Linkwitz Lab LX521 Dipole Loudspeaker Project

The LX521 Monitor, designed by Siegfried Linkwitz, is a dipole speaker with an acoustic radiation pattern that remains fairly constant with changing frequency. The exceptional Linkwitz Orion was partway there, but this design takes it even further. As a result, the off-axis reflections of sound coming from the walls should closely resemble the on-axis sound. This provides a better spatial rendition of the "acoustic space" in which the music was recorded. In other words, more realism - a fine goal for good loudspeakers.

This speaker will have a hybrid active/passive crossover. Pluto and Orion are completely active loudspeakers. The LX521 differs by being a 4-way speaker (tweeters, upper-midrange, lower midrange, and a pair of 10" woofers) and uses a simple passive crossover between the upper-mid and lower-mid. Active speakers require additional amplifiers for each active driver, and this can get costly. The LX521 requires at least 6 channels of amplification if the two woofers are driven in parallel as one unit. This requires a robust 2-ohm capable amplifier.

I ordered plans and circuit boards for the ASP (analog signal processor) from Linkwitz Labs shortly after the LX521 speaker design was announced in autumn 2012. Even though I was partway through my construction of a set of Orion loudspeakers, I took the leap. Because these replace the Orions, that hurt a little. I am still pondering whether to finish the Orions, or to abandon that project at ~80% complete.

These are now completed, and photographs of the finished project are located at the bottom of page three.

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[Skip to Photos of the Finished Speaker...]

Construction Log, Page One - *Baffle template, bracket, and woofer box fabrication.*

Plans Arrive [November 20, 2012]

I've ordered the plans and ASP circuit boards from Linkwitz Labs. They arrive in about a week via Priority Mail.

<--click any picture to enlarge

Planning Baffle Fabrication

The photo shows the baffle layout being sketched on 3/4" MDF. I plan to use this as a master template for routing subsequent copies. This piece won't be used on the loudspeaker itself.

The baffle is an unusual shape. The width of the baffle changes with each driver to make it small acoustically. Because it is an open baffle loudspeaker, the fabrication of the baffle should be easier than with a box-type loudspeaker. I'm still exploring what materials to use (black-painted MDF or plywood, hardwood, etc.). I've also ordered some unusual size Forstner bits to cut the tweeter holes and the upper midrange speaker hole.

The Baffle Bracket

In the plans, the baffle is held to the structure with a bracket that I'm making from a combination of 1-1/8" MDF and 18mm Baltic birch plywood. I used my table saw sled to rough cut the pieces, and also used it to cut the angles on the brace uprights. You can see the hold-down stick in the first photo to keep my hands away from the spinning blade. It has a rubber facing on the side that contacts the work piece.

I've already taken some of the parts to the router table to put on a small 1/8" radius on the edges of the MDF "foot" and the plywood sides. That should help prevent skinning my knuckles on sharp edges when I'm working with the passive crossover to be located between the uprights. [*Edit: Later on in this project, I re-routed a much larger chamfer instead of the small 1/8" roundover in order to match the appearance of the rest of the bridge.*]

In a slight deviation from plans, I made the brace "foot" into a trapezoidal shape to echo the angles designed into the baffle. This brace assembly will be painted black like SL's, probably using Lamp Black water-based General Finishes Milk Paint. It will be sprayed or rolled-on after a good shellac coat is done to seal the wood/MDF.

Work continues on the Pattern for the Baffles [November 30, 2012]

I ordered some Forstner bits from Woodcraft to cut the upper mid and tweeter holes. I could have done it with the router, but I dislike the process - especially when the weather is marginal. If I can't use the router table, I route MDF outdoors because of the dust. With poor weather outdoors, the Forstners will make life easier.

One Forstner is 1-7/8" in diameter (tweeter) and the other is 3-1/8" in diameter. The 3-1/8" diameter is slightly too small for the driver (by about the thickness of a business card), but I used a sanding drum on my drill press to enlarge the hole in the pattern to the needed dimension. This enlargement took about 10 minutes with pauses for measurements along the way.

A 3+ inch Forstner is about the upper limit that my drill press can swing without straining. I took light cuts, and repeatedly pulled the cutter from the hole to clear chips and to cool the tool.

I was very pleased with how clean the Forstner bits worked. Not much dust went airborne - unlike cutting the holes with a router.

After I cut the holes, I trimmed the overall length of the baffle on my table saw. The table saw's sled made this very easy.

To cut the outside shape of this irregular baffle, I took it to my Sears Craftsman band saw. I've improved this hand-me-down band saw over the years so that it cuts straight and smooth. However I quickly discovered that the narrow throat of my band saw is too small for the baffle when it was angled for some cuts. I did as much

as I could with the baffle facing up, then carefully marked the problem cut on the back and cut the rest that way. If turning it upside down hadn't worked on the band saw, I was prepared to use the jig saw for any remaining problem cuts. After all, this has to be close to the line, and not exactly on it. The excess will be trimmed to dimension in a subsequent step.

I am able to cut fairly close to the mark with the band saw, but I'm leaving a little extra material to be trimmed off either with sanding (if there isn't much material left to remove), or on the router table using a pattern bit after I tack down some scrap pieces of MDF to use as a temporary guide for the cuts. I eventually went with the router table approach because it is so straightforward and fast.

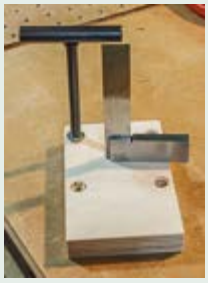
This pattern must be well-made. The resulting baffle copies will echo any flaws it contains. Outside edges must be smooth and straight. The router bit will ruthlessly expose any sloppiness or irregularities.

Continuing Work on the Brackets [December 2, 2012]

With the baffle pattern in its current state, I was able to mark out the mounting screw hole pattern on the baffle. I drilled 1/8" pilot holes in the baffle, and used transfer punches to mark the front of the bracket.

I plan to use 1/4"x20 machine screws to hold the baffle to the bracket so that I can easily interchange baffles. I may make painted MDf baffles to start with, but later switch to hardwood as time and materials become available. I like being able to change my mind.

I drilled 1/4" diameter through holes on the bracket front, and used a 3/8" diameter counterbore with a 1/4" diameter pilot to have near perfect concentricity. The changeable-pilot counterbore tool was purchased at McMaster-Carr a while back, and it works splendidly. It has interchangeable pilots to align with just about any size pre-drilled hole.

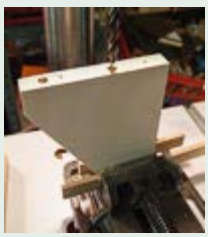


After creating the 1/2" deep x 3/8" diameter counterbores, I inserted 1/4"x20 threaded brass inserts into the rear side of the baffle bracket. That leaves about a 1/8" inch "land" of material on the front to eliminate the chance of pullout.

The threaded inserts are installed using a T-wrench that I purchased from Woodcraft years ago. I have to use a washer with it to prevent it from wedging into the back side of the threaded inserts, but that's easy. While installing the inserts, I keep a small square handy to judge how straight the insert is going in.

I may use screws that are longer than the thickness of the baffle bracket and baffle combined, so I bored 5/16" diameter holes into the edge of the bracket sides. This will permit a fairly long screw to pass completely through the threaded brass insert and still fit without bottoming.

I added a couple of small holes on the vertical centerline of the bracket in case I wanted to mount a hardwood baffle without any mounting screws visible from the front of the speaker. They are just "what if" holes just in case. It is easier to drill and countersink them now than after the bracket is assembled.



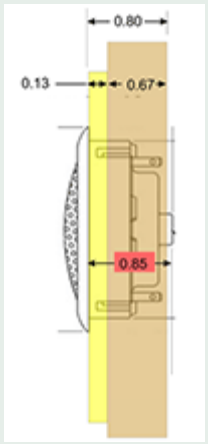
Once everything was fitted nicely, I put a thin layer of glue on the mating surfaces, and tightened the 1-1/4" deck screws that I used to clamp it together.

Things are nice and square, with just a tiny bit of misalignment. It's nothing that a couple swipes of a hand plane or a few minutes with sandpaper can't fix quickly. It's funny how something can dry-fit perfectly, but there's always a slight bit of misalignment when glue is applied!

Baffle Material Thickness Issues

On the Orion/Pluto/LX521 owner's forum I posted a couple of pictures of two kinds of plywood being measured with calipers. I'm not concerned about increases in strength that come with thickness

My concern is having enough cavity depth to hold the tweeter. Thin plywood, no matter how well it is made, will not allow the tweeter to seat. My sample of Baltic birch plywood is only 0.67 or 0.68 inch thick. The hardwood plate attached to the front and to the back of the baffle is 0.13" thick. Added together, you have a cavity for the tweeter body that is 0.80 inch deep.



However the tweeter is 0.85 inch deep. It won't fit. The feature on the back of the tweeter interferes with the rear tweeter plate (Part C) when it is mounted. (Note that it's not shown in the illustration to the left.)

One could use a Forstner bit and drill about halfway through the thin hardboard piece on the rear to provide a space for the tweeter protrusion. You'd have to do the front plate too because there are two tweeters. While this is possible, it slows down construction.

If baffle material that is a minimum of 0.72 inch is used (typical for some USA-specification "3/4" plywood), then the tweeter hole/cavity inside will be just deep enough to contain the tweeter. I'd still be worried about buzzes and rattles if the tweeter fits with zero clearance. If I were using 0.72 plywood, I'd put a piece of very thin LD polyethylene foam in the cavity first to absorb any contact.

Perfecting the Pattern Edges

Because the baffle pattern was first cut on a band saw, the edges were not as smooth and straight as you get from a table saw. However a table saw can't cut the angles needed for the baffle. The edges were left a little proud of the pencil layout lines because I knew that I had to trim to the final shape somehow.

To trim the edges right to the pencil mark and to make them very smooth, I cut some MDF scraps into various wedge shapes for use. I used double-stick tape to adhere them to the baffle pattern exactly at the pencil lines.

I took the stack of parts to the router table to do a light trim pass to match the straight edges of the scraps. There wasn't much left to remove because the band saw cut was very close to the layout lines. I estimate that I had to remove only 1/32" of material in the trim operation.

I cut the left edge and the right edge is two separate passes. I simply reused the scraps from the left side on the right side for the second pass. I merely flipped them over and used fresh double-stick tape.

Easy work. Faster than sandpaper.

I used spot putty on only one edge where the band saw went very slightly into the line. When the putty dried, I sanded it flush. Then I gave the MDF pattern a coat of shellac to "case harden" it for its eventual pattern duty.

