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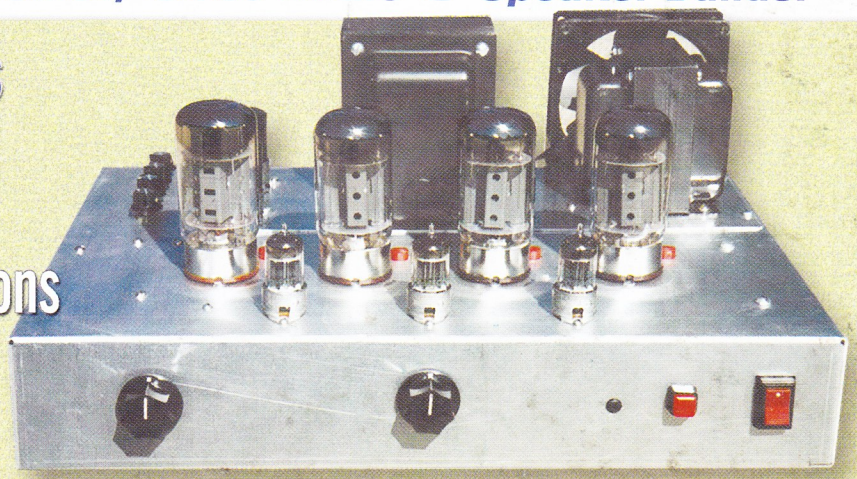

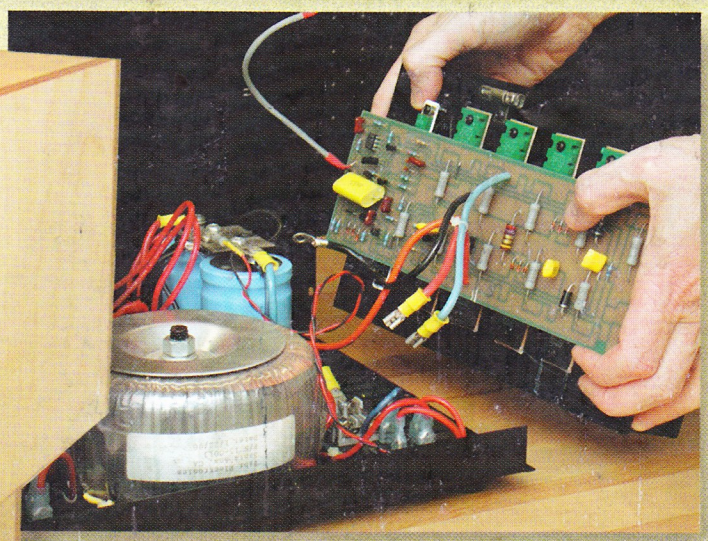

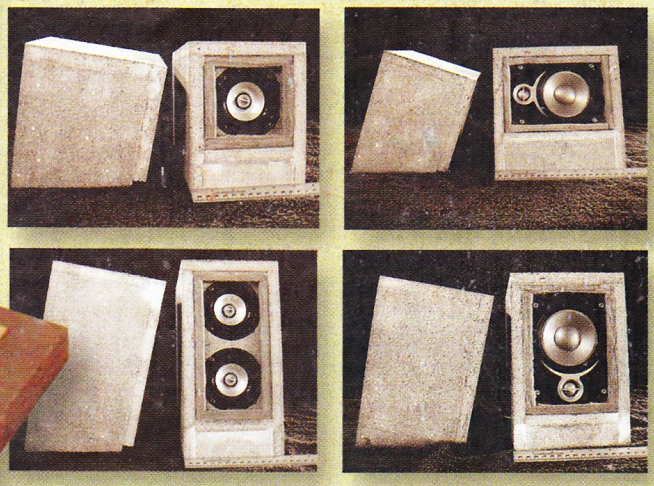

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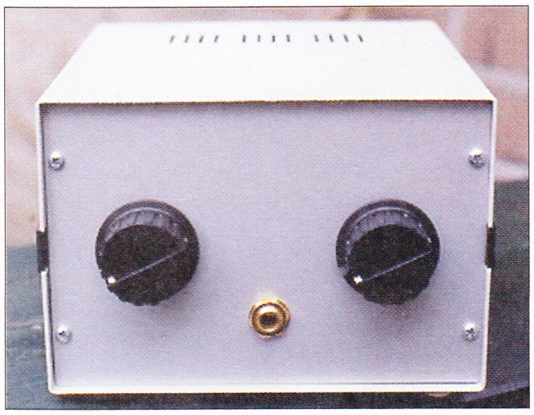

