

TRANSFORMERS

"The Zero Autoformer," Paul Speltz, January, p. 38.

"Vintage Glass: Merit Output Transformer," Reed Hurley, May, p. 72.

Author

BACON, MARK

"Optimizing Frequency Response in the Bass Range," February, p. 36.

BERRY, JOE

"A MOSFET Update of the Forte 1A Amplifier, Part 1," May, p. 10.

"A MOSFET Update of the Forte 1A Amplifier, Part 2," June, p. 60.

BROSKIE, JOHN R.

"Tube-Based Crossovers," September, p. 16.

BRUNNER, PATRICK M.

"Easy Layouts and Other CAD Tricks," January, p. 36.

"Tools, Tips, and Techniques: Free Filament and Bias Voltage," October, p. 68.

BUBECK, HANS

"JJ Electronics' ECC99: A New Power Triode Driver," February, p. 32.

BUDDEE, PETER

"Audio Uses of Transformers," May, p. 50.

CHEN, IGNATIUS

"Showcase: Building Rozenblit's 80W OTL," September, p. 69.

COCHRANE, LANCE

"Four Unusual Electro-Voice Amps," December, p. 69.

COLIN, DENNIS

"A 6-Channel Volume/Balance Control," February, p. 6.

"Building Adire's HE10.1, Listening Critique," February, p. 46.

"SEAS Froy MK3, Listening Critique," April, p. 58.

"Considering Negative Feedback," December, p. 24.

CRAWFORD, DICK

"Build a Reactive Load," August, p. 48.

D'APPOLITO, JOSEPH

"Building Adire's HE10.1, Test Report," February, p. 46.

"Testing the SEAS Froy MK3," April, p. 57.

DAVENPORT, DAVID

"Odyssey of a Line Stage, Part 1," February, p. 20.

"Odyssey of a Line Stage, Part 2," March, p. 22.

DELL, JR., EDWARD T.

"Building Adire's HE10.1 High Efficiency Coaxial," February, p. 42.

"Constructing the SEAS Froy MK3," March, p. 60.

DICKER, GRAHAM

"Disposable Camera = Tube Power," May, p. 46.

"A Tube Preamp for Computer Soundcards," June, p. 36.

DIDDEN, JAN

Book Review: *Opamps for Everyone*, July, p. 72.

DUFRESNE, DANIEL

"Improving Dynaco's FM-5 and AF-6 Tuners," August, p. 28.

ENGLISH, KENT

"The Legend of El Pipe-O," (with Nelson Pass), May, p. 22.

FERGUSON, DANIEL L.

"A Center Channel Speaker: A Different Approach," September, p. 24.

"A Servo Dual Voice Coil Subwoofer," November, p. 18.

FITZMAURICE, BILL

"The DR15A Horn," January, p. 16.

"Behringer DSP8024, Critique," February, p. 54.

"Make a Panel-Cutting Jig," April, p. 38.

"The DR5 Horn," July, p. 10.

Book Review: *Pro Audio Reference*, September, p. 68.

FUTRELL, RAYMOND A.

"The LP Terminator," January, p. 8.

GALO, GARY

"A De-Emphasis Fix for the D2D-1," January, p. 46.

"Monarchy DIP Upsampler," January, p. 56.

"Adcom's GFP-565 Preamp, Part 1," November, p. 6.

"Adcom's GFP-565 Preamp, Part 2," December, p. 42.

"Onkyo DV-SP800 SACD and DVD Audio Video Player," December, p. 52.

HAMMER, ADRIAAN

"Phase Inverter Design," September, p. 56.

HANCOCK, JON MARK

"An Unorthodox Two-Way, Part 1," September, p. 40.

"An Unorthodox Two-Way, Part 2," October, p. 46.

"An Unorthodox Two-Way, Part 3," November, p. 50.

HANSEN, CHARLES

"Upgrade Rotel's 970BX CD Player," February, p. 26.

"Behringer DSP8024," February, p. 52.

"A Digital POOGIE for HP's 339A Test Set," March, p. 16.