In the last photo, you will spot the 1/8" hole drilled between the two tweeter bores. It will hold one of the 1/8" metal dowel pins used to hold the pattern and the work piece in registration. I also drilled 1/8" holes to mark the centers of the mounting screw holes, and a second dowel pin will be inserted through one of them for registration. The two 1/8" steel dowel pins will hold the pattern securely to the stock for flush trimming around the edges.

The holes are placed strategically in places that are either hidden later (i.e., under the tweeter sub-baffle), or are used/enlarged later (one of the mounting screw holes). I plan to use 1/4"x20 threaded fasteners through the baffles into the brackets to assemble them.

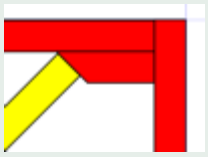
Back to Brackets

I drilled through holes in the base of the bracket assembly for #6 x 2" deck screws to hold the base and the upper assembly together. The base is 1-1/4" MDF from stair tread purchased from Lowe's.

I needed to drill perpendicular pilot holes to receive the screws in the legs of the upper bracket assembly, but the shape of the top part made that difficult. It wouldn't stand square by itself. I solved the problem by using one bracket to support the other upside down bracket. Then I drilled the 3/32" pilot holes square to the material.

In the router table, I routed a 45 degree chamfer around the base of the bracket assembly for appearance. Because most of the base is behind and fairly far from most of the drivers, I presumed that there wouldn't be any significant sonic change.

I also made the base for the bracket a slight trapezoid shape to echo the angular baffle appearance. Angular is in!

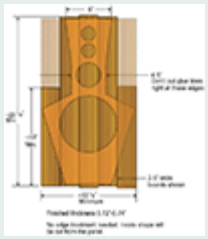


Woofer Box Joinery

I am deviating from the plans slightly in an attempt to improve upon the joinery of wooden parts for the woofer box. The items shown in red (Parts A, D, & E in the top picture, and Part C in the bottom picture) have been slightly changed to meet these goals. This will allow me to use biscuits to join the baffle to the box in some areas, and I will move a butt joint to the top surface for visual reasons. I also plan to miter the angled woofer baffle where it meets the front of the box.

I completely redrew the plans because I'll use Baltic birch plywood which measures 0.68" thick. This is somewhat thinner than the nominal 3/4" material used in SL's plans. To get a tight fit everywhere, I had to determine new sizes of the parts for the cabinet. Redrawing to scale allowed me to do this.

For non-owners of plans, I'm sorry I can't present more detail or show an overall picture here. If I did so, I might be inadvertently releasing intellectual property. For Linkwitz plan owners, these pictures combined with your existing plans on page 11 should be enough to understand my approach.



Baffle Material [December 15, 2012]

While I was shopping at the local farmer's market, I saw a vendor selling wooden cutting boards there. It is someone with whom I have worked on some projects at the university, and his woodworking looked solid. I asked about getting some cherry boards glued up into a panel to serve as baffle material. His similar sized kitchen cutting boards were $45 each, and he said that it would be the same for an all-cherry panel. He also stated that he could plane the thickness close to what SL has specified in the plans.

I sent him an email about getting the work done, and supplied this sketch (sorry about the lack of supplied dimensions - intellectual property, you know). Cherry should look nice, and I have lots of cherry boards in the garage for other parts of the build (bridge) if I choose to go that direction.

Tweeter sub-baffle fabrication [December 17, 2012]

I attempted to make do with a hole saw to cut the radius at the bottom of the tweeter sub-baffle. However hole saws are terribly inaccurate. This hole saw, almost new, probably has a whopping 1/16" runout. In addition, the center hole wants to wander, the saw chatters when it doesn't like the feed rate. It was a miserable experience. The cut edges were chewed-up and not clean. I decided against doing any more work on this project with a hole saw. I discarded the parts affected by the hole saw, and began with a new approach.

A router, a 1/4" spiral downcut bit, and a hole cutting jig (a Jasper jig, in my case) was a better way to go. However, the tweeter sub-baffle is small and hard to hold. I decided to make a jig to hold the work. With a little thought, the jig performed a couple of other duties too, as you'll see.

The jig is made from a scrap piece of 3/4" MDF, and pieces of Masonite the same thickness as the tweeter sub-baffle. The work piece has to sit flush on top of the jig so that the router base passes over it smoothly. To allow a little clearance between work and the jig sides, I used a piece of heavy paper as a shim. This provided

just a little clearance so that I could remove the work after it had been routed. It also accommodated the slight variations in the width of each sub-baffle blank.

I also carefully marked and drilled three 1/8" holes in the jig that locate the center of the two tweeter locations (the low tweeter in front, the high tweeter in back of the baffle and the center of the arc to be routed on the bottom. The two tweeter center holes are used to guide a transfer punch for marking the hole center, and the punch also helped remove the work from the jig. I used double stick tape to keep the work in position, and it is then difficult to remove from the jig. Using a transfer punch, a light tap through the jig onto the back of the sub-baffle loosened it, and simultaneously marked the center of the tweeter hole. Using the punched mark for alignment, I bored the tweeter holes afterward using one of the Forstner bits shown earlier in this build log.

The 1/8" hole located at the center of the arc did two things - it let me flip the jig over and drill the sub-baffle blank from the rear for perfect alignment. It then held the pin in location for the router jig.

The jig didn't take long to put together, and it did a satisfyingly accurate job with all aspects of fabricating the tweeter sub-baffle. The punch marks left by the transfer punch were extremely accurate. In the second-to-the-last photo in this group, you can see how the ruler line (the 6" graduation) is exactly at the punch mark when the left and right edges were on their respective marks.

I used my table saw to cut the angled sides of the front tweeter sub-baffles, and trim the "legs" of the rear tweeter sub-baffles (per the photos on SL's site, not exactly to plan). All that's left is to mark, drill, and countersink the mounting holes for black #4x3/8" sheet-metal screws. And paint it, of course.

I'll keep this jig in case I want to change the material for the tweeter sub-baffle. While it's currently ordinary Masonite, some thin cherry or other attractive hardwood might look nice. For now the Masonite, painted, will work fine.

I have to keep momentum going on this project. There are several other commitments looming that will occupy weekends and all spare time.

The Woofer Box [December 19 & 20, 2012]

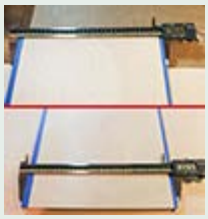
I spent most of today cutting down some 3/4" Baltic birch plywood for the woofer box. I began outside on a very chilly day cutting some large sheets to more manageable sizes. I used sawhorses and a circular saw on a track. After doing that, I took the small pieces to the table saw for another pass at rough cutting. My goal was to get clean edges and square corners. After that, it's easy to cut the pieces to the final size fairly accurately.

I use a crosscut sled for both crosscutting and also for minor ripping duties. It works well both ways.

When crosscutting, I try to use blue painter's tape on the cut line to reduce chipping of the plywood. I'm using a 40-tooth general purpose blade, and it needs a little help when crosscutting plywood. I dislike splintered edges.

When rough cutting outside on the sawhorses using a circular saw, I knew that my crosscut sled would handle only 24-1/2" pieces between the front and back. You can see from the first photo that I just made it. The width of the piece just fits into the sled.

While I have a Rockler track and a flip stop mounted on my sled, it can't quite reach much beyond 22" without exiting the track. I resorted to the old-fashioned way of c-clamping a block of wood to the fence. It worked fine as you can see from the third photo. I have a detachable table saw stop for crosscutting longer boards, but I didn't' have to use it today.



With each speaker build that I attempt, I try to achieve even more precision than the time before from my tools. I wanted to rough-cut cut a board to 24", and you can see that I did OK in the photo with the tape measure.

Even better is the parallelism that I get from edge to edge. Take a look at the measurements made with a caliper at the top and bottom width of one of the boards. It's parallel to 1/1000". That's satisfying! [Yeah, I'm bragging a bit! It took a while to get to this point.] This was a rough-cut to square up all sides with clean edges. Now if I can keep this precision for all the final cuts!

I now have all pieces F cut to final size, and the top panels are the appropriate length. There's much more work left on these.

On my Orions, I spent a great deal of time hand planing the plywood boards smooth and flat before cutting them to final size. The plywood had a nice, nearly glass-smooth finish after planing. I'm not doing that here, and I somehow feel like I'm omitting a step that will ease painting later. We'll see.

Update December 20, 2012
All table saw work is done. I mitered a couple pieces to either improve appearance, or to improve the joint between parts B and E. I don't have a crosscut sled for doing miters, but an Incra miter gauge that I had careful adjusted for squareness did an admirable job. This gauge is used only on the right side of the blade, and sees little use. After mitering one end, the pieces were cut to the final dimensions on the other end.

All the cuts look good. If I can't get a square box out of this, I need a different hobby.

Biscuit Cutting [December 21, 2012]

It was cold and it snowed today, so I didn't go outside to route driver holes. Instead, I took a little time to cut slots for biscuits, and to check the fit of the newly cut parts.

I like to use a biscuit cutter because of how it keys the pieces of a project together. Dry fits are much easier to do because the tight fit of biscuits in the slots holds them together, and gluing later on is much easier.

I have thought about the sequence of assembly that will keep things as square as possible. I'll put the front "skirt" on the top panel first, gluing them together while both parts are biscuited together with the side panels. That will register the parts so that they will fit the side panels exactly later on. I'll remove the side panels when the glue dries and continue with other parts.

I use a biscuit cutting jig to ease work cutting the biscuit slots. Over time it has evolved to solve problems that arise - i.e., warped boards. I have a pivoting hold-down arm that presses the work flat against the jig surface if the work is warped slightly. I have been able to apply so much pressure that the MDF base bowed, mis-registering the slot, so I glued a piece of 1/2" Baltic birch plywood under the work surface to stiffen it.

To cut face slots in vertically oriented boards, I have a push stick for safety. It keeps my hands far from the spinning cutter.

One of the remaining problems I have with the biscuit cutter is that its carriage has a little up/down slop in it. I'm still trying to figure out "windage" to give me perfectly flush joints each time. In one of the pictures, I did it. The metal square is flush along the joint. In other joints, I applied corrections the wrong way, and there are slight mismatches between mating parts. Because it was a bone-headed error, I wrote down the corrections on a reminder sticker ("Press down on handle when cutting face slots") and added that on the jig. I don't use it enough to remember the steps months later, so I have to write things down.

However even the larger mismatches are only 0.020" from flush, so it isn't a big deal. A couple swipes with the hand plane will level things.