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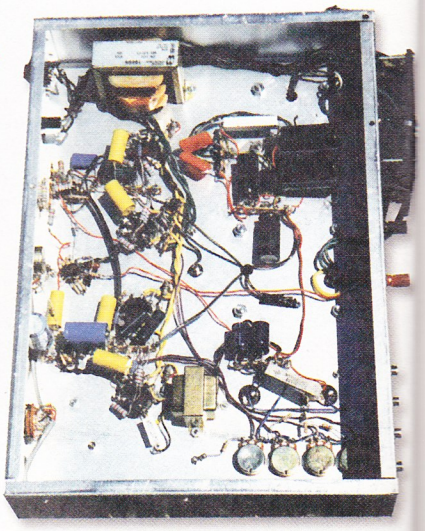

audioXpress (US ISSN 0004-7546) is published monthly, at $34.95 per year, $58.95 for two years. Canada add $12 per year; overseas rates $59.95 per year, $110 for two years; by Audio Amateur Inc., Edward T. Dell, Jr., President, at 305 Union St., PO Box 876, Peterborough, NH 03458-0876. Periodicals postage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

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

An Affordable Full-Range Speaker Project

The author demonstrates why you don't need to build a complicated enclosure to use full-range drivers. **By Pete Millett**

I've been interested in full-range drivers for a while. I built a small TQWP (tuned quarter-wave pipe) design I found on the Internet, using 3″ full-range drivers, and was impressed with how they sounded. And just for fun, I put some little Radio Shack drivers into ported boxes, and again was amazed at how they sounded. So, I decided it was time for a serious attempt at a full-range speaker (*Photo 1*).

I looked at many designs and quite a few different drivers. The "classic" full-range speaker looked as though it would be a Lowther driver in a big back-horn enclosure. These drivers were a bit out of my price range, though, so I focused on the more affordable drivers available from Fostex.

Most of the enclosure designs I ran across for these drivers were either back horns, or TQWPs. I don't have anything against them (I've heard many that I thought sounded wonderful) but I found the simplicity of a vented box appealing. I'm no speaker expert, and I thought that this would be the easiest configuration for me to understand.

I was happy to find that there are full-range drivers available designed to work in a simple vented box. In fact, the least expensive series of full-range drivers from Fostex are all specified to work this way.

WHY FULL-RANGE?

Full-range speakers aren't for everybody. I'll discuss some of the good and bad points about them, as compared to a conventional two-way (woofer and tweeter) speaker.

First, the advantages:

Since a full-range speaker is, well, full-range, you don't need any kind of crossover network to split the incoming audio to different drivers. In most cases, the output of the amplifier just hooks up to the two speaker terminals—nothing there but wire. This removes all the potential for phase and amplitude anomalies caused by a crossover network. I think that getting a crossover right is probably the hardest part of designing a multi-way speaker.

Since all frequencies originate from the same source, there are no temporal or spatial issues with alignment of multiple drivers. It can be difficult to blend the sound from multiple drivers correctly, since some distance separates them on the baffle of the speaker. This can cause imaging anomalies, and perhaps is the reason why many listeners find the imaging of single-driver speakers superior.

Last, partly because of the lack of any crossover, you can usually build full-range systems for less money than a comparable multi-way speaker.

Now for the disadvantages:

At high frequencies, most full-range drivers are very directional, much more so than a good tweeter. This "beaming" makes for a very definite "sweet spot" to listen from, with the sound becoming progressively duller as you go off-axis.

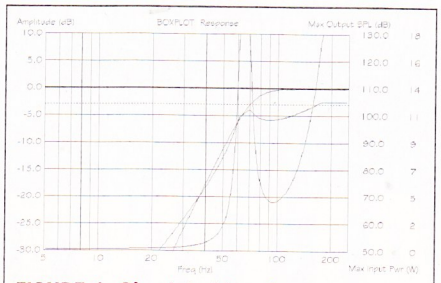

FIGURE 1: Simulated low-frequency response (using FE-164) using Boxplot software. B-2224-1

In order to reproduce high frequencies, you must make some tradeoffs that limit the amount of cone excursion the speaker can accomplish, as well as limiting the maximum cone diameter. The end result is that full-range drivers are somewhat limited in their ability to reproduce very loud, low-frequency bass notes.

For me, the advantages outweigh the disadvantages. I'm not a big fan of bass that shakes the room, and I tend to listen in a room where I can position the speakers—and my chair—exactly where I want them. For these limita-

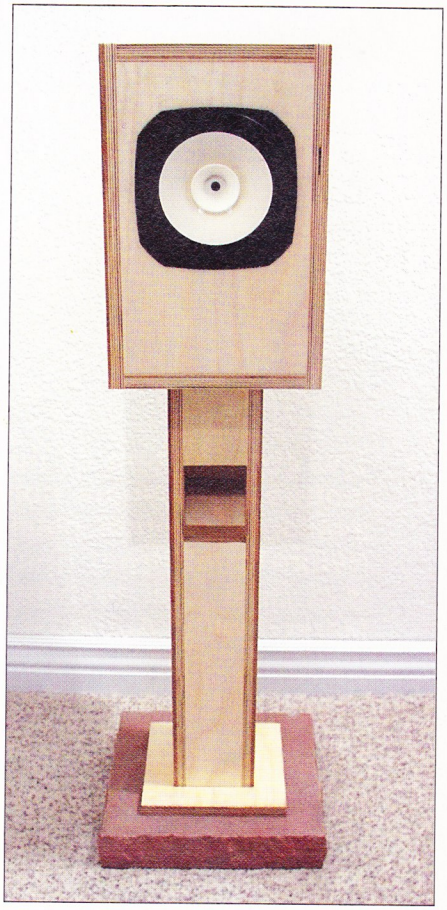

PHOTO 1: The finished speaker (front view).

tions, I'm rewarded with a clear, live sound and excellent imaging, for a low price.

