# THE MICROLINE

BY JOHN COCKROFT

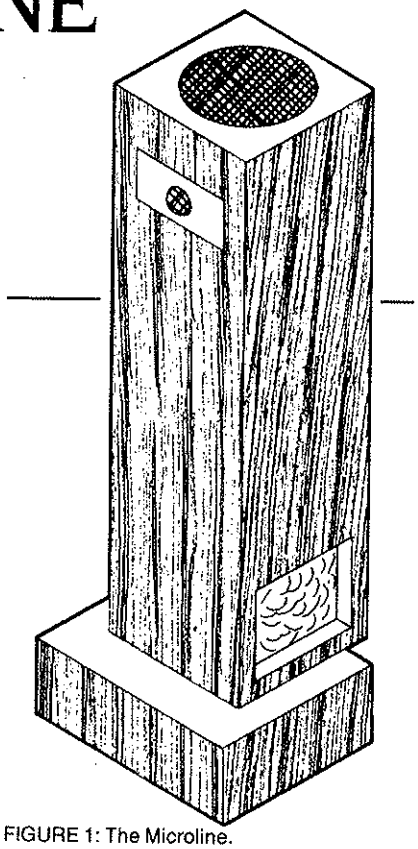

FIGURE 1: The Microline.

The Microline came into being when I was trying to simplify and shorten the Octaline (*SB* 3/87). This was two years before I conceived the equations for designing short transmission lines ("The Unline," *SB* 4/88). My intent was to design a small loudspeaker system of excellent quality that was very easy to construct. I wanted to come up with a Volkswagen of loudspeakers that practically anyone could construct and enjoy. The Microline comes very close to achieving those goals.

Being a small system with only a 5¼" driver, it is naturally not going to be at home in a large living room, but in a smaller room or in an apartment a pair will bring a joyous amount of fine sound, with surprisingly natural bass, to your ears. If you are sensitive to the timbres of live acoustic music you'll find the Microline a refreshing alternative to the small speakers in the commercial marketplace.

When a delicate nuance is called for it is deftly delivered. When authority is required it comes from somewhere and is presented with great musicality. Its appearance is like a shrunken Shortline (*SB* 1/88). In actuality it is the Shortline's dwarfish parent. Like its progeny it performs best against the wall and away from corners and overhead obstructions. If the back of the enclosure is within one-half inch of the rear wall, all should be well.

**LINE TO BOX.** The Microline, like my other short transmission lines, is a hybrid in that it uses a larger cross section and higher density stuffing than the classic transmission line, presented to the world by A. R. Bailey in 1965.

In my systems I often use drivers with a higher $Q_{ts}$ than is generally associated with the Bailey type line. As those who read my Unline article will remember, as the length of the transmission line is shortened, you must increase stuffing density to compensate. This requires an increase in cross-sectional area to aid "breathing."

You may then need to raise $Q_{ts}$ to offset possible overdamping. As the line continues to shorten the system begins to behave as a stuffed box without a bottom. On the other hand, the aperiodic, pressure-relief type of enclosure proceeds from the sealed box and heads towards the bottomless box, becoming at some point essentially similar to my hybrid short lines. They behave like one big happy family.

**THEORIES.** As I mentioned in my Octaline article, I think most of what happens in a transmission line happens because of the slowing and attenuation of the wave motions by the acoustic stuffing material in the line. I am aware that many may disagree, but this is my present belief. Unstuffed lines have wild fluctuations due to the action of the line, which is similar to a pipe with one end closed (actually a fluctuating closed end), but a stuffed line is another animal altogether.

Acoustic stuffing in densities high enough to slow the speed of sound in air by a factor of three, or so, is exerting a great amount of frictional damping in the line, causing a considerable reduction of its natural functions. The highly damped impedance peaks and the smooth sound characteristic of transmission lines testifies to this condition. The impedance peaks remaining in a properly stuffed line are like the appendix that most of us carry around for no known purpose. The peaks merely express intimations of their pipe heritage.