"Budget Phono Preamps," April, p. 40.

"Budget Milliohm Bridge," May, p. 18.

"New Chips: AKM AK4363 and AK4364,"

May, p. 67.

"New Chips: AK4358," June, p. 72.

"Hybrid Solid-State Power Amplifiers," July, p. 6.

"Marchand PM48 Computer Amp," July, p. 58.

"New Chips: AKM AK4395 and AK4554," August, p. 72.

"New Chips: TI 1394a-2000, TSB43CA43A, and AD 1896," September, p. 72.

"Modifying Peavey's TKO 80 Bass Amp, Part 1," (with G.R. Koonce), October, p. 16.

"DACT CT 102 Power Supply," October, p. 56.

"New Chips: PMD-200 and AKD1833/AD1836," October, p. 72.

"Restoration of Peavey TKO 80 Bass Amp, Part 2," (with G.R. Koonce), November, p. 40.

"New Chips: AD 1959 and Weber Copper Caps," November, p. 69.

HARNER, STEPHEN

"Acoustical Shrinkage of Large into Small Rooms," July, p. 28.

HILLS, MATT

"A Small Reflex TL," March, p. 6.

HONEYCUTT, RICHARD

Book Review: *Loudspeaker and Headphone Handbook*, May, p. 68.

"The ABCs of Filters, Part 1," September, p. 38.

"The ABCs of Filters, Part 2," October, p. 50.

HOTCHKISS, MARK

"Audio Aid: A 1¢ Diffraction Detector," April, p. 69.

HURLEY, REED

"Vintage Glass: Merit Output Transformer," May, p. 72.

JENSEN, FLEMMING

"Capacitor ESR Tester—the Good, the Bad, and the Leaky . . .," April, p. 14.

JOYE, COLIN

"Build a Plasma Tweeter," April, p. 4.

KECELI, JENOE

"DC Protection and Switch-On Delay for Power Amps," September, p. 34.

KELLY, MARK

"Direct Heaters: a Guided Tour," January, p. 28.

KOBAYASHI, SATORU

"Line-Transformer-Driven SV300B SE Amplifier," July, p. 32.

KOONCE, G.R.

"Simple Satellites, Part 1," (with R.O. Wright, Jr.), May, p. 32.

"Simple Satellites, Part 2," (with R.O. Wright, Jr.), June, p. 44.

"Modifying Peavey's TKO 80 Bass Amp, Part 1," (with Charles Hansen), October, p. 16.

"Restoration of Peavey TKO 80 Bass Amp, Part 2," (with Charles Hansen), November, p. 40.

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"Simple Satellites, Part 2," (with G.R. Koonce), June, p. 44.

Glass Shard

Four Unusual Electro-Voice Amps

Many of us enjoy tube hi-fi for its exotic allure. In tube circuits we can find the common, as well as the road less traveled. While the unusual does not necessarily sound any better than the mundane, departures from the every day do have the charm of novelty. Don't be deceived by a fancy faceplate or a high price into thinking the product is necessarily exotic.

These schematics show (here and on the aX web site) amplifiers that truly are different (Fig. 1). You would not suspect from the outside appearance (Photo 1) that these amplifiers are other than standard design old tube models. I would wager that a number of readers have these amplifiers sitting neglected on their shelves, forgotten and disregarded. Don't judge an amp by its faceplate.

A cathode-follower output stage is a rare animal indeed. In this configuration the output transformer is driven not from the plates of the output tubes,

but from the cathodes. Manufacturers could not just use off-the-shelf parts to make these units; special order was necessary. As a result these items are rare, but not as rare as you might think.