THE DESIGN

I searched the Internet for full-range, bass-reflex designs, and didn't find very many. The most interesting was a "recommended enclosure" design published by Fostex for their FE-167E, a 6″ full-range driver. The enclosure was a floor-standing unit, which used part of the "stand" as the port.

I loaded the appropriate data into Boxplot, an excellent (and affordable) speaker-box plotting program, to examine the response of the Fostex box. It seemed too small, and had a fairly high resonant frequency. I think Fostex did this to ensure that the low-frequency power handling wasn't too limited; as noted previously, these speakers don't have a lot of cone travel, and if you design a box with a very low resonance, it would move too far with high-amplitude bass notes.

Retaining the 6″ Fostex driver, I opted for a box volume and tuning much closer to the "optimal" QB3 alignment for the speaker. I ended up with a

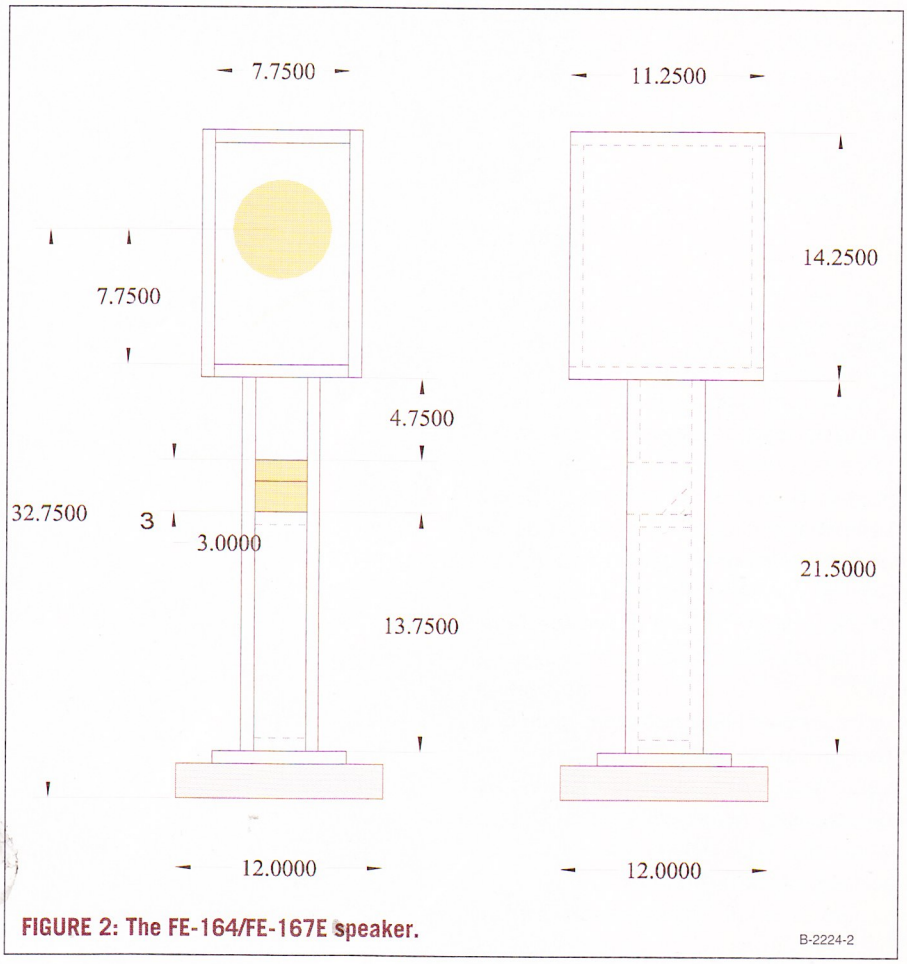

FIGURE 2: The FE-164/FE-167E speaker.