I believe a transmission line behaves as a stuffed folded baffle. The length of the line is the "width" of the baffle from the center to the edge. The acoustic stuffing, by slowing the speed of sound, acts to increase the "width" of the baffle. At the same time the stuffing also attenuates the magnitude of the sound to a fraction of that issuing from the front of the driver. The sound emerging from the line terminus has only enough energy at best to partially cancel the frontwave, even though the rear wavelength might be longer than the baffle is wide. It may or may not be in phase with the frontwave, depending on the wavelength, the line length and the stuffing density.

Ideally nothing would escape from the terminus port, which would allow the frontwave to operate unimpeded, but in the real world such niceties don't often happen. Given a single density of stuff-

**ABOUT THE AUTHOR**

*John Cockroft is a senior cryogenics technician at the Stanford Linear Accelerator Center, where he has worked for 26 years. His interest in designing loudspeaker systems dates from around 1958.*

ing (say the 0.5 lb./ft.$^3$ that seems almost standard), it makes sense that longer lines would exhibit better bass characteristics because the additional attenuating material in the line reduces the backwave. The "baffle" is also wider.

**DRIVERS.** I originally designed the Microline for the Radio Shack (40-1022) 4½-inch driver. However, when I discovered Radio Shack had altered the parameters (while pretending not to have done so) I decided to use another driver. I couldn't locate any 4½-inch types that seemed to have reasonable parameters. Fortunately I had been quite conservative with the enclosure cross section, which allowed me to consider 5¼-inch drivers as substitutes.

I settled on the new Danish Peerless K050 WFX PP, which has the following published specs: $F_{sa}$ 60Hz, $Q_{ts}$ 0.43 and $V_{as}$ 0.353 in.$^3$ (although $V_{as}$ isn't an important transmission line parameter, I include it for the benefit of those who might want to use this driver for some other project).

$F_{sa}$ was higher than I liked, so I added three grams of ⅛" solid solder wire (two pieces about ¾-inch long, curved to fit around the outside of the dust cap; I glued them in place, 180° apart using white glue) to reduce the resonant frequency a bit. This was a compromise. I wanted to lower $F_{sa}$ a little more, but $Q_t$ was relatively high to start with and a bit of restraint was necessary. Also I didn't want to reduce efficiency any more than necessary with the added mass.

**ADJUSTMENTS.** As they do in fairy tales, things worked out well. Assuming a moving mass ($M_{MD}$) of about 6g (the actual mass wasn't specified) which was the mass of the old American Peerless 5¼-inch cone, the added weight should give a new $F_{sa}$ of about 49Hz and a new $Q_{ts}$ of about 0.52, which is in line with the figure in *Table I* presented in my Unine article for 25-inch lines. The Microline is actually 23¾" along its centerline.

With this modified woofer in place I observed an impedance peak of 13.2Ω at 101Hz and no lower peak. By removing 39g of stuffing I located a peak at 33Hz of 11Ω. (I did this just to see what was going on down there, then replaced the stuffing.) The stuffing density of the Microline is 0.9 lbs./ft.$^3$ I used 4.6 oz. of polyester pillow stuffing (130.5g).

Microline construction is simple and straightforward. A 2 x 3-foot piece of ¾-inch particle board is more than enough.

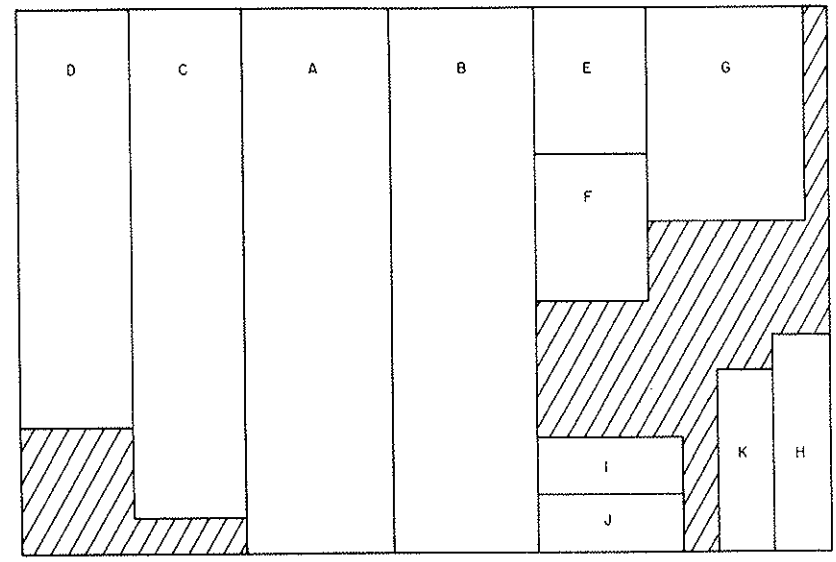

FIGURE 2: Cutting guide—¾-inch particle board, 24 by 36-inch sheet.