Electro-Voice, a major manufacturer, made many collectable speakers sought after in today's secondary mar-

ket. The company also made a lot of electronics that currently are not particularly sought after. This is curious considering the innovative circuitry used. The four schematics here and on the website are for Electro-Voice amplifiers using cathode-follower output stages. I

(continued on page 72)

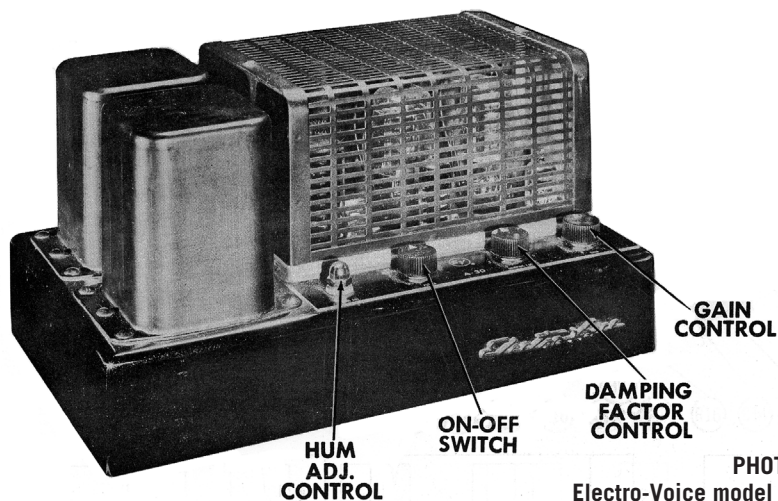
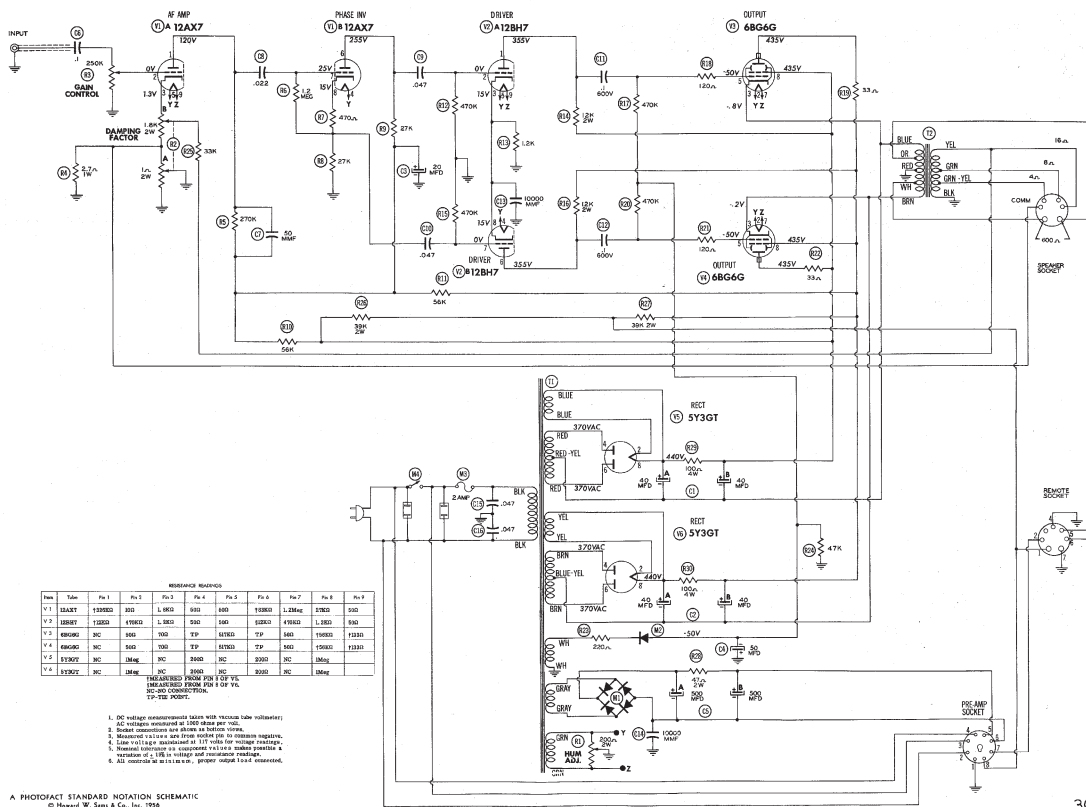


PHOTO 1:
Electro-Voice model A30.