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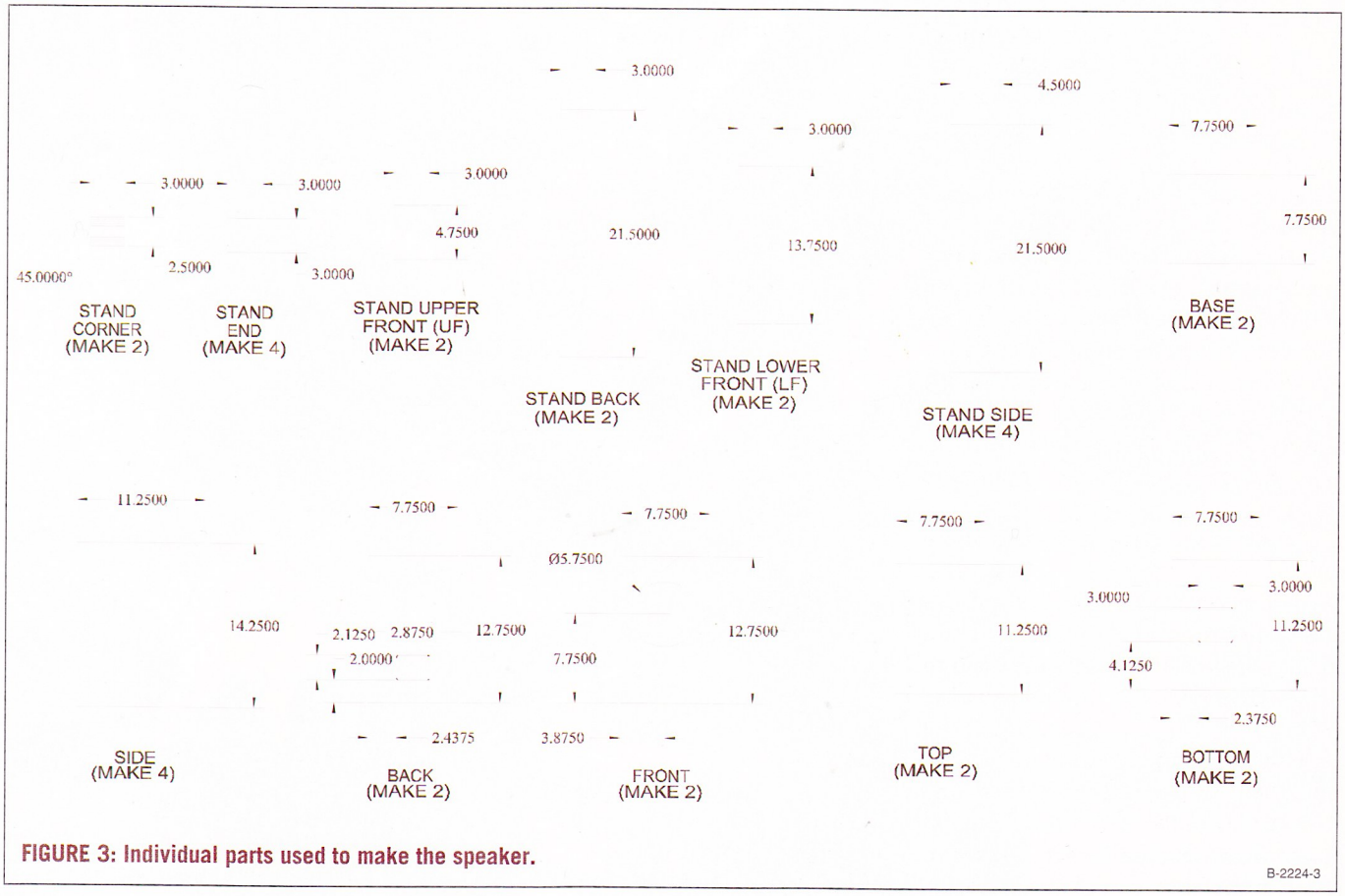

FIGURE 3: Individual parts used to make the speaker.

B-2224-3

design that called for 0.52ft^3 of volume and a box tuning frequency of 65Hz. The Boxplot simulation (*Fig. 1*) showed the bass response of the box to be –3dB at 70Hz.

I used the FE-164 driver instead of the FE-167E. They are very similar, and the FE-164, though recently discontinued by Fostex, was cheaper ($45.25 each at Madisound), and still available. It also had the advantage of a larger X_{MAX}, which allows it (on paper) to handle a little more power in the low bass. I think that you could use either driver in this design with equal success.

I kept the same general design as the Fostex box, using a stand to form the port. I made the stand tall enough to place the centerline of the driver at about the same height above the floor as my ears, sitting in my usual listening chair. I also added a sandstone base to the bottom of the speaker, in place of a plywood square.

Figure 2 shows the speaker assembly and overall dimensions.

CUTTING THE WOOD

I chose Baltic birch plywood for the speaker. You could also build it out of MDF or other material, but I like the looks—and sound—of the birch plywood. It costs a bit more than some other materials, but you need only one sheet. I spent about $50 for a sheet at a local store.

Figure 3 shows the dimensions of all the individual parts that you need to cut, and *Fig. 4* shows how I laid out these pieces on a 5′ × 5′ sheet of ¾″ (actually, 19mm) thick Baltic birch. Note the dotted line down the center of the sheet; I had the store where I bought the plywood cut it down the middle for me. This makes it much, much easier for one person to handle on the table saw.

I laid the parts out so that you cut the sheet the full length into seven parts. Then cross-cut these parts to get the final finished parts. I cross-cut the smaller pieces on a miter saw; I had to cut the bigger ones on the table saw.