**PARTS LIST**

For a stereo pair everything on the list should be doubled. Don't forget to make the side ports on opposite sides of the pair for symmetry.

**Particle board**

1 pc. ¾ by 24 by 36" from which the following parts are cut as per the cutting guide:

2 pcs. 6½ by 24" front/back A/B
1 pc. 5 by 22½" long side C
1 pc. 5 by 18½" short side D
2 pcs. 5 by 6½" top/bottom E/F
1 pc. 7 by 9½" base top G
1 pc. 2½ by 9½" base front H
2 pcs. 2½ by 6⅜" base sides I/J
1 pc. 2½ by 8" base back K

**Components**

1 ea. Peerless K050WFXPP (Danish) 5¼" foam surround poly woofer. No substitute. Judging from the specs in the new Peerless catalog, the 831745 woofer appears to be the same as the K050WFXPP. I sure hope so.

1 ea. Peerless K010DT (Danish or American OK) 1" dome tweeter. No substitute

1 ea. 8Ω L-pad 15W or better—Madisound/ Radio Shack

C1, C2 3.7μF Mylar capacitor 50V or better—this may be made by paralleling a 2.7μF and a 1μF, listed in Madisound catalog

Cz 6.5μF Mylar capacitor 50V or better—this may be made by paralleling a 5μF and a 1.5μF, listed in Madisound catalog

L1, L2 1mH Sidewinder air core coil—no substitutes (Madisound)

R1 0.5Ω resistor 10W or better
This could be made by paralleling two 1Ω resistors. Madisound doesn't list the correct values. It is probable that this resistor could be eliminated from the circuit.

Rz 8.34Ω resistor 10 watt or better
This could be made by paralleling a 10Ω and a 50Ω resistor, or paralleling three 25Ω resistors. Madisound doesn't list correct values, try local source

**Misc.**

4 ea. feedthroughs. Could be 10-32, 1¼" brass panhead machine screws with lugs, nuts and washers or whatever excites you.

8 ea. #6, ¾" sheet metal screws for mounting the drivers

2 ea. banana jacks or whatever you like for input terminals Radio Shack

1 ea. roll of surgical or "household" cotton. Note: Don't double up on this item for a stereo pair. There is enough for both.

16 gauge zip cord for wiring (Radio Shack)

White glue

RTV Silicone Sealant (Bathtub Caulk) to mount crossover parts

Duxseal or Mortite to seal drivers (or whatever you like)

**Sources**

Madisound Speaker Components
8608 University Green
Box 4283
Madison, WI 53711

Mahogany Sound
2430 Schillingers Rd. 488
Mobile, AL 36695
Acousta-Stuf costs $7 a pound. Postage is an additional $1 a pound.

Radio Shack

For stereo, of course, two will be required. I prefer to cut all of the pieces first and fit them together. This tends to eliminate surprises. All pieces are simple butt joints, so no exceptional ability is required to build the Microline. While I recommend cutting all the pieces beforehand, in most cases cutting the holes for the drivers and the feedthroughs is more easily done after the assembly is partially complete. It is easier to grab a structure than hanging on to a loose board when using a saber saw.

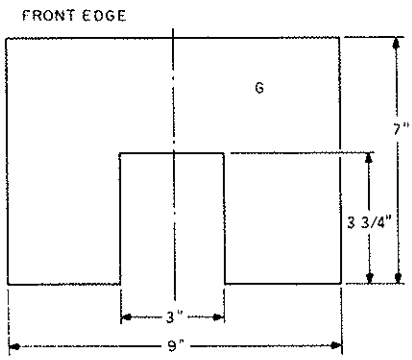

FIGURE 3: Base top showing notch to clear feedthroughs.