304-6

FIGURE 1: A30 circuit. (Photos and schematics reproduced with express written permission from Sams Technical Publishing LLC.)

Glass Shard

from page 69

have provided schematics for four types of output tubes: 6BG6, 1614 (a 6L6 variant), 6V6, and 6BQ5.

The ambitious amateur thinking about building one of these units from the schematic may wish to reconsider. Each unit requires either two separate

power supplies or the special power transformer used in the original. The output transformer primary winding for the four tubes shows respective impedances of: 1030 Ω , 1600 Ω , 2000 Ω , and 1600 Ω . Certainly these are available for a special-order price.

More to the point, quite a few of these units were manufactured. The circuit in its variations is truly exotic, and the 6V6 or 6BQ5 models should only

claim modest prices on today's market. Prefer something truly different? Track a few of these down and let me know what you think. ♦

Submitted by Lance Cochrane
San Francisco, Calif.

For more schematics of the Electro-Voice amplifiers in this series, visit our web site, www.audioXpress.com/ax/addenda/

Onkyo DVD Player

from page 57

counterparts on this player. The DVD-Audio transfers reveal more of the ambience of the original recording venues, with better spatial characteristics and greater depth. They also sound more open and airy compared to the CDs, and exhibit greater low-level detail.

When an SACD transfer has been badly done, such as Sony Classical's *Bernstein Conducts Bernstein*, the DV-SP800 is a good enough CD player to reveal the superiority of Sony's CD transfer over the more recent SACD (see the sidebar for more details). When Deutsche Grammophon re-mastered Carlos Kleiber's outstanding performances of Beethoven's Fifth and Seventh Symphonies for their series "The Originals" (447 400-2), they used their "Original Image Bit Processing" during re-mix to reveal a sense of depth from

their over-miked, multi-track analog masters missing from previous incarnations of these recordings. Although the SACD is smoother and more extended in the treble, there is less depth than on the CD. The Onkyo is able to reveal the virtues and shortcomings of both transfers. Although the DV-SP800 is not a world-beater CD player, it does a respectable job of revealing the essential characteristics of individual recordings.

For those who own an outboard D/A converter, I am pleased to report that the DV-SP800 is an excellent transport. Feeding my Parts Connection D2D-1/DAC 3.0, CD playback is stunning: open, airy, and spacious, with superb inner detail and very smooth midrange and treble. DVD-Audio playback is also substantially improved through the outboard processors, though the limitations of the discs themselves are still apparent. With an outboard processor, you will still need to make an analog connection to your preamp for SACD play-

back, but all other formats can take full advantage of outboard D/A conversion.

As a transport, it may very well be better than the one you're now using. I attribute the player's excellent performance as a transport to its solid construction and the use of conventional, non-switching power supplies. I suspect, but can't verify, the use of a low-jitter clock, as well.

CONCLUSIONS

The Onkyo DV-SP800 represents a price breakthrough in multi-format DVD players. Although separate players for each format would yield superior performance, buying three separate players would also cost much more. The DV-SP800 packs a great deal into an under-\$1000 package, and will probably be hard to beat in this price range. If you already own a good outboard digital processor, the DV-SP800 will give you an excellent transport, while adding SACD and DVD-Audio capability. ♦

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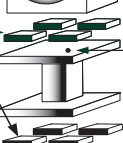
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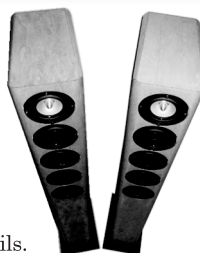
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WANTED

Service manual or schematic for Bang and Olufsen BeoCord 5000 and A.D.S. model C2 audio cassette decks. Also want original RCA 45 RPM record changer from 1940s/50s. Prefer working but will consider any condition. Ron Tipton, 5260 Cochise Trail, Las Cruces, NM 88012, 505-382-3173, RTipton@zianet.com.

Operating/service manuals for Nakamichi 700 II cassette recorder. Will pay copy costs. Harry Liber, 10201 No. 99 Ave. Lot B50, Peoria, AZ 85345.