Curious to see if my modifications worked, I dry fitted even the baffle parts even though they don't have biscuit slots cut. If I do cut slots in them and the side panels, it will be a tricky deal, and I will have to remove the cutter from the jig for some cuts. I have a plan though.

I was very satisfied with how the parts fit together at this point. The miter cuts on two pieces worked perfectly per the drawing I made earlier. I deviated slightly from SL's plans here, but I believe that it will prove to be a better woodworking joint in the end, and will improve appearance a smidge.

Routing Holes [December 23, 2012]

The weather warmed enough today to go outside for the messy task of routing driver holes. Sawdust flies everywhere. Outdoors, I merely use a leaf blower after I'm done to clean up. Indoors, I'd still be vacuuming crevices for hidden sawdust instead of writing this.

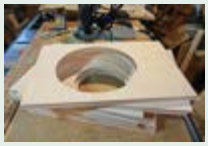
Of course I'm a prisoner to weather. Lately we've had rain, strong winds, then snow. And cold temperatures that make work outdoors unpleasant.

I took advantage of today's weather. It began as a chilly 31 F morning, but by the time I was done, it warmed to 42 F. Snow was melting.

I used the drill press to drill 1/8" pilot holes for my Jasper Circle jig. The jig rotates around the pin in the wood, cutting neat circles and arcs. My first two passes were made with a Bosch 1/4" downcut spiral bit. I've found that they leave a cleaner edge to the cut without splintering. Then I switch to a Bosch 1/4" upcut spiral bit to finish the work, cutting through to the other side. The upcut bit cleans out waste better in deep grooves.

I also noticed something malfunctioning with my router. The depth-stop fine adjustment was turning rapidly all by itself when the motor was turned on. I'd estimate that it was completing a revolution in 10 seconds. That's a problem with stepped routing like I was doing today when each revolution changes the depth by 1/32". To bypass the problem, I turned the depth stop all the way to its limit so it could no longer turn by itself. I used the coarse adjuster to get me close. Close is good enough for this work, but I'll have to remember to look into fixing that later. [Update - there's a small 3/16" i.d. x 5/16" o.d. o-ring in the adjuster to provide friction and to seal the threads from debris. It must be worn, and it's inexpensive to replace.]

Even though I used the downcut bit first to cut clean edges initially, I still had a couple plywood panels chip at the edges after I switched to the upcut bit. I tried to sand a small bevel on the remaining panels with a sanding sponge, and it seemed to help, but not eliminate, the problem. Thankfully the chipped edges will be hidden by driver flanges or will be rabbeted to a larger diameter in the case of my top panels.



I still need to rough cut some 1/4" hardboard, then route the circular covers for the tops of the woofer boxes. I cut openings in the top of my boxes to allow for access when mounting the heavy woofers. The openings will allow easy use of tools. It will be covered up with the circular covers after drivers are installed. If you are thinking of manhole covers found in streets, you wouldn't be far off. Same concept.

Now, If anyone has a really clever use for the 3/4" thick disks left over from speaker building, just let me know. I'm starting to collect way too many.

Marking and Drilling Woofer Mount Holes [December 25, 2012]

I spent a little time in the workshop today marking and drilling screw holes for the woofers. The shop was very cold today. I'll have to start wearing a coat in there when I work.

To mark the screw locations, I place a woofer into the routed opening and center it using some marks made with a square and some little punches made with the tip of my calipers. The original pencil centerline is still visible for use. I measure the center to center distance of the actual holes in the woofers, divide by two, and set the calipers to that distance. I reference from the centerline and make a left and right hand scratch using the calipers on either side of the centerline. Then I use the combination square to draw short lines through the caliper scratches. The steps are repeated on the left side, which is 910 degrees opposite the original marks.

These lines are visible through the woofer mounting holes when it is positioned correctly. The woofer sits in an opening that is about 1/16" (for me, at least) larger than the driver itself, so these lines aid in centering the woofer in that opening. It isn't perfect, but it gets me close.

Once the woofer is positioned as desired, I use transfer punches through the woofer mounting holes to make a small center mark.

Afterwards, drilling the holes is a piece of cake. I drilled the holes large enough (7/32") to easily accept #10-24 screws. I'll use locknuts and washers on the back side.

Treating Edges [December 26, 2012]

I managed to cut the recess for my "manhole cover" in the top of the woofer box. It will allow access to the top woofer when it comes time to mount the driver and solder wires. Note that this is my modification, and is not part of SL's plans. I will fabricate round pieces of 1/4" hardboard to fit into the recesses. They will be installed with weather-strip gasket material to make a tight, rattle-free joint.

I cut the recess on my router table using a 1/2" rabbeting bit. I knew that this plywood was susceptible to splintering from my earlier routing work, so I applied some shellac around the area to be cut. My thinking was that the shellac would sink into the top wood fibers and serve as a glue, binding them together. It was an experiment to reduce the tearout.

It didn't work. Even with a very light first cutting pass, I had fairly significant splintering of the wood along the cut edge. Thankfully the woofer box will be painted, and wood filler is an option to hide the chipping. With a couple of applications so far, it looks good.

Hindsight thought - the Bosch 1/4" down-cut spiral bit worked best with this plywood to prevent tearout. I should have made a light scoring pass with it before cutting the through hole in the part. [Hindsight alert #2. What the heck - maybe cut *everything* with the spiral down-cut bit! I wonder what sort of new problems that would bring about?]

I'd like to find a way to put a 1/8" radius along the cut edge, but no router bit I own will fit into the shallow recess to make the cut. Even the small-pilot Dremel bit that I ground down hits bottom in the recess before the cutting edges make contact. I'll probably just use some sandpaper to ease the edges and be satisfied. In the end, this part is mostly hidden beneath the bridge anyway.

I revisited the tweeter sub-baffles with a small block plane to chamfer the edges along the sides and tops. This went very fast, and took only 10 swipes down each edge. It's looking more finished now. Primer and paint will come later - probably in spring when the weather improves.

A Day of Drilling [December 27, 2012]

I needed a way to clamp the angled baffle to the bottom of the woofer box for when I glue them together. There's nothing simpler than using screws to clamp a joint tightly while glue dries.

I didn't want the screws to show from the listening position, so I planned to insert them from the bottom of the box into the miter. To estimate position and depth, I stood the pieces on edge, and just placed different screws into position - by eye. I settled on #8x1" self-drilling screws from McFeeley's as a good length if I counterbored the screw hole about 0.150" below flush. They were positioned about 0.7" from the box's front edge.

Because of the need to counterbore and to countersink the land for the screw head, I used a countersinking tool that does it all simultaneously in one drilling operation. My kit is cheap, and the cutting edges are fairly dull, but the #8 bit did an OK job considering the tool quality. Once decisions were made considering screw size, placement, and depth, the drilling went very fast.

I also placed three mounting holes in the piece at the top inside of the box. The screw holes here won't show either. They will assure a good clamping pressure when the time comes.

I needed to fabricate the "manhole covers" that cover the access holes in the top of the woofer boxes. I will make these 7.5" round parts from 1/4" hardboard. After rough cutting some square blanks, I drew the cut outline. Before I cut away the center, I also drew the bolt circle for the mounting screws. I plan on using 6 screws in each cover to hold it in position.

From mathematics, when you adjust a compass for drawing the desired bolt circle, the compass radius is *exactly correct* for marking the spacing between the 6 holes on the bolt circle. I drew arcs that intersected the bolt circle to mark locations for the screw holes. I plan on using small #4 x 1/2" flathead screws to mount the covers to the top of the boxes.

I also contacted Madisound by phone today to add items to my order before it ships. I added 8mm female quick disconnects for spade terminals (part number QC8MM) to fit the large woofer terminals.

The quick disconnects that I added to the order don't cost much money, but by including them in the driver order, shipping costs are essentially free.

More Woofer Box Work [December 28, 2012]

I didn't have as much time today as I'd like, but I got a couple of things completed for the project. First, I routed the "manhole covers" from 1/4" hardboard using a downcut spiral bit - outdoors at 31 degrees F. Brrr! I made the OD 7-7/16 inch to allow a 1/32" clearance all around (1/16" total difference in diameters). The rabbeted recess for the covers was within a couple thousandths of an inch of the 7.500" target, and I knew that I had to allow a little extra room for paint.

Back inside from routing, they looked good in place. There's a small 1/8" pivot hole drilled through the center of the piece for the router jig, but I will probably not even attempt to fill it with Bondo or other filler. It will be too small to make any difference at the woofer crossover point of 120Hz, and it's hidden under the bridge.

I also cut biscuit slots to join the two angled baffle pieces inside the box. I might choose to not screw them together at the joint, but to just clamp in position for gluing.

After all that was done, I did another dry fit of the parts with biscuits inserted to hold it all together. The fit was very good. I'm still pondering methods of placing biscuits accurately enough along the sides of the baffles to avoid running screws through the side walls of the enclosure. Screws are simple, and will be mostly hidden by the bridge of the top units, but there's something about the challenge that appeals to me. We'll see if cold logic (use screws!) wins out, or if I attempt new techniques to get good registration with biscuits.

At any rate, the fit was good and I'm pleased with progress so far. I am looking also for a way to fasten the top angled baffle to the miter on the spacer to hold it in place while glue dries. Nothing appears easy, but drilling pocket screws at a 45 degree angle is one possibility. The drill press table tilts, and I'd have to clamp securely to do this. It seems like a lot of work though.

One last photo in this group was made looking through the "manhole cover" port on the top panel. Because my shop is illuminated by different compact fluorescent bulbs mounted in round clip-on fixtures, the color temperature for photography varies among them. The differently angled pieces were illuminated by the different color temperature bulbs, and I found the effect fascinating. Consider it speaker art.

Today, I ordered some items from Parts Express for the project. I plan to inset round Speakons into the tops of the woofer boxes, at the rear. That will make it easy to connect and disconnect the mid/tweeter part from the woofer box for moving. I expect that I will need to adjust position many times once they are in my listening room to find the best sound. I've never had dipoles before, and I'm sure that they will react differently to my room's acoustics.

While I could surface-mount the 2" diameter Speakons, they will look better recessed into the top surface of the woofer boxes. I'll use a 2-1/8" diameter Forstner bit to do that. Forstner bits are available in a Woodcraft store that's about 45 minutes away by car, but the we have about 5" of snow on the ground and it is still coming down.

No driving today for non-essential items.

Not Much to Report [December 29, 2012]

I sanded the parts for the woofer boxes today. It's boring work, but some sanding needs to be done before assembly. After assembly, access becomes limited for interior parts.

I did manage to try some Mirka Abranet sanding pads on this project. I've heard good things about them, so I bought a small assortment to try. I began with 120 grit, and followed that with 180 grit. They worked well.