I've found it much easier to cut the parts that are on the "outside" of a glue joint about 1/16″ larger than needed, and then use my router with a flush-trim bit to remove the excess. This guarantees a nice flush outside joint. This is especial-

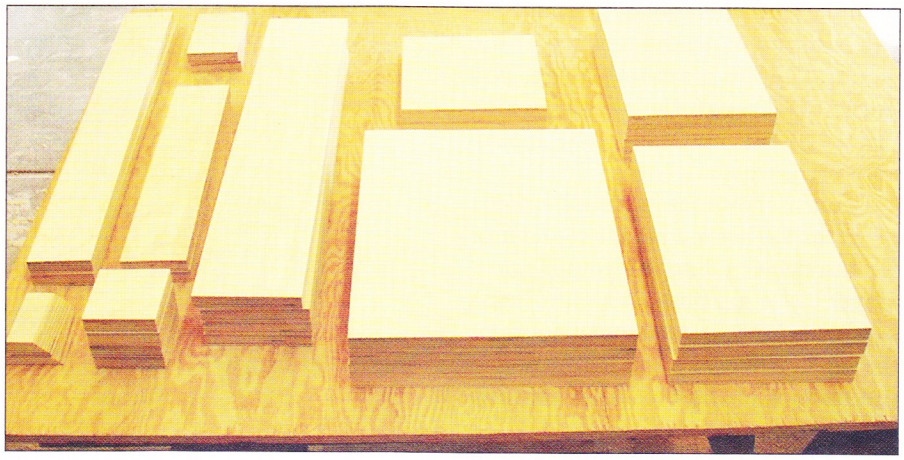

PHOTO 2: The cut-out parts.

ly important when using plywood, because if you sand the surface of the wood to make a smooth edge, you might go through the veneer, which messes up the otherwise pretty appearance of the wood.

Photo 2 shows the parts all cut out, ready for the holes. I cut the round hole for the driver using the router and a Jasper circle jig. I used a reciprocating saw to make the rectangular holes for the input connectors and for the port at the bottom of the box, after drilling holes in the corners.

One last detail is to install T-nuts or threaded inserts to attach the driver. I just set the driver into the hole, centered it, and marked the hole locations with a pencil. I then drilled holes on the drill press and installed the fasteners. I used 8-32 threaded inserts, which install into a ¼″ blind hole ½″ deep.

ASSEMBLY

Assembly is a simple process of gluing the pieces together. I began with the stand (*Photos 3* and *4*). First, glue the bottom part together. When it is dry, mate it with the sides and upper front piece. Note that the bottom section is a closed box, while the upper section is open at the top. This upper section is the port for the speaker.

Once the glue has dried on the stand, fill it with sand, which not only helps weigh the bottom of the speaker down to make it more stable, but it also prevents it from becoming a resonant cavity. I drilled a small hole in the bottom of the stand and filled it with "play sand" from a local home improvement store (*Photo 5*). It took a lot of tapping with a hammer to settle the sand, but eventually I got as much in as I could, and sealed it closed by gluing—and screwing—the base onto the end of the stand.

With the stands finished (*Photo 6*), box assembly is next. First, glue the top and bottom (with the hole cut for the port) to the front and back (*Photo 7*). Next, before closing the box, attach it to the open end of the stand using glue and screws (*Photo 8*).

The insides of the boxes are covered in ⅜″ thick wool felt. The material that I used is called "F-13 gray felt," which I purchased from McMaster-Carr, an industrial supply house. Cut the felt to