**ASSEMBLY.** First, pre-glue all the joints, brushing a coat of white glue on both faces and letting it dry. A much stronger joint is accomplished in this manner. I also urge you to go over the joints at least once (twice would be better) during assembly, adding extra glue to the outsides of all joints for added rigidity and to make sure that they are sealed.

I construct my enclosures entirely with glue-only joints, using weights and fixtures for alignment and relying on well fitting pre-glued joints. This is mainly because of the environment where I build my speaker systems (an apartment kitchen table). Assembly would no doubt be much quicker using four-penny finishing nails to hold the parts together while the glue dries. The nailheads could then be set about 1/16-inch below the surface of the wood and the depressions filled with spackle. Even when using nails you should pre-glue the joints.

Before I get into the construction details I must confess a goof I made when I built the Microline. After working 12 hours the night before, I came home one morning with the idea of cutting the hole for the tweeter before going to bed. My mind apparently crawled into bed ahead of me, because I cut the hole in the wrong panel. This meant that when the tweeter faced forward the line terminus port faced to the side, instead of to the front as I had planned.

After looking at the enclosure for a couple years and noting the clean looking columnar front as compared to the gaping mawed front of the Shortline, I think that my subconscious mind must have merely taken over the design and improved upon my original thinking. I can think of no reason why the Shortline couldn't be built in the same manner for improved looks. For symmetry, the right and left speakers should have the ports on opposite sides. Either system should work well with either port placement.

**CONSTRUCTION.** Begin by fastening the top to one of the 6½ by 24-inch pieces. Follow this with the 5 by 18½-inch piece and the 5 by 22½-inch piece, then the bottom piece. I refer to the dimensions rather than calling the pieces front or side, and so on, since I don't know where you plan to put the port.

When the glue has dried and the regluing has dried, it is a good time to cut out the driver holes. If the tweeter is on the panel not yet glued, set it in place (the panel, not the tweeter) and cut the hole. This supports the board and allows space beneath it for the saw blade. Ideally the back corner of the woofer hole should be rounded off to make a smoother path for the sound to exit from the speaker back, but the speaker sounds well without this effort. I leave it to you.

Since the tweeter has a sealed back, this nicety isn't required for its hole. After the holes are cut, brush a couple of coats of glue in an area about one inch beyond the front edge of the hole. This makes it easier for the sealing material to do its job.

**CONNECTIONS.** The four electrical feedthroughs may now be installed. The simplest thing to use would be 1¼-inch, 10-32 panhead brass machine screws with nuts, washers and lugs, but use what you like.

Now solder the speaker wires to the feedthroughs inside the enclosure. I used 2½-foot lengths of 16-gauge zip cord, available at Radio Shack or hardware stores, where it is often known as "heater wire." Fasten all the wires together with tape or a rubber band and bring them all out of the woofer hole to get them out of the way. Now is a good time to mark them and the feedthroughs for polarity and what speaker they are associated with.

Mark both ends of the feedthroughs and the outer ends of the wires. You will probably want to trim the wires a little when you mount the speakers, so don't mark them at the extreme ends. Little flags of tape work well for marking the wires. A felt tip pen is fine for marking the feedthroughs.

**STUFFERS.** The upper part of the enclosure should be lined with surgical cotton to help reduce midrange reflections from the enclosure walls. Use the roll just as it comes from the box and cut two lengths (for double thickness) long enough to go around all four inside faces of the box (maybe just a little longer to be sure). Use the full width. Glue or staple it to one of the side walls, right at the top so one edge is touching the speaker baffle. Continue

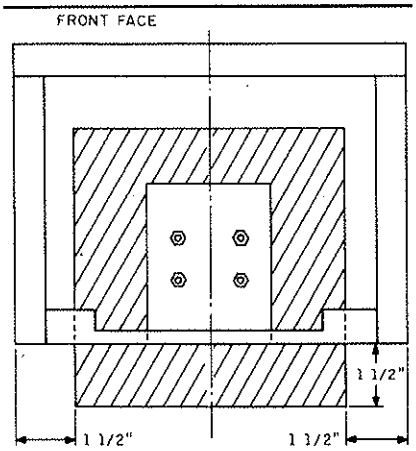

FIGURE 4: Bottom view showing base in relation to bottom of enclosure (shaded area).

with the other two sides. The final panel isn't yet in place, so let the rest of the cotton flap in the breeze awhile.