Dust, however, settled on everything in the shop. Even with the dust collection bag built into the sander, fine dust managed to get everywhere. While it's possible to attach a vacuum to the sander, I couldn't run my Shop Vac for a couple of hours without damage, or blowing the circuit breaker on the power strip. I suppose that I should refrain from power sanding indoors, but the weather outside is miserable.

I have some cleaning to do.

Holes for Speakons and Pocket Holes [December 31, 2012]

The Speakon quick-connect parts were ordered from Parts Express on Friday. They arrived via FedEx this morning around 10 am. That's fast service.

I drove to Woodcraft in Parkersburg yesterday to pick up two Forstner bits - 2" and 2-1/8" diameters. I though that maybe I'd try the smaller 2" even though the Speakon is 2" also. Having both the recess and the part 2" in diameter provides no clearance in the recess for paint, etc. However stated specifications are sometimes off a little, so I thought that I'd try it anyway.

It worked. I'll have a little paint buildup in the recess, but I can always file the outside of the Speakon flange a bit to make it smaller. The tight clearance looks very tidy, and I was afraid that going to the larger 2-1/8" recess would look sloppy by comparison.

I began by trying the 2" WoodRiver bit (their house brand, usually Asian in origin) on a piece of scrap plywood. Even though the WoodRiver-brand Forstner bit was inexpensive ($12.59) compared to the higher-quality Famag ($46.19), it did a great job. Both the 2" and the 2-1/8" WoodRiver bits were in stock, too, which wasn't the case with the Famag brand. I did use a fine-grit diamond file to touch-up the cutting edge of the 2" bit before I used it. It had a burr on the leading edge that was easy enough to remove.

Once the test with scrap wood worked out OK, I went on to the real baffles. I set up a fence of sorts on the drill press so that the baffle wouldn't move around much. It also aided finding the center when it came time to cut the 1" through-hole with another Forstner.

Once the holes were cut, I rounded the underside through-hole edge on the router table. The 1/8" chamfer bit was already in place in the router table, and it took about 10 seconds per panel to do. Now I won't cut myself on sharp, splintery edges when it comes time to wire the Speakon.

This work should really pay off when it comes time to move the speakers to find the best sound. The Speakon quick-connect system is a proven design.

A few more preparatory steps (drilling wire holes, etc.) for the woofer box panels, and I should be able to glue-up soon.

I also cut some pocket holes for the upper baffle. I need a way to clamp it for gluing, and pocket holes with screws made sense here. I used my Kreg pocket hole jig to cut the holes on an angle. The 1" long screws will exit the baffle at its end and enter Part E. I'll drive the screws after glue is applied and other box parts are positioned correctly to ensure a good fit and squareness.

For now, I just placed the parts on end to get a sense of the arrangement. If I can, I'll use the Kreg plugs to fill the pocket holes. Even though they are well under the top panel of the box, I don't want to see them if it's possible - even when I crouch down behind the speaker.

I didn't have enough time to begin gluing, but I did start planning the wiring run, and where to put through-holes in the baffle. I am planning to place the larger 8-pole Speakons left-of-center on one speaker, and right-of-center on the other. It will shorten the speaker cable run a few inches, and I believe the wire routing makes more sense visually. A big wire in the center splitting off left and right didn't seem appealing.

I also plan to use Wood Artistry's Speakon brackets instead of fabricating them from wood. I'm borrowing them from my Orion build because it will be easy, and because of appearance.

Gluing Begins [January 1, 2013 - New Year's Day]

I had all day to work on the speaker today. No interruptions, nothing.

I began to glue together some sub-assemblies. In the first photo, I glued the top panel to the short front panel. I did not glue them to the side panel. Because I used biscuits, I could use the side panel as a jig for gluing. To prevent the two pieces being glued from sticking to the side panel, I put some wax paper between the top/front pieces and the side panel. After about an hour, I pulled the now-glued top and front panels from the side panel for further work.

I needed to run the clamping screws through Part E into the top panel accurately, but was having a little difficulty with the piece moving while driving screws. It has a miter which makes clamping more difficult. To solve that problem, I used a corner clamping block made for another project to apply firm pressure to the part, and drove the screws home.

Now it was time to glue the upper baffle to Part E at the miter. I positioned the parts using one side panel as a jig, and used the pocket screw holes that I drilled yesterday for clamping screws. I allowed the glue to dry several hours for this sub-assembly because of the small, unsupported glue area. I wanted to be sure of a solid joint.

After a safe period of time passed, I pulled everything apart again and plugged the pocket screw holes with Kreg plugs. They were Maple (close enough) and were glued in place. After the glue dries, I'll use a hand plane to trim the plugs flush to the surface. Right now, it looks fairly rough.

One thing that I noticed with all the fitting is that the side panel material is slightly bowed. I'd have to clamp with a considerable pressure in the center to ensure good contact with the baffles. If I were to use biscuits, that would mean clamping with cauls. That's too much work, so I made the decision to use screws through the side

panels. I spaced the holes for the #6 deck screws 5" from the front edge and 5" from the back edge where they intersected the baffles. To do that, I positioned everything in its final assembled position, then traced the baffle edges onto the side panels with pencil.

It's not ideal to have screw holes in the sides of the boxes, but they are flat head and countersunk. . I located the screws so that they'd be covered the bridge of the speaker, and not visible in normal use. I've milled countersinks for them about 0.020" below flush which will allow me to use Bondo putty to cover them over, if I wish to anyway.

More Progress [January 2, 2013]

Yesterday I filled the pocket holes with wooden plugs. The glue dried by morning, so I planed then sanded the protruding parts of the plugs flush with the surface of the baffle. When painted, you won't be able to see the plugs at all. Also, this is up very high underneath the woofer box, so you'd have to crouch to see them anyway. It was just something to do while glue dried elsewhere.

I had forgotten to mark the screw locations for the "manhole cover" on the top panel, but with only #4 screws, pilot holes were not necessary. Good thing, the top panel had the short front panel piece already glued to it making difficult the use of the drill press. With the little #4 screws, all I had to do was to use some heavy cardboard (measured 0.023") as a spacer to center the hardboard cover in the recess, then drive the screws down. Easy.

I included a picture of my very small, crowded shop with both of my "work tables" occupied with work. The "work tables" are a piece of MDF on my table saw, and the top surface of my router table. Oh, and the little 12" square top of my cheap band saw. The room is located under my garage, and has low ceilings too. Access is limited, and it's crowded because of its use as a storage area too.

When the glue dries, I pull the subassemblies from the side panels and move on to other pieces that need work.

[Later today - more gluing]

I began gluing up the sub assemblies into the part that fits between the side panels. I forced parts square to the side panel that is used as a jig for the assembly and gluing. Note that I left these pocket screws open - I inadvertently glued the small Part E to the top panel before I realized that wouild make it very difficult to clean up the plugs. It's not an issue structurally. Even the appearance isn't affected unless someone crawls around on their knees looking at the top part of the woofer box, and even then it's neat. It's one of those things that bothers me more because I did a step out of plan.

To clamp the two baffles together without using screws, I used a 6" clamp through the woofer hole, and two others pulling on bolts that I had inserted into the driver mounting holes. It made a handy grip point for applying good clamping pressure for the glue. There are biscuits in the joint too, and those were liberally glued before insertion. Note the use of wax paper to keep the squeezed-out glue from adhering the assembly from the side panel. I will remove the glued together parts tomorrow for a little more work (drilling pilot holes into the baffle edges) before the final step - attaching the side panels.

Working step-wise like this allows me to check the quality of fit as I go. If everything were glued at once, I wouldn't have time to check squareness, adjust clamps, whack pieces into proper alignment, etc. before the glue set up. I don't have enough arms and hands for that sort of approach.

Note that some of the clamps you see in some of the pictures aren't being used for clamping glued joints. I'm using some of them to flatten a slight bowing in some of the side panels, and in others, I clamp assemblies square to each other. By clamping them square to another part and flattening any slight warping, I simulate the position in which the pieces will be eventually assembled.

Gluing Again [January 3, 2013]

Gluing takes time when faced with limited work space and clamps. I've begun gluing the side panels to the center assembly. I noted with some irony how square things are before the glue goes on. I know that the gluing process, being somewhat rushed, always tweaks squareness. I wish there were a way to assemble the panels and then somehow wick the glue into the joints. Plastics, yes, wood, no.

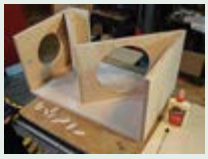
I'm glad that I put 4 screws through the side panels to tie it to the baffles. It would be very difficult to apply pressure on the mid-panel without using some sort of cauls. I still resorted to using one makeshift caul because of the bow of the side panel. It was barely making contact between screws in one location. I placed a piece of scrap plywood on top of the panel with a few folds of paper towels in the center to apply local pressure. It's not ideal, but it did take out some of the bow of the panel and made a little better contact with the baffle edges. It would have been OK without it, but it helped, I'm sure.

I finished gluing the sub-assemblies together on the other box. This time I was a little better prepared for the baffle clamping by using screws, washers and nuts at the clamping point. The last time, it was a rush to jam the screws through the holes while glue was setting. It worked, but this looks tidier and it places less stress on the wood around the baffle holes.

I've employed just about every clamp that I own today, as well as both flat surfaces on which to work. Naturally, after gluing, I can't do anything more while it dries.

I'll probably not update this log for a few days until gluing is done. After all, how many pictures of clamping/gluing do you want to see? (If you think this is bad, just wait until spring when it comes time to paint. Prime, sand, spot putty, prime, sand, etc., etc., etc....

Flash update.... Madisound sent an email stating that the back-ordered drivers have shipped. I'm officially behind now.



Woofer Box Gluing DONE! [January 6, 2013]

The top picture in this group shows the last box about to have its final side panel glued on. That was the last gluing task for these boxes. I finished gluing the woofer boxes together yesterday, and removed the clamps this morning.

Time to step back and take a look.

They are looking good. Not perfect, but very close. As I expected, gluing tasks aren't exact, and a little sanding here and there to flush some joints is still needed.

I am very pleased with the 45-degree miter at the lower front edge. That came together very, very well, and only the slightest touch up was needed at the front edge to make it perfect. I sanded a very small radius there to blend the angled piece with the box. There's no gap, no ridge, just smooth goodness now.

Squareness of the boxes is also very good.

I still have to sand away squeezed-out glue from the joint locations. When it warms up in spring, I will probably use some sort of grain filler or heavy, sandable primer to hide most of the appearance of wood grain from the painted surface. The plywood edges are particularly visible without a little work with fillers, primer, then paint. I know that from experience with the Orion woofer box.