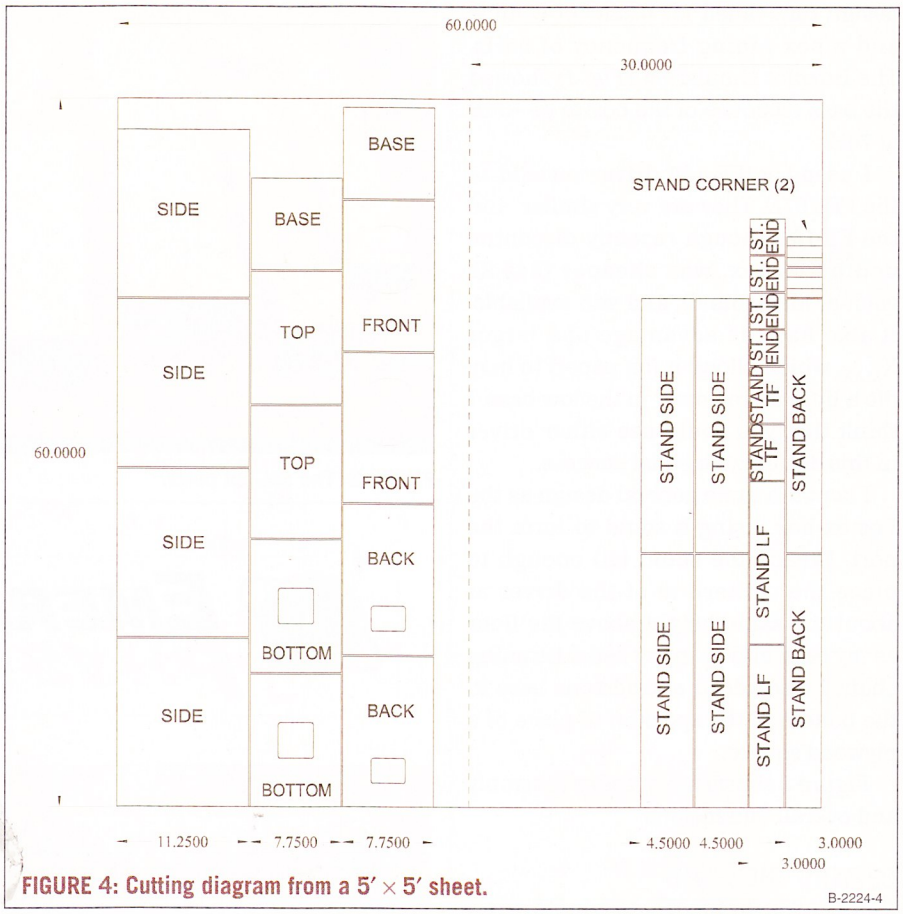

FIGURE 4: Cutting diagram from a 5′ × 5′ sheet. B-2224-4

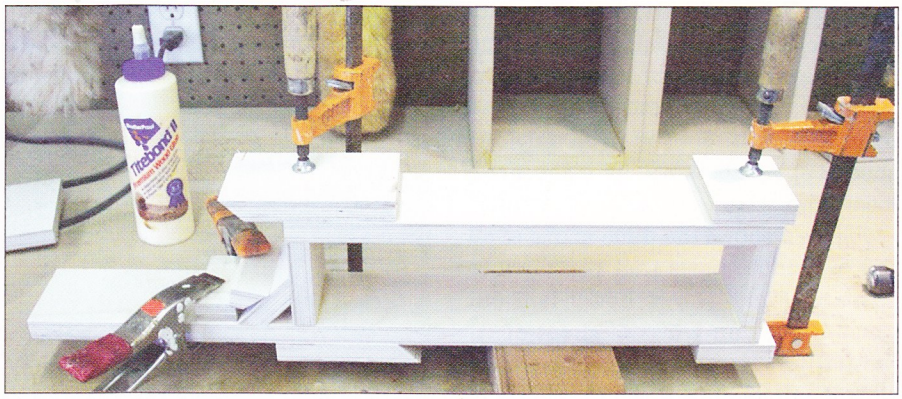

PHOTO 3: Gluing the bottom of the stand.

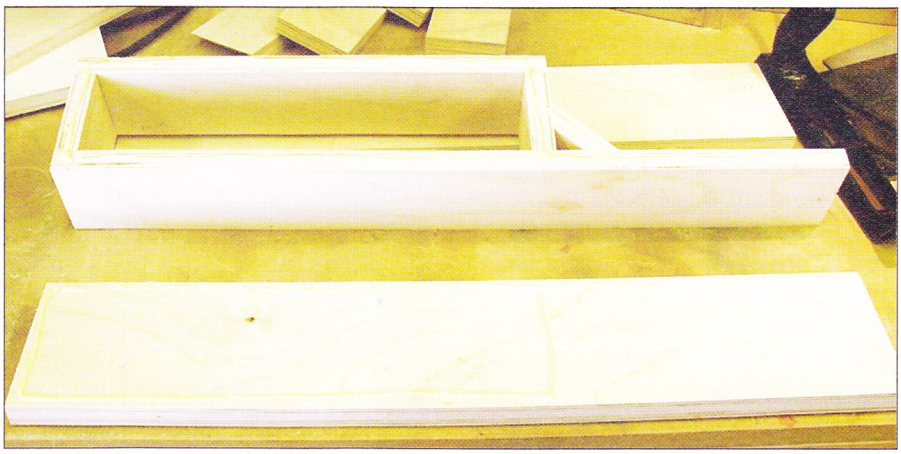

PHOTO 4: Gluing the sides of the stand.

size with a sharp knife to cover all of the inside surfaces of the box, except for the front where the driver mounts (*Photo 9*). I added a small piece below the driver (*Photo 10*), which shows the inside of the box before closing it up. I glued the felt to the inside of the box using "Liquid Nails" adhesive—very sticky, gooey stuff.

After putting felt on the inside of the sides of the box, I glued them in place, closing the box as shown in *Photo 11*. I then used the router with a flush-cut bit to remove overhanging plywood and glue from the corners.

FINISHING TOUCHES

Baltic birch is a little difficult to finish. It doesn't appear to take stain well, and lacquer didn't look nice either. I wound up sanding the plywood with 150 grit, then 220 grit sandpaper, on a random-orbit sander. I then applied clear oil, Watco's Danish oil finish. It gives a smooth, natural-looking finish.

With the woodwork finished, all that remains is to attach the stone base. I used some 2″ thick sandstone, quarried locally, which cost me only $4 per 12″ × 12″ square. I drilled holes through the stone using a masonry bit in my drill press, and attached the stone using long screws (*Photo 12*). The finished base looks quite nice (*Photo 13*).

If you can't obtain stone locally for a reasonable cost, you could also use a concrete stepping stone, or even several stacked layers of plywood. The idea behind the base is to make a platform that's large enough and heavy enough to keep the speaker from tipping over if somebody bumps into it.

INSTALLING THE DRIVER

The Fostex drivers come with a self-adhesive foam gasket. I stuck this gasket to the back of the driver, and soldered on wires, before installing the driver into the hole in the box. It's secured with four screws; I used 8-32 × ⅜″ black-oxide button-head screws, and nylon washers.