The cotton can be placed right over the tweeter hole (leave it a little loose). Then, just poke two holes for the wires with the point of a pencil and feed them through. If you are building the side port version the hole is in the panel that isn't glued on yet so you don't have to worry about it at this time. Make sure the wires aren't pulled out too tightly, but are allowed to remain a bit loose and relaxed in the enclosure. This is so there won't be any strain on the solder joints at the feedthroughs and the speaker terminals and to minimize any effects of vibration in the wire being transmitted to the outside.

Now it's time to stuff the Microline. Lay the enclosure on a table with the opening caused by the missing panel facing up. I have used polyester fiberfill from several sources with good results. K-Mart, Woolworth's and local dry-goods stores are probably the easiest sources. Use a scale to measure the amount (4.6 oz.) if you have one available. If not, buy a 12-oz. package and attempt do divide it into three equal parts. From the third pile take a handful of the stuffing that when compressed as tightly as possible in your fist makes a ball about two inches in diameter. After refluffing, add one of these to each of the other piles.

**STUFFED.** Take one of the piles, lay it on a spread-out newspaper and pull it apart and fluff it up as best you can (this sounds a lot fluffier than you will actually get it, but don't worry, just do your best and let it go at that). If the texture is reasonably even and the big hard lumps are pulled apart all is well.

Place the material in the enclosure as

*Continued on page 32*

*Continued from page 30*
evenly as possible, going right over the cotton at the top, right down to the bottom of the enclosure. Lift up the speaker wires and place some of the fluff beneath them so they won't rattle against the enclosure walls. Work carefully and use a gentle touch, but remember, this isn't neurosurgery, so don't work yourself into a pathological wreck over the stuffing.

A while back (but after I completed the Microline) I received a sample of Acousta-Stuf, similar to the pillow stuffing I have been using, but the longer fibers are much more evenly distributed, which is excellent for this application and it is much easier to use. I reviewed this material in *SB* 4/88; available from Mahogany Sound. I prefer its qualities over any similar material I have found.

When the stuffing is complete, fold the final flap of the surgical cotton batting in position, trim if necessary and press it down a bit. If you cut the tweeter hole in the unmounted panel, now you can make the pencil holes in the cotton batting and carefully bring the wires through the stuffing and out the holes. To accurately locate the holes just lay the panel in place and use the tweeter hole as a guide.

**GLUING.** Then glue the remaining panel in position. Make sure all the mating surfaces have been pre-glued (you only get one chance at this panel). Gently press the cotton and fiberfill away from the joint areas to eliminate the possibility of getting fibers in the joints. Run generous ¼-inch glue beads on all of the joint surfaces of the structure (not on the free panel). If the tweeter hole is in the free panel, feed the tweeter leads (which have been poked through the cotton before gluing) through the tweeter hole and then carefully lay the panel in place on the glued surfaces. (As an alternative you may bring the tweeter leads out of the tweeter hole after the glued panel has dried.)

Glue will squirt and ooze and drip, so place the enclosure on old newspapers. Line up the panel and weight it down (or nail it down) first and then clean up the mess with a damp paper towel or cloth. Make sure the panel is lined up on all four corners before securing it. Let the glue dry overnight.

**BASES.** While the enclosure is drying assemble the base. I want to bring up a point here regarding the base. Due to the design of the Microline, the enclosure must be placed as close to the rear wall as possible (¼–½ inches). The base is designed to allow this to happen. If you have oversized baseboards or other problems in the area

where you plan to use your speakers, you may have to redesign the base.

With that decision out of the way, start by gluing the base front to the underside of the base top (make sure the feedthrough cutout is cut first). Then glue one side, followed by the back and then the other side. When the gluing and the regluing has dried, mark the location of the enclosure on the top of the base. Pre-glue the bottom of the enclosure and the mating area of the base top. When this is dry place a generous amount of glue on the base top where it is to receive the enclosure.