My available free time left to work on these is rapidly disappearing. I have the rest of this week away from work, then I will be very busy for a while. I will have small bits of time in the evenings, and on the weekends (those that I don't work), so maybe its time to start on the electronics. Electronic assembly work is more suitable for small blocks of time.

[continued on page two]

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[main audio page]

Linkwitz Lab LX521 Dipole Loudspeaker Project - Page 2

Construction log - continued from page one

[Skip to Page Three...]

Click to enlarge thumbnails below...

Drivers Arrive [January 7, 2013]

UPS delivered the package from Madisound this morning. Because I already owned the woofers, they were not part of the shipment. I could actually lift this modest sized box!

The tweeter does have a steel back. I had assumed that it would be aluminum, but there's no doubt that it's a turned steel piece. It will take a little more determination to shorten the stub on the back to fit the baffle if I need to do that.

I was also curious about how steel screws might affect inductance of the coil. I had pre-drilled holes for screws to clamp the vertical sides of the bracket to the foot while glue dried (or maybe not even use glue). The screws would be positioned into the wood near the coil, which can be problematic.

I performed an experiment. With no screw near the coil, my meter read 4.17mH. With a steel screw placed over the opening of the coil, the inductance rose to 4.22mH. Brass screws caused no change (4.17 mH), so the solution is easy. Use brass screws near the inductor.

<--click any picture to enlarge

Test Routing Baffles [January 11, 2013]

I'm waiting for my cherry panel blanks to arrive for my "official" baffles. For practice (or to make idle hands busy) I used some left-over MDF in the shop to test the template/routing steps to find a good workflow.

I created 3 MDF clones of the template I that made earlier. I may use 2 of these to use temporarily to listen to the speaker before finishing it. Who knows?

I did discover a sequence of steps that made work a little easier - rather I learned what NOT to do. It didn't affect the outcome, just production speed. What I learned will be useful when the cherry panels arrive.

While I used 1/8" metal pins to attach the template to the stock for routing, one could just as easily use double-stick tape.

If I were using tape to hold the parts together for routing, here's a step sequence that makes sense:

- Cut the stock to be a little larger than the baffle.
- Draw a vertical centerline on it. Position the template to align with it, and trace around the template.
- Using a jig-saw or a band saw, cut to within 1/16" (or tighter if you're good!) of the traced line. Cut rough holes for the driver openings (which can't be done on a band saw).
- Attach the template with double-stick tape to the stock using the center lines and traced outline for positioning.
- If you have a router table, you can probably figure the rest out from the third picture in this group. Use a flush trim bit. If you don't have a router table, you will route from the top with the work positioned above the template using a flush trim bit. Support the work well, and pay attention to the proper routing

direction with either case.

There are other possible scenarios, but these two approaches will get the job done.

I want more time to continue work on these, but that doesn't pay the mortgage. My day-job beckons.

Look for only sporadic updates until I manage to get more free time.

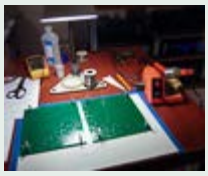
Fabricating the Passive Crossover Board [January 21, 2013]

Martin Luther King day was a holiday from my job, so I went into the [cold!] shop to do a little work. I tackled how I was going to make a "cradle" for the passive crossover components and their connections.

I arrived at a sub-assembly that would nest inside the bracket, held at the bottom by Velcro. The 4-connector lead from the Speakon would be inserted into the cable clamp, and the leads pass through a false-bottom into a sub-chamber where all the messy soldering would be. That way it's hidden from view.

It's a little hard to explain, so I'll let these three pictures hint at how it will be configured eventually. There's still a lot of work to be done.

I've been seeing some nicely executed LX521 baffles where the wiring is almost entirely hidden. I hadn't planned to go to that extent - especially if I use a hardwood baffle - but it's becoming a temptation. I don't NEED to have the wires hidden, but a challenge like that is sometimes fun.



Minor Update [February 19, 2013]

Progress is slow because it's been a very busy time in my life. When I had a free hour or two in the past two weeks, I worked on stuffing the ASP circuit boards. Another delay occurred because I ordered some additional capacitors for stuffing the boards. I measure everything before soldering, and I felt that some of the tolerances were a bit sloppy. With extra capacitors available, I'm able to sort them and pick those closest to the design values. Unfortunately, the extra Mouser order took about a week to arrive using their economy shipping choice.

With the new order, I was also able to incorporate some changes suggested on the Orion/Pluto/LX521 owners web site. For example, the circuit board has 15mm pin spacing for the C7 & C100 caps, but the 10/15/2012 Bill of Materials specifies a smaller 5mm capacitor. I didn't want to bother with soldering extension legs onto any capacitors to fit the boards, so the re-order gave me an opportunity to choose alternative parts that fit better. The published tolerance range of the new caps is better too.

The capacitors that are attached to a paper strip allow easy labeling once measured. I find that useful when trying to match capacitor values between left and right channel circuit boards.

Bridge Musings [February 22, 2013]

While unable to get into the shop to do some real work, I've been pondering what I can do to make the bridge stronger side-to-side and perhaps to make it more attractive too.

In early ideas, I entertained the idea of using 2x2 lumber legs with 2x2 cross bracing to support the upper parts. Because the 2x2 is thicker than the 3/4" plywood specified for the sides, it would require a bit wider upper platform to mount to. The increase in side-to-side strength would be sizable. I'm not convinced that this can be made to look attractive, although visually the 45-degree braces would echo the 45 degree woofer

baffles inside the box. I've "sketched" it in several different color combinations, some with very thin panels located behind the braces to hide the box somewhat.

Another idea was to use PVC pipes with a finish similar to my Pluto tweeter tubes. I was able to make a very attractive audio rack/table using these tubes finished in the way that I used for my Plutos. The nicely textured lime-wash surface, applied in a spiral fashion, completely hides humble PVC water pipe origins. It looks mysteriously high-tech in its own way.

The audio table uses 1/4" x 20 all-thread rod through the center of the PVC tubes to pull things tightly together. It is stronger that I'd expect. I'd do the same thing if I use this approach on the LX521 bridge. This approach too would require a slightly larger upper platform on the bridge, but I might be able to incorporate gentle arcs in the platform between pipe attachment points.

I attached a picture of my audio table so that the end result could be more easily visualized.

On another front, the woodworker who is gluing the cherry-wood baffle blanks said that he'd deliver them by the weekend. He says that it took three attempts to get a warp-free glue-up for the baffles. Perhaps the weather swings we've had affected the process. In any case, it will be good to get back to some woodworking, and to finish the front baffles.

It's still way too cold to do any spray-painting though!

Baffle Stock Arrives! [February 23, 2013]

The woodworker delivered the glued-up baffle panels today. He had trouble with flatness in two previous attempts. It appears that the problem was one of heat. Because he was drum sanding them to thickness without letting them cool, the heat likely changed the wood's moisture content and they warped. Usually, he is in a production mode making a number of cutting boards, and does a bunch at a time. The cutting boards can cool as the next one is drum sanded, then they are reversed for sanding the other side. Cooling between sanding the front and the back appears to be key.

I was happy to get the cherry panels, and spent about an hour on the project this afternoon. I began by marking a centerline on the panels, positioning the template to align with the centerline, and marking the top registration hole with a transfer punch. After the 1/8" hole was drilled through, I inserted a 1/8" steel dowel pin through both pieces to register the top half. Then I carefully aligned the bottom of the template with the centerline. Once aligned, I drilled through an existing hole in the template into the cherry panel so that I know that registration will be perfect. I'll put a steel dowel pin in the lower hole to hold the pieces together for the routing steps instead of the double-stick tape. It will keep the surface of the cherry neater - no tape residue.

More work tomorrow, I'm sure!

More Baffle Work [February 24, 2013]

I began the morning by accomplishing a lot in two hours. I was convinced that I could get these finished today. But then I was called upstairs because our 30-year old clothes washing machine leaked sudsy water onto the laundry room floor. Why can't I get a whole day to work on anything?! Just ONE whole day? Please!

Ranting aside, I did put larger counter bores on the rear side of the two tweeter holes per a suggestion on the Orion/Pluto board. Because the two tweeters face 180 degrees from each other, the upper counter bore, about 1/8" deep, is on the front of the baffle, and the lower tweeter's counter bore is on the rear of the baffle. I am hoping that these little extra spaces, made invisible by the tweeter plates, will provide a generous space for tweeter wires. I marked the center of the counter bore by placing the template over the work and using the

smaller Forstner bit to mark the spot. Then I removed the template, and drilled the shallow counter bore in the appropriate positions.

Once that was done, I pinned the template to the work once again, and used it to guide the Forstner bits accurately. At this time, both baffles have three holes in them, and what remains is to rough-cut the large midrange hole, rough-cut the outline of the baffle, then route everything flush with the template.

Lots of sawdust to come.

Wish me luck with the clothes washer in the meantime.

Boards and Baffles [March 3, 2013]

The LX521 ASP circuit boards are stuffed. That work is easy to do in small chunks of time. It takes the soldering iron about 5 minutes to warm up, and I have a card table set up next to my computer desk to hold the work. I play some music through my Plutos, and work until I have to stop. I need to insert the opamps and do some spot electrical checks. I feel confident that I won't have much trouble. Both the Pluto boards and the wASP subwoofer boards went together without a hitch. There's no reason to believe that my luck will change this time. Famous last words, eh?

I had most of today to do some more work on the cherry baffles. I rough-cut the mid-woofer hole with a jig saw, then used the band saw to rough-cut the outside shape. Deja vu! I still have the MDF baffles done earlier if I completely change course and decide on paint instead of natural wood.

After rough-cutting, I pinned the template to the board, and took the "sandwich" to the router table to trim. I used a Katana 1/2" dia. [#17805] flush trim bit from MLCS that I had purchased in the distant past. I wanted to get a top quality Whiteside flush trim bit to ensure good results, but couldn't find the time to drive to Woodcraft. However the Katana bit cut very well, even across the grain. I was left with a very smooth cut when done, without much sanding needed. I left a light burn mark on only one spot - completely my fault. It sanded out easily though.

After cutting the cherry boards to shape, I drilled the bracket mounting holes and test-fit the baffles to the brackets. I used 1/4" x 1-1/2" flathead machine screws, and things lined up very well. There was no binding when the screws were inserted.

I left the shop satisfied today.

There's still work to do on these. First, I need to mark and drill pilot holes for the wood screws to mount the drivers and tweeter sub-baffles. I also need to drill, saw, or mill out a slot or hole for the internal wires between the two tweeters. This doesn't have to be very neat because it will be hidden by the tweeter sub-baffle.