Another Milestone

from page 6

In 1991 we began publishing a U.S. edition of *Elektor Electronics*, a reprint of the British version of one of Europe's premier do-it-yourself electronics publications. Although reader response was excellent, our advertising staff, at that time, was unequal to the task. After two years we ceased publication. We also attempted a newsletter for the tube industry without success, but our annual *World Tube Directory* has flourished very well since 1995.

In 2001 we combined *Audio Electronics*, *Speaker Builder*, and *Glass Audio* into a single periodical, *audioXpress*, which after three years is now a well-accepted journal for those who like to know how audio equipment works and how to build it.

As I write this we are preparing to

launch a new business periodical for audio/video product managers who are facing a new world of changed realities where very little A/V hardware is still being manufactured outside of the Pacific rim. *Multi Media Manufacturer's* first issue will mail in December of 2003.

I hope you will help us celebrate our 35th year of technical publishing in 2004. We have made many thousands of friends who have subscribed to our offerings—some for decades. I am also very grateful to our over 800 authors from all over the world who make the content possible. I am also deeply grateful to our staff who work with such diligence, competence, and enthusiasm to make the Audio Amateur Inc. enterprise work so well.—E.T.D. ♦

AD INDEX

ADVERTISER	PAGE	ADVERTISER	PAGE	ADVERTISER	PAGE
ACO Pacific Inc	49	K&K Audio	67	Welborne Labs	13
Adire Audio	67	KAB Electro-Acoustics	50	World Audio Design.....	47
Alpha Core	11	Kimber Kable/WBT-USA	4,5	Zalytron Industries.....	72
All Electronics	51	Laboratoire, JC Verdier	29		
Antique Radio Classified	55	Langrex Supplies.....	45	CLASSIFIEDS	
Audio Amateur Corp.		LC Audio Technology ApS	15	American Science & Surplus.....	70
<i>audioXpress gift subscription</i>	56	Liberty Instruments	21	Aspen Amplifiers	70
AAI Owner Statement	68	Linear Integrated Systems	59	Audio Classics LTD	70
Classifieds	70	Madisound Speakers.....	22	Audio Electronic Supply	70
<i>Old Colony Sound Lab Catalog</i>	61	Marchand Electronics	66	Borbely Audio.....	70
<i>Ribbon Loudspeakers</i>	64	MCM Electronics	10	Classified Audio-Video	70
<i>Sounds Cylindrical Music CD</i>	36	North Creek Music Systems	35	Creative Sound Solutions	70
Audio Consulting	61	Parts Connexion	43	E-Speakers	70
Audio Electronic Supply	1	Parts Express Int'l., Inc.	CV4	James M. Lawrence	70
Audio Transformers.....	49	Pass Laboratories	59	Faraday Sound	70
audioasylum.com	33	Plitron Manufacturing	41	Klein Tech Systems.....	70
Avel Lindberg Inc.....	66	Reliable Capacitor.....	11	London Power	70
Cardas Audio	CV3	Rhintek	19	Per Madsen Design.....	70
Chelmer Valves	27	Rockler Woodworking & Hardware	63	Precision Sound Products	70
Classified Audio-Video	65	Rotac électronique	65	OZ Enterprises	70
Diamond Groove	62	Selectronics.....	39	Sonic Craft.....	70
Dynasonic Ltd	68	Sencore	37	Southwest Electronics	70
E-Speakers.....	CV2	Solen, Inc.	7	TDL Technology	70
EIFL	31	Speaker City USA	63	Thorens of America	70
Electus Distribution Pty Ltd	60	Swans Speakers	17	Vintage Hi-Fi	70
S-5 Electronics	57	Test Equipment Depot.....	41	Welborne Labs	70
Hammond Manufacturing	25	The Last Factory	60	WR Smitherman	70
Harris Technologies	23	Thetubestore.com	58		
Hi Fi Do Inc	35	Usher Audio.....	9		
House of Tubes	48	Vidsonix.....	62		
JENA Labs	53	WBT-USA/ Kimber Kable	4,5		