The joining procedure is best done on a table top, or a bench top, on newspapers. Set the enclosure in place on the glued base and try to line it up. It will want to slip about on the glue puddle like a new ice skater. Keep pressing the enclosure down and keep realigning it until all of the excess glue is squeezed out and the enclosure stays in place. Wipe off the excess glue and let it dry overnight (you sure can get a lot of sleep on this project) or about 12 hours.

After a couple of hours add a fillet of glue around the partially dried joints. If you live in an environment where the speakers may be treated roughly (read kids), you might want to run a couple of long screws through the base into the enclosure. I have had no trouble with just glue. My kids (and grandkids) have grown up.*

**WIRING.** With the enclosure upended, the open bottom of the base is exposed, making it easy to work on the crossover and attenuating circuits, which should be done at this time. I used standard banana jacks for the input sockets because I think they make the simplest connections and they have excellent conductivity. They require $\frac{5}{16}$-inch holes and are placed in the necked-down section of the base back, which will also contain the 8Ω L-pad. I used 16-gauge zip cord for all of the connections.

I fastened the crossover components in place with RTV silicone seal (bathtub caulk). Many speaker systems have the crossovers mounted inside the enclosures. This is probably fine in some cases, but when working out a new design, it's better to have the critter where you can get at it (again and again). Even later, since I am a tweakerholic, it is comforting to know I can get my hands on the crossover, the heart of the system.

After you choose the drivers and the enclosure, the crossover is where it's at. The photograph in my previous article apparently confused some readers because it showed capacitors (or resistors) the schematic did not call for. I merely used several smaller units in parallel to obtain the required values. This is sometimes necessary. (I wasn't trying to trick you.)

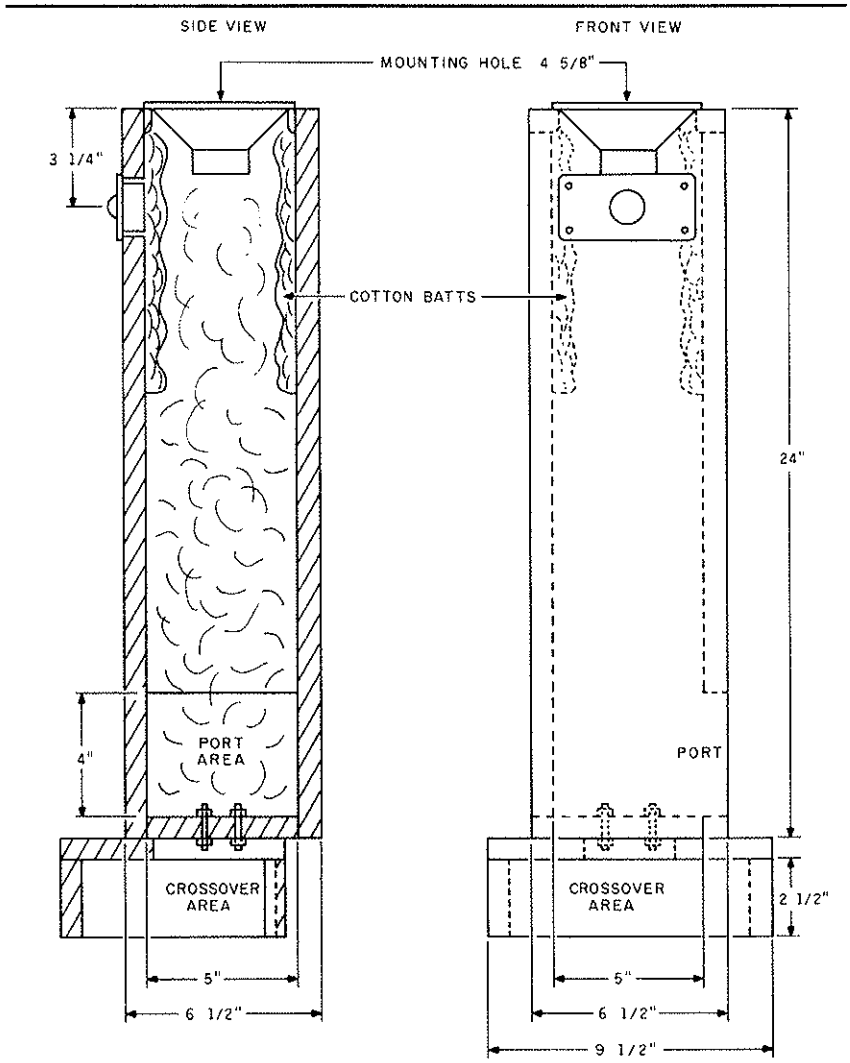


FIGURE 5: Front and side view. For a stereo pair place the port on opposite sides.