I will probably use either Danish Oil or General Finishes Arm-R-Seal Urethane Topcoat on these. The GF finish would go much faster, but builds on the surface more than the Danish Oil. It's also more prone to brush marks and embedded dust, unlike the Danish Oil.

More Mockups [March 7, 2013]

It's too cold in the shop. I'm a wimp. Instead of cutting wood, I played at the computer.

As you can see from the picture, I'm narrowing down the choices for the bridge. I mocked up a version in my drawing software (CorelDRAW X6) showing the Pluto-type posts to support the upper assembly, but the front view looked too "stocky". The extra width of the columns added girth to the front view, and proportions looked wrong. I'm glad I took the time to model this before I committed to cutting material.

I settled on cherry sides with extra edge trim for appearance. It will add a little additional side-to-side strength too. I'll might use some 5/4 cherry to add even a bit more width to the side trim than I have shown.

I'm wondering about the top panel of the bridge, and how just a slab of cherry will look. End grain appearance can be a problem*. If I add four mitered trim strips around the periphery of the top panel, it will take a lot of time. The extra trim around the panel won't extend very far out, so the vertical uprights will have to attach to the trim itself, or even span the joint - neither of which is best practice.

Maybe I just think too much and do too little. These choices will have no effect on the sound.

*Edit: In later experiments, this was found to be NO problem. In fact, the finished cherry end-grain is beautiful!

Test Finish [March 9, 2013]

I wanted to see how the cherry baffles responded to Danish Oil finish. I've had good luck with it before, and it's easy to apply.

I was very, *very* pleased with the color of the cherry with the natural, uncolored oil. Also, I was astonished at how good the end grain looked with the oil on it. I will not try to hide end grain in other parts of the construction as mentioned above. I'm embracing it!

Preparing Cherry Veneer [March 13, 2013]

Because of it's superior engineering properties, I chose to use Baltic birch plywood instead of solid cherry boards for the side panels. Baltic birch is strong, and straight, and doesn't move much with changing humidity. However, it's rather plain looking.

I am going to attach a thin veneer of cherry over the Baltic birch plywood to match the solid cherry used elsewhere in the bridge. Paperbacked veneer is easy to cut with scissors, and attaches using ordinary wood glue. I've used the iron-on method in the past, although sometimes I wish that I had a vacuum bag to do it without heat.

I used one of the Baltic birch panels as a template to determine the size of each piece that I'd need. I merely stepped it along the veneer, and loosely traced lines around the panel with a pencil. Ordinary scissors cut the veneer easily. The veneer sheet is only 0.023" thick, with 0.010" being the paper backing.

Cherry darkens with exposure to light, unfortunately. In the top veneer photo, the far end of the sheet was positioned on the outside of the veneer roll for display in the store, and has darkened. I avoided having a visible demarcation line halfway through a piece of veneer. The cuts I made produced one panel comprised entirely of dark veneer, and three panels of the lighter veneer. The dark veneer piece will be placed on one side of one speaker, and over time, the tones of the other three sides should approach that of the already-darkened piece. At least there won't be a distinct line bisecting one panel into darkened and almost-darkened wood to worry about.

I chose an interesting pattern in the veneer sheet to use. It has a light herringbone appearance to it. The grain and pattern will run vertically.

That's about all that I had time for this evening. There are other chores that I've been asked to do. I have to maintain domestic harmony!

Veneering the Bridge Side Panels [March 16, 2013]

I had a few hours after my Saturday morning shopping chores to get some work done. I completed the veneering of the bridge's side panels. They need trimmed, but I will do that tomorrow.

Using a sponge paint roller, Titebond wood glue is rolled onto both surfaces to be mated. The plywood received two coats, and the veneer got just one coat. I use fairly heavy applications of the glue.

The plywood parts are coated easily - just lay them side by side, and roll on the glue.

The veneer requires taping the edges to prevent curling and to prevent glue from reaching the face of the veneer. That preparation takes more time than actually applying the glue.

Once the glue dries, I align the panels and veneer using pencil marks I placed earlier. I use an ordinary clothes

iron to tack it all together. The iron moves slowly, and I press down with as much weight as I can muster. I've successfully used this method of veneering for a number of loudspeaker projects, and it works very well for me. Best of all, the required equipment is simple and inexpensive.

Tomorrow I expect that I'll fire up the router table (shown in the last picture here) and trim the excess veneer from the edges of the plywood.

Trimming Veneer and Adding Finish [March 17, 2013]

I decided not to use the router table, but instead chose to limit myself to hand tools for the veneer trimming. As they say, I went Neanderthal.

I had purchased a veneer saw years ago, sharpened it to a razor's edge using waterstones (veneer saws ship with fairly dull edges regardless of manufacturer's claims), and hadn't used it much. This was the perfect opportunity to try it again, and it worked very well. A veneer saw isn't really a saw, but a serrated knife that has a flat bottom for cutting flush with an edge. I just score the material with long strokes until it cuts through. I don't use a back-and-forth motion like sawing.

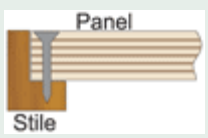
Cutting with the grain took about 5 passes to cut off the overhanging veneer, and across the grain took more - maybe a dozen passes. I used medium-light pressure to avoid tearing out the thin veneer, especially when cutting across the grain.

Once cut, there were a few thousandths of an inch veneer overhang remaining, and a small block plane quickly removed the excess. Very easy, no noise, no sawdust flying around! It was satisfying. The hand plane is a Lie Nielsen low-angle block plane. The low-angle blade is ideal for trimming end grain. I love that little plane!

After some light sanding of the veneer surface with 220 grit sandpaper, I arranged the panels side by side and added a coat of Danish Oil. I am trying for a semi-gloss surface, so it will take many applications of finish to get them looking the way I want. It might even require some wet-sanding with the oil.

I also did a little work on the vertical "stiles" for these panels. They needed sanding, and a rabbet cut for receiving these panels. The sanding is done, but the rabbet is only 10% of the depth needed for the panels. I'm setting the router table to take shallow passes to avoid problems, but that means slow work. There are 8 stiles to do, and each one is about 2 feet long.

The stiles will be attached using flathead screws through the panels. The panels will be attached to the top of the bridge and to the feet using pocket screws. All fasteners will be placed out of sight on the inside of the bridge assembly. The stiles will hide the exposed plywood edges.



I'm not gluing parts together because, ever fickle, I might change my mind about the side panels. I keep thinking about how nice it might look with some Ambrosia maple panels contrasting with the cherry found in the rest of the build.

Bridge Uprights [March 23, 2013]

The upright panels for the sides of the bridge were given pocket screw holes on the top and bottom ends. Screws will attach the panels to the underside of the bridge top panel, and to the feet. With the Kreg jig, drilling them is straightforward.

Next I needed to shape the stiles into an "L". This became a little tricky on the router table. As the cut progressed across the width of the stile, I was cutting away support. When the piece became strongly "L" shaped, there was little material left on the bottom to contact the table's surface for support. I was concerned that the piece would slip during a cut with damaging results. At some point, I ceased cutting on the router table to avoid such a mistake. However I still had about 0.10" wood remaining to cut away.

(Hindsight alert: Next time I need to make narrow "L" shaped stiles, I will explore the possibility of cutting a wide channel down the center of a wider board, and then rip it in half to get two stiles. It would require less time, and would be safer than the method I used on the router table. I suspect that the wide channel could be cut with either the router table or with a dado blade on the table saw . The dado method would be the fastest. I'd need to buy a dado blade set for my table saw, but I'm overdue for that anyway.)

Another issue was that the 1/2" straight-sided router bit didn't produce a clean cut on two of the boards. I'm sure that grain direction was the culprit. Even with light passes, I had some tearout on the problem boards where they contacted the straight sides of the router bit. There was no easy solution to the grain direction issue on the router table. I desired a 1/2" spiral downcut bit for the possibility of a cleaner cut, but I didn't own one. I ordered a 1/2" spiral downcut bit later in the week, but not until the router table work was done for the stiles. I'll have that router bit on hand for the next time.

To cut the remaining 0.10" material away without risking damage on the router table, I used a medium shoulder plane. Set up to take a medium cut, it still took about 2 hours of work to cut the rabbets for all 8 stiles to final dimensions. Cutting away the remaining material with the plane removed all traces of the router table tearout, as I knew it would. When I encountered minor tearout on the wood surface using the plane, I could flip the board end-for-end and reverse the cutting direction. As a plus, I got quite a workout.

I was pleased with the fit of the stiles. They look as I had envisioned, and will provide a nicely finished appearance to the bridge uprights.

They are not sanded nor finished yet so the color is currently much lighter than the veneered panel itself. The next step will be to drill and countersink screw holes near the edge of the panels for attaching the stiles. I have the hole locations marked, but not drilled. It was time to quit.

Final Fabrication and More Finishing [March 24, 2013]

By the conclusion of the shop work today, all the major parts fabrication needed for this project is complete.

The first task today was to drill and countersink holes in the back side of the bridge uprights. The holes are for

the screws that fasten the stiles into place. I realized that the engagement of screw threads was a little less than what I'd prefer, so I'm considering a bead of glue on the side of the upright to secure the stiles in place to augment the screws. The glue can be applied to hidden, non-finished edges of both parts to increase strength. I can't realistically apply wood glue to the already-finished surfaces. The finish would greatly reduce the holding power of wood glue.

For the edges of the feet and the bridge top, I milled a combination of curves and chamfers. The edge corners were rounded on a disk sander before routing chamfers. It's fascinating to watch the wood disappear from view when sanding to a line on the disk sander. It's easy and very fast to sand to a pencil line. The corners have a 1/2" radius (1" diameter) arc.

After sanding the corners into arcs, I took the parts to the router table to add the 45-degree chamfer to the top sides. I didn't have much trouble with the edge routing, with only a couple minor spots where light burn marks showed up. These happen more often when going across end-grain, and when I pause slightly in a corner. A few swipes with 180 grit sandpaper removed the blemishes.

It was time to apply finish to the completed parts. I wiped on Danish Oil, as I did for the upright panels. For the the uprights, it was a third coat.

With so many parts and with the complicated geometry, I'm tempted to switch to General Finishes "Arm-R-Seal" Oil and Urethane for the remainder of the finishing. It will build more quickly than the Danish Oil. Properly using the Danish Oil for a very smooth finish requires sanding between each coat, possibly oil-sanding during applications, and substantial drying time between coats. The Danish Oil finished speakers I've done in the past were simple boxes, and oil-sanding didn't consume as much time compared to the multitude of little pieces that I'm working with here.