PHOTO 5: Filling the bottom of the stand with sand.

PHOTO 6: The completed stands.

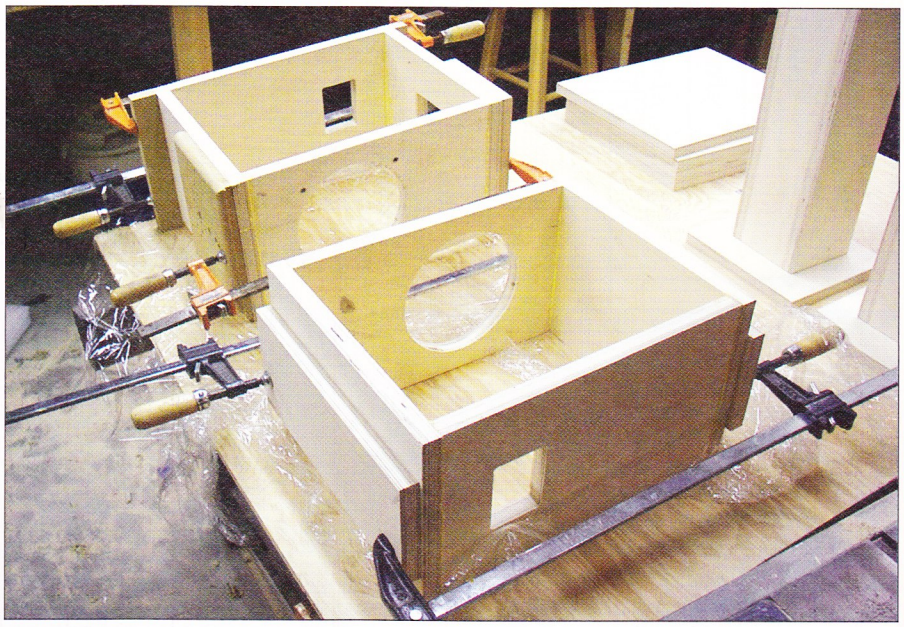

PHOTO 7: Gluing the boxes together.

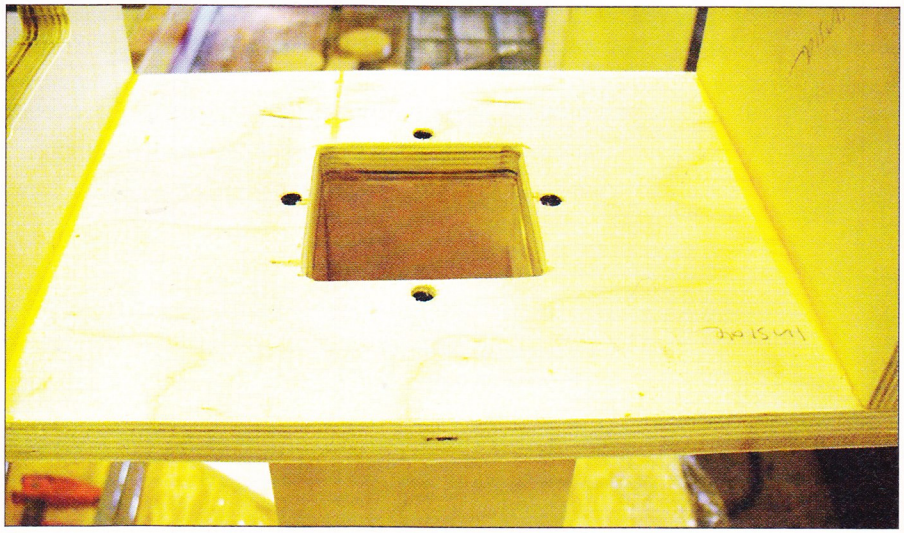

PHOTO 8: Attaching the open box to stand.

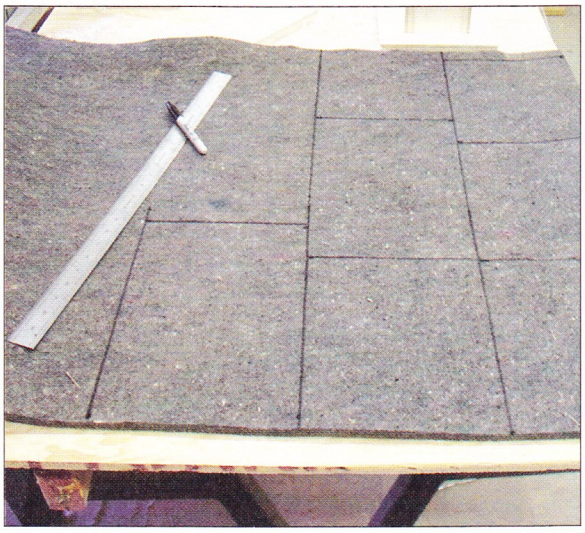

PHOTO 9: Cutting the felt.

PHOTO 10: View of inside the box before closing.