**SEALERS.** The drivers should be mounted at this time. Don't forget to brush glue around the outside edges of the speaker holes, and let the glue dry before proceeding. If you are planning to paint your Microlines it is a good idea to paint the area under and around the drivers before mounting them.

The speakers may be sealed in many ways. Some builders use foam weatherstrip material, others use silicone rubber (RTV bathtub seal). I prefer to use Duxseal, which is a putty-like material made by Johns-Manville for sealing ducts and electrical boxes. I use it because it is available and because it allows easy driver removal later, if required.

Before sealing with the Duxseal, place the driver to mark the mounting holes and drill pilot holes. A drill bit of about $\frac{3}{32}$-inch diameter works well for this if you use #6 sheet metal screws (panhead) as I did. Before you drill, run your finger into the speaker hole and around to the back of where the pilot hole will come. Make sure the fiberfill, or cotton is not close to the area. Press it down so that when the drill exits the wood it can't get caught in the stuffing. It can wind up on the drill bit and make a real mess.

**TIGHT TRICKS.** For a small woofer I make a ball of Duxseal about $\frac{7}{8}$-inch diameter and roll it between the palms of my hands until it becomes pliable. I then press it with a rolling motion so it begins to elongate. I continue to press it, pull it and otherwise manuever it until I have a sort of rope about $\frac{3}{16}$-inch in diameter and long enough to fit around the back of

*Just to make a liar out of me, my daughter, Laura, called as I write to say another round is on the way!

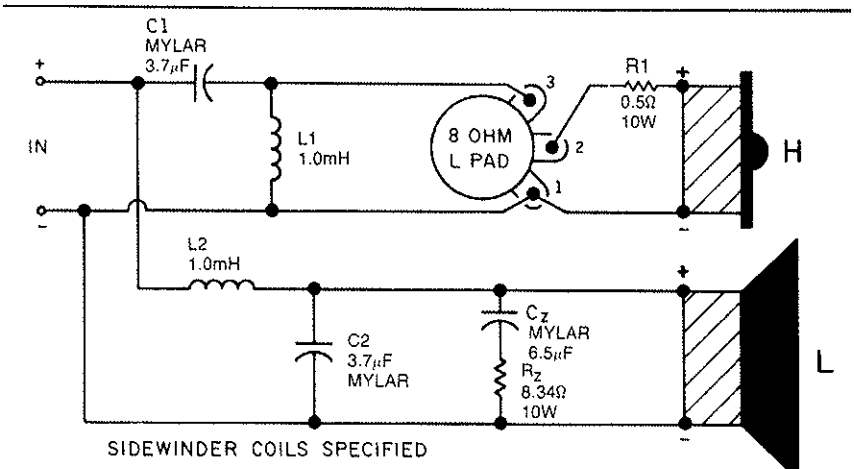


FIGURE 6: Crossover network. R1 may be eliminated.

the basket flange, where it will seal against the enclosure when the driver is pressed in place.

Break the Duxseal so the the ends overlap slightly. Work the joint with your finger until it becomes like the rest of the ring. With your fingertip press the entire ring firmly in place, flattened a bit so that it will tend to squish outward and not mushroom into the holes in the basket when the driver is secured. Push the Duxseal away from the four mounting holes so you can locate the pilot holes.

**CONNECTING.** With the Duxseal in place it is time to wire the leads to the speaker terminals. Bring the wires out from the speaker cavity. Make sure you have the right ones and they are correctly marked for polarity. You might want to trim the wires a bit. I usually just let them coil down into the cavity when I insert the speaker. Before soldering, it is a good idea to place a bit of tape on the basket below, so there is less chance of shorting out the speaker terminals. Electrical tape is best, but in a pinch, adhesive or even masking tape (two layers) will do.

Turn the woofer over on its face near the edge of the hole. Some of it will be over the hole, with the wires coming out next to it. If this is done with gentle care no damage will come to the driver suspension which will be temporarily flattened a bit. Strip the wires back about ½-inch and tin the leads with solder.