I remain impressed with the grain and color of the bridge top that has a knot hole. The hole will be covered by the bottom of the baffle bracket, so it won't show or matter. The color and grain that extends beyond the bracket will be a display of wooden beauty though.

I also have one bridge foot that has some interesting spalting in the grain. It's an eye-catching piece of wood. I wish all four feet looked like this one piece.

By the way, the feet and the bridge tops were made from thicker 5/4 cherry. It's about 1.1" thick. The thicker tops should add some mass to the upper assemblies. I have some other ideas to further damp high-frequency propagation into the side panels. I plan to add some felt to the bottom of the bracket assembly before attaching it to the bridge. Maybe. We'll see when the time comes.

The season is nearing to be able to paint the woofer box, and some other assorted parts. I need good weather and big spans of time to spray paint in the garage. While it snowed again today, it won't be much longer before favorable weather returns. For now, I can continue working indoors by applying additional coats of wood finish.

Finishing, Finishing, Finishing [March 29, 2013]

Finishing continues. There's nothing interesting to show picture-wise. It's slow work, especially with the penetrating, slow-drying Danish Oil. I haven't yet switched to the General Finishes Arm-R-Seal which dries much faster. Unlike the GF product, the Danish Oil finish won't build to a semi-gloss without a lot of sanding work.

This is where I think the Arm-R-Seal finish will have the edge and I'll switch, but instructions indicate that one should wait at least 72 hours before applying the Arm-R-Seal product. I will probably wait even longer than that between the two finishes to make sure that they work together. I'm in no hurry.

I did get curious about how a bridge upright would appear, so I held the loose parts together for this snapshot. I like it!

Finishing Continues [April 8, 2013]

This is slow work. I did switch to Arm-R-Seal to complete the finishing. While the parts aren't to an acceptable level yet, I thought that I'd post this picture of how the General Finishes semi-gloss Arm-R-Seal worked with the baffles - especially the end grain parts. Semi-gloss Arm-R-Seal has the ideal sheen for my skill and

patience.

I do wish for some absolutely lint-less cloth to use for wiping finish. I've opened a roll of Webril Wipes, said to be lint-free, but they do shed cotton fibers in use. When that happens, all you can do is to wait for the finish to dry, then lightly sand the area before recoating.

The trouble is when you add new finish to go over the sanded area, more lint happens. Still, I believe that I'm making headway. The low sheen of semi-gloss looks upscale to me.

In hindsight, I probably shouldn't have used the Danish Oil initially because of how slowly it builds. It took forever to dry too. It did pop the woodgrain appearance though. However, it probably cost a week of finishing time compared to a simple washcoat of 1# shellac, then to build sheen with the Arm-R-Seal.

One advantage of Danish Oil is that any damage can be repaired with just a little sanding and reapplication, but my overcoat of GF Arm-R-Seal negates that advantage. Danish oil is fine on large surfaces where surface quality can be obtained by wet oil-sanding. I've done it before on box speaker cabinets with excellent results. And you don't get runs and sags. However, it's just not the ideal finish for this project with its intricate parts if a semi-gloss is desired.

Lesson learned.

Painting Driver Backs, and I'm *Still* Finishing Wood [April 14, 2013]

The drudge work continues, and some aspects of finishing have become fairly difficult as the finish builds. With a near-glossy surface, the slightest imperfection shows.

I have some slight surface undulations on the veneered panels that resist work. I used the random orbital sander to sand the surface as flat as possible, but managed to go through the finish into bare veneer in a couple of spots. The newly uncovered areas take finish differently, and it will require building back up to an even sheen over the next few finishing passes. I'm halfway tempted to go to a satin finish instead of semi-gloss. The semi-gloss builds to almost a full gloss and requires extreme care when applying.

Even after all that work, I STILL have some slight undulations on the surface. It looked and felt dead-smooth after the sanding session, but still shows a slight waviness after finish is applied. I'm about to throw in the towel, and just be satisfied that it's as good as I can get it. The first picture of the side panels shows where I am now.

The midrange drivers have silver plates on the driver magnet, and that color was not going to integrate well. I decided to paint them. While waiting for the wood parts to dry, I masked off the back of the mid-range drivers. I loosely inserted some flat-head screws into the vent on the back to avoid getting paint inside. After masking, I used some now-discontinued Krylon semi-flat black in a spray can to paint them. The back of the drivers look much nicer now.

Not Much to Report [April 21, 2013]

If you guessed that I'm still finishing parts, you'd be correct. It's a good thing I don't do this for a living or I'd starve.

I have a very smooth coating of semi-gloss on the side panels, and I have a nice shine on the baffles. Even so, there are minor things that require a little more rework - unless I just give up.

After painting the plated-steel end cap of the midrange drivers, I found a little paint leakage under the masking tape onto the annular ring of exposed magnet. I scraped the unwanted paint blobs smooth with the end of a stainless ruler, and then painted the exposed magnet with some General Finishes Lamp Black water-based paint. It's a flat-finish paint, so it will contrast against the satin sprayed paint. Because I used a small artist's brush, I was also able to blacken the ugly white cardboard of the terminal pad. I probably should have painted

the red half too, but didn't. If the drivers need a second coat, I'll take care of it. I have this photograph to determine which terminal is the "+" one, so I don't need the red color anymore.

[Edit: I did apply a second coat today, and the red is now covered in black too. It looks better.]

Assembly of Bridge Components Begins [April 28, 2013]

Enough wood finishing! With that behind me, I began to assemble the parts that comprise the bridge. First, I placed the 1/4-20 threaded brass inserts in the underside of the bridge top. I had a little trouble with my older T-wrench. It expanded the slotted end of the brass insert because of a chamfer where the shaft meets the threads. It wedges into the opening of the insert, and spreads apart the screwdriver-slot part of the soft brass under load. I bought a new T-wrench from Woodcraft to use, but it came with a chamfer too. It also spread the brass insert. The T-wrench should not have had a chamfer at all. It's a flaw for its intended use.

I worked around the problem by turning the brass insert upside-down when I threaded it into the wood. The bottom of the insert is a solid ring, uninterrupted by any screwdriver slot, and provides more strength.

After working through the insertion issue, I tested the fit using connector bolts that I had purchased from Woodcraft. Inserted in the baffle bracket bottom piece and threaded into the inserts in the bridge top, they look nice and "high-tech". The bracket bottom piece, now bare MDF, will be painted a flat or satin black when I reach the spray painting part of this project. I might strip off the flat-black oxide finish from the connector bolts, polish the heads, and use some gun bluing on them to reach a glossy black finish. Maybe.

Thinking about potential problems ahead, I drilled 3/8" diameter blind holes into the bottom of the bridge feet. If I ever need to use conical rubber pads or spikes for use on carpet, I can just install the 1/4-20 threaded brass inserts into them, and screw in the pads. It's far easier to drill the holes now than after the speaker is assembled. If I never need the pads, there's no harm done.

One issue I keep thinking about is the number of mating parts on my bridge. The uprights are each made of three parts - the panel, and two side pieces. They are screwed together. I had intended to insert some very thin polyethylene foam at the junction of the parts to suppress any buzzes or rattles. However it became obvious that it wasn't meant to be. I couldn't juggle all the parts and foam strips while trying to get a clamp into position for marking pilot holes, then repeat again for driving screws. I abandoned the idea. If I encounter buzzes of rattles, I'll run a bead of silicone sealer down the length of the joint. I hope it isn't an issue.

Even though I used some small #6x1 self-threading screws to fasten the sides to the panel, I still drilled very small, shallow pilot holes in the cherry strips to prevent splitting. It took a while to assemble each panel - clamp the pieces together to mark the hole locations with a transfer punch, drill the 1/8" deep pilots, and re-clamp while driving the screws. It took a couple of hours to get them all completed.

I left the vertical side pieces ("stiles") a little long when I fabricated them, planning to trim to fit after assembly. Now was the time. I had registered each panel and its stiles at the bottom end against a flat surface when inserting screws, and that left the stiles a little proud by ~1/16" at the top. It took about 30 seconds per panel on the disk sander to remove the excess for a flush fit. Easy.

They look good overall. I temporarily placed one of the assembled panels onto a bridge foot to preview how they look together. The wide panels have almost a mirror shine to their surface even though a "semi-gloss" finish was used. The stiles remain more satin for contrast.

There is still the occasional piece of dust embedded in the finish, but the flaws are very small and I was anxious to get moving along. I doubt very much if I could have done better with my current capabilities. It still amazes me that a surface this smooth comes from a wiped-on finish. Spraying might be even better, but I refuse to spray solvent-based finishes in my garage. If it's not water-based, I don't spray it for a number of reasons.

One thing concerns me - the panels transmit sound readily. A rap with knuckles delivers a resounding THONK!. I may investigate some sound damping material for the back side of the panels.

Bridge Dry Fit [May 4, 2013]

I fastened the feet to the vertical panels, and then dry fitted (stacked) things together to get an idea of how it

was looking. I still need to attach the side panels to the top panel, but I will wait until I decide what to do about panel damping, if anything.

Finish on the wooden parts looks good. Painting will begin soon for the woofer box, bracket parts, and other sundry items. I'm at the mercy of the weather from here on out. It's been too windy to paint today and rain is forecast for much of next week. I'll see what I can squeeze in.

A Damping Consideration [May 6, 2013]

I have prepared the surfaces of the woofer box and other assorted parts for paint, but it's raining today with 4 more days of rain forecast. I paint in the garage (and still might attempt it), but for now I've been doning "busy work". I have been thinking about how the side panels might "ring" if excited by vibrations, and one obvious approach is to minimize any vibrations that may reach them. I had some 1/16" thick F1 white felt from McMaster-Carr, and decided to cut a pad to fit between the bracket bottom and the top panel of the bridge. It should absorb some of the acoustic energy that may be transmitted from the baffle.

Thicker felt may do an even better job, but at some point, mounting rigidity will be compromised. However, no pad is specified in the original plans. It's really just busy work for an idle mind while waiting for better weather.

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Construction log - continued from page two

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[photos]

Click to enlarge thumbnails below...

Primer and Paint for the Woofer Box [May 6, 2013]

<--click any picture to enlarge

I intend to experiment with some new (to me) primers and paints. These are commercial paints, and probably not available at most retailers. I purchased them from Homestead Finishing. The owner is Jeff Jewitt, for those of you who know of his books on finishing. The cost of these gallon cans of paint is high, but if they provide the features that I need, they will be worth it.

All are water-based coatings. I do not wish to spray solvent finishes in my garage, and suffer the clean-up hassles associated with them. Being water-based coatings, they will be safer to use too.