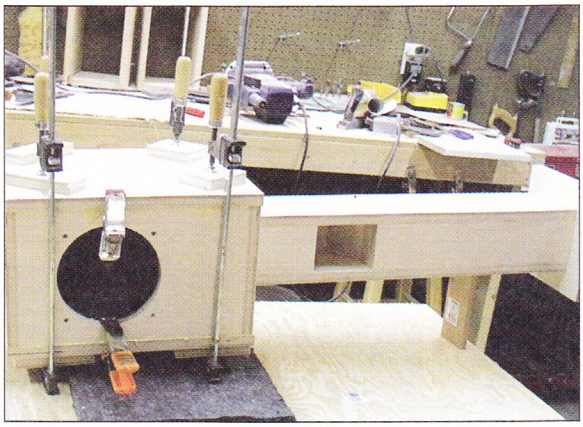

PHOTO 11: Gluing on the box sides.

Pull the wires through the hole in the back of the box, and solder them to an input terminal. You could also use solderless crimp connectors to attach the wires to the speaker and input terminal, if you prefer. I used a rectangular unit with gold-plated binding posts from Parts Express, part number 260-309. The terminal has an attached gasket, and is held in place with four wood screws. And with that, you're ready to hook it up and listen!

MEASUREMENTS AND LISTENING IMPRESSIONS

As with most speakers I've seen, the drivers needed a little time to break in. Unlike others that I've built, these speakers initially seemed a little rolled off on top, with somewhat boomy bass. After a few hours, the highs filled in and the bass calmed down.

I made some unscientific measurements of the speaker in the listening room, using a hand-held Radio Shack sound level meter. In general, the measurements appeared to follow the simulation and the driver's frequency response graph pretty well. If anything, the lowest frequencies were stronger than the simulation, probably because of room effects; I measured about –10dB at 45Hz. The overall frequency response was pretty flat from 60Hz up to almost 20kHz.

I was somewhat concerned that the limited cone motion of the speaker would lead to distorted bass. I ran a 60Hz sine wave through the system and raised the volume until I could hear distortion. This occurred at about 95dB at 1m—right in line with the simulation. I repeated this at 1kHz, and got to over 105dB, where I reached the clipping level of my amplifier.

With music, at what I consider pretty loud listening levels, there appeared to be no problem with the speaker hitting its limits. Even fairly bass-heavy electronic music sounded fine, with a lot more bass than I ever expected to get from these speakers.

I'm currently driving

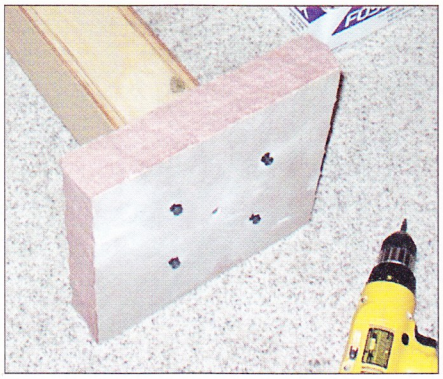

PHOTO 12: Attaching the sandstone base.

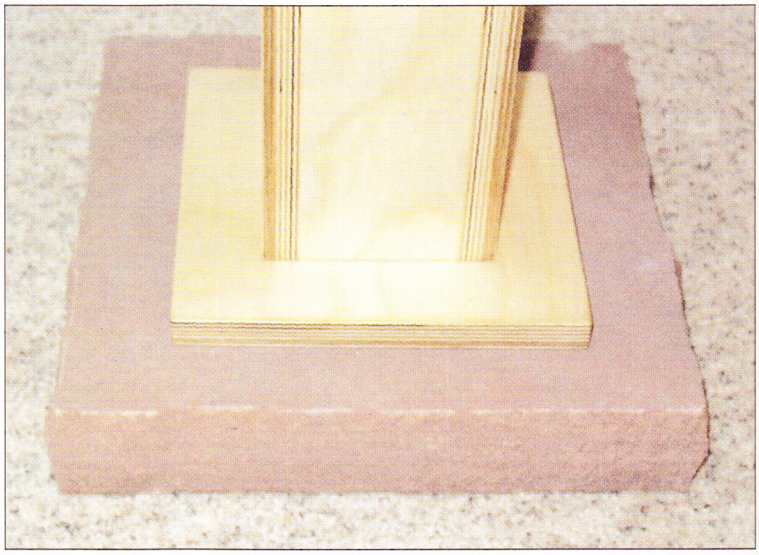

PHOTO 13: Close-up of the sandstone base.

the speakers with 20W SE amplifiers, using 813 tubes connected as triodes. They also perform quite well with my 7W push-pull 6B4G amplifiers. I think that at the specified sensitivity of 92dB @ 1W (1m), you can certainly do with less power, unless you like to listen very loudly.

These speakers have the same "live" character as other good full-range speakers I have listened to. Acoustic instruments—piano and acoustic guitar—are outstanding, like they're in the room with you. The soundstage is wonderful, extending well beyond the speaker locations.

All in all, I deem this project a success—maybe the best speakers you could build for under $150! ❖

PHOTO 14: Close-up of the driver.

PHOTO 15: Finished speaker (quarter view).

CONTACTS

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