Also tin the terminals. It is hard to get 16-gauge wire into the terminal holes so I usually just solder the wires at right angles across the terminals and bend the wires back a little so that when the speakers are in the proper mounting position the tension on the wires is relieved.

**MOUNTS.** When mounting the driver make sure the wires aren't caught on the edge of the hole where they will damage the seal. Make sure they are going nicely into the hole. I should have mentioned that you must pull apart the zip cord for about 6 inches so that each wire is separate and can find its own way into the enclosure. Be a little generous with the solder so that fillets are formed at the joint for added strength. Before inserting the woofer, compress the stuffing beneath the hole a bit to allow the woofer a little space. Be gentle, don't pack the fill down too hard.

Next, mount the tweeter in a similar manner. As the screws draw down the drivers the Duxseal will squirt out at the edge. Leave it alone until all the screws are in. By the way, just tighten the screws until everything seems firm; don't overtighten. With a putty knife or a screwdriver scrape along the baffle next to the edge of the speaker flanges, and the Duxseal will be cleanly removed leaving a neat-looking mounting job.

Now stop and listen to your Microlines, for a while. After all that work you deserve to enjoy yourself. You might start out with the treble control turned to a bit less than ¼-turn rotation from the off position. From there you're on your own.

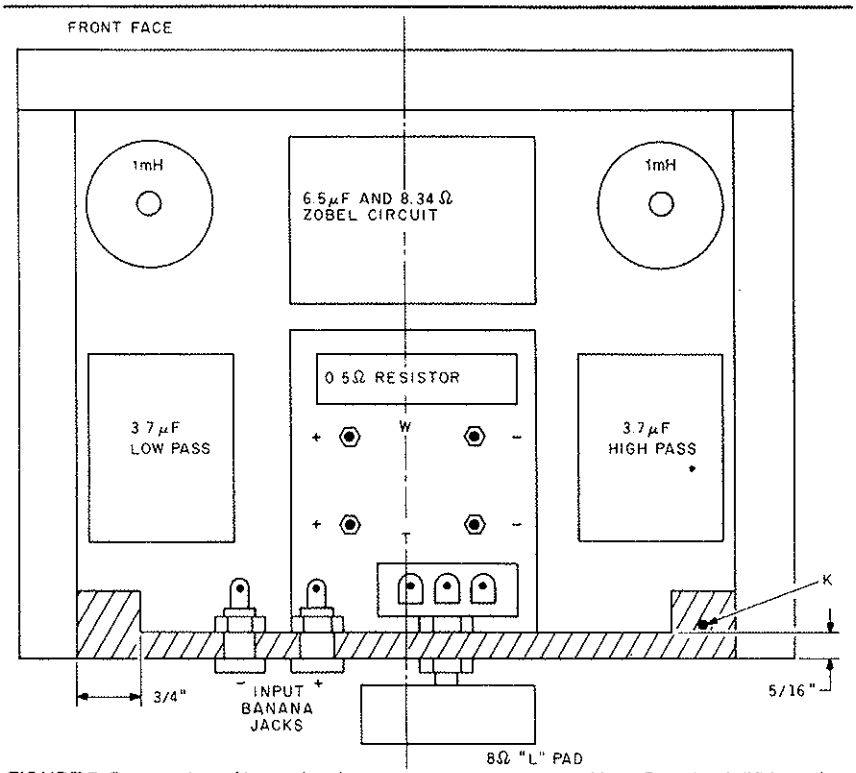


FIGURE 7: Bottom view of base showing crossover arrangement. Note: Base back (K) is undercut to allow banana jack installation. Alternately, use ¼-inch plywood with corner cleats.

## If you should have a *TECHNICAL QUERY...*

about an article appearing in this magazine, write it clearly, leaving space for a reply and referencing the magazine, the article and the page about which you are inquiring. Enclose a self-addressed stamped envelope and send these to *Speaker Builder*, PO Box 494, Peterborough, NH 03458.

If it's warranted, we will forward your query to the author or a Contributing Editor for a prompt reply.

Help us by not calling in your question. We have neither the staff nor the time to respond to technical questions by phone.