I have high-hopes for the primer. I've been looking for a water-based primer that sands easily. I'll have some answers as soon as the weather clears.

Painting Has Begun! [May 8, 2013]

There was a break in the weather today, and I took advantage of it. I had purchased a new Qualspray AM-5008P spray gun from Homestead finishing to use with heavy finishes back in the autumn while I was still working on Orions. I put it to use today for the first time. I needed more tables/platforms on which to place all the small parts. I definitely wanted to get started on the woofer boxes, so they took precedent.

I used the General Finishes Enduro undercoat to spray. I chose black undercoat because that's the color I'll end up using. No sense trying to hide white undercoat with additional layers of black finish. I used the Enduro undercoat straight from the can - no dilution. It sprayed well using the 1.8 needle/nozzle @ 29 psi at the gun's regulator. The GF Enduro undercoat smells just like their water-based Milk Paints. It's a little thinner though, for ease of spraying no doubt.

During the weather-induced downtime, I had used some Bondo spot putty, an automotive product, to fill in any obvious divots or flaws. It comes in a tube and is available at most auto supply stores. In some places, the wood itself was a little rough - almost wash-board looking for whatever reason. I had put on a wash-coat of shellac earlier, so perhaps that caused the wood surface to react. This Baltic birch wasn't the best sample I've worked with.

Painting the outside surfaces of the boxes was easy. The gun lays down paint quickly so I could easily maintain a wet edge on the large areas. However using the gun on the inside recesses of the woofer housing produced bounce-back spray. I wore an old pair of glasses, and I'm glad I did to prevent paint spray from spattering my good glasses. I wear a respirator even though it's water-based paint because there's much more than just water in the spray.

Overall, I was very pleased with the first painting session. Keep in mind that it's just primer and painting becomes more difficult while finessing top coats. I'll have to spot putty a few additional areas, especially the cut ends of the plywood. Once things are painted black, the minor flaws become much more visible. It's all part of the finishing game, and the appearance improves with each new coat.

I'll start sanding after the second coat goes on. Wood-grain texture still shows, and additional applications of primer together with sanding between coats will level it out.

Clean-up of the spray gun was easy. I had previously filled a bucket with fresh water before painting, and used

it to fill the spray-gun's cup for cleaning. I tossed the cap in the water, and I sprayed a minute's worth of plain water through the gun to clear most of the paint After that, took it indoors to disassemble it for a thorough cleaning.

The major "dimples" in the finish will need attention beyond just primer. They will be filled with some Bondo Spot Putty, an automotive product, and then sanded flush with the surface.

Damping the Bridge Uprights [May 14, 2013]

As I had mentioned before, the bridge upright panels rang surprisingly when they were rapped with knuckles. I doubt that much acoustic energy will make its way to the uprights to excite them, but just in case, I did an experiment. It worked, and it will be part of my build just in case.

I had ordered two pieces of 0.030" thick steel sheet that measured 12x24" from McMaster-Carr. I took the sheets to a heating/cooling company to have them sheared into 6"x18" pieces to line the back of the bridge upright panels. RTV silicone adhesive is spread between the metal and the wood.

It might appear strange to use metal to damp sound, but I've done similar things in the past - successfully. Both the wood and the metal have differing natural frequencies, and when they are firmly combined together, neither can resonate normally. Once piece wants to vibrate at one frequency, but it's tied to the other piece that doesn't want to move in the same way. It's essentially a system with two different spring rates tied together with the rubbery adhesive acting as a damper.

I desired a thicker sheet of steel than what I used, but two factors made that less attractive. I know that industrial foot-operated metal shears can handle up to 20 gauge steel - about what I ordered. Thicker steel would require more powerful shears and I wasn't sure that I could locate anyone with that capability. Second, the thicker the metal, the closer to the woofer box the sides become. The gap is narrow now, and I didn't want to approach the point where accidental contact between bridge and woofer box could happen. If I had planned to do this before cutting wood, I could have used thicker material, but I'd have to order it from a supplier offering custom cut sizes. A quick search found a place called Metals Depot that cuts to order.

After I drew the hole pattern for the mounting screws, I used a Whitney Jr. sheet metal punch for the holes around the periphery of the metal, and drilled the hole located at the center of the sheet. The punch wouldn't reach the center. After the holes were made, I used a small countersink bit to let the flat head screws seat a little closer to the panel. I didn't want them protruding much toward the woofer box. I gave the pieces of metal a quick paint job with Krylon spray paint from the can. That should protect the steel from surface rust later on.

A toothed spreader was used to provide good adhesive contact between the metal and the plywood. After using the screws to clamp the metal to the plywood, I pressed down firmly on the other areas to make sure that there were no gaps underneath. Upon lifting the completed panel, it was obvious that I added mass to it. There's noticeably more heft to it than before.

I need to get to the hardware store tomorrow to get enough additional adhesive for the remainder of the panels.

The silicone is just now curing, but a preliminary knuckle rap test shows the resonant frequency to be lower in pitch, and to damp out faster than before. There was a noticeable difference between the damped panel and an undamped one. I will try again tomorrow after the adhesive has cured to determine any further changes. I expect damping to get better as the adhesive becomes firmer.

I made a short video showing the "knuckle rap test" comparison, but decided not to consume internet

bandwidth posting it. You're going to have to take my word for it.

More Painting and Uh Oh! [May 15, 2013]

I've been adding more coats of primer to the woofer box and the small parts. It was looking fairly good.

I also finished adding the damping materials to the bridge uprights - a task that I started yesterday. I had to fetch more silicone adhesive from the hardware store to complete that work, and it went well.

Then I managed to snatch defeat from the jaws of victory with the most recent coat of primer. I have something that looks like micro debris showing in the paint (now dry). When applying wet finish, it almost appeared there there were hundreds of little "bubbles", each about 0.02" or 0.03" in diameter.

Disclaimer: After spraying, I always remove the cup from the gun, disassemble the nozzle and cap from the front to clean the gun and to remove debris. I use a toothbrush on the parts that I can reach. Clear water is run through the gun to flush paint away, and one final burst of compressed air blows out the remaining water before I put it away. The pre-paint precautions were the same today as before - strain the paint through a paper funnel strainer into the gun's cup to prevent particles from being sprayed. In the cup there is a another small, wire-mesh strainer installed as a backup.

However when spraying this coat today, it was obvious that the finish was going on with problems. The air line has a filter too, so I'm at a loss to explain what caused these very small "pimples" on the painted parts. The last picture in this group shows an extreme close up on the problematic finish. I wonder if something happened chemically to the finish? Was the box outgassing in small, local areas because of temperature/humidity swings and "blowing bubbles? And things were going so well.

In the meantime, I'll sand them like a madman and try again. Thunderstorms are predicted for the next several days, but I might be able to work around them.

Maybe I should have veneered the boxes!

Edit: I found that bubbles in a water-borne finish are evidence of an excessively heavy finish in HVLP equipment. Even though I have a conversion gun, I'll try lightening the coat a bit. Thanks for the internet!

Rain, Rain, Go Away [May 17, 2013]

It's been too damp to paint, so I tackled the assembly of the bridges. I had planned on using pocket screws alone to hold the sides to the top, but I felt that wasn't going to be enough support. I went to the hardware store and bought some 1-1/2" right angle brackets, and a box of #8 x 5/8" wood screws. I didn't really want #8 screws, but the brackets came with countersunk holes for them. Smaller #6 screws slipped through the bracket holes. Using larger #8 screws certainly required drilling pilot holes for them, and that meant some precision was in order.

I butted the top of the uprights against a right-angle jig to position the brackets, then carefully marked, center-punched, and drilled the pilot holes. It took time and care to do, but it wasn't difficult.

Part of the flat heads of the #8 screws protruded below the sheet metal bracket and prevented effective tightening. I lightly countersunk the wood located under the bracket holes to provide space for the bottom half of the screw head to fit. This allowed the screws to seat fully and sit flush against the bracket.

I also cleared the partially obstructed pocket screw holes and gently countersunk them to provide a space for any "burrs" pulled up by the screw threads. This helps to get a strong, square seat, without any burr of wood trapped between the two pieces. I used 1-1/4" long, fine-thread Kreg pocket screws for this fastening task.

Both bridges went together well, and are much more stable side-to-side than I would have guessed. I suspect that the combination of pocket screws and the brackets is responsible for the strength. I suspect that either of them used alone would produce a less secure junction. I should not have any structural wobbles when they are playing.

Both bridges look nice too, enough so that I took them into a living space for a work-in-progress cameo shot. I'm very pleased with this aspect of my LX521 project.

I'm a little concerned that the exposed screw heads on the damping panels may contact and mar the paint on the woofer box when the bridges are lowered into position. I intend to buy some self-adhesive felt strips from McMaster-Carr to cover the screw heads and prevent paint damage. The metal brackets could also contact the woofer box paint when the bridges are slid into position, so they'll be treated similarly.

Update: The weather, while not perfect, changed enough to be OK for painting. The morning fog burned off, but it was still very humid in the afternoon. Because I am merely adding primer at this point, I was not overly concerned about perfection. I just need a fairly smooth primer base for the paint, and sanding primer coats is going to be part of the process anyway.

I did not have the painting problem that occurred a couple of days ago. Paint went on smoothly - well, smoothly enough for garage painting.

One of the hazards of garage painting is the presence of unwanted critters. Here a bug found it's way to the wet paint, and left a trail of footprints. I used needle-nosed pliers to remove him after taking his picture. I'll have to sand that area a little more than the rest before the next coat of primer.

Decision about Paint Color [May 18, 2013]

I've mixed two custom batches of General Finishes Milk Paints in an attempt to find a shade of red that works well with the cherry baffle. Neither blend worked out. The first experiment used a lot of Lamp Black mixed into Brick Red, but it became very deep, brownish purplish - and not very attractive (not shown here, it was that bad!).

The second mix used much less black, and I ended up with the red color shown in the top picture here. The trouble is that while it looks great against a black item, it clashes with the color in my cherry baffles. It's not the most attractive combination.

The red color shown, for my own recollection later, was made by mixing 85ml brick red with 10 ml lamp black. I added 3 ml of distilled water to the paint mix to thin it for spraying.

I've decided to just paint these parts black instead of trying for a color that works with cherry. Basic black is boring, but it will work. The black shown in the lower picture is just primer, but it lets me see the color combination.

The M4 x 8mm screws thread into the back of the opposite-facing tweeter. The self-threading screws fit into pilot holes that I've already drilled in the baffle. Together, they should clamp things together tight enough to prevent buzzes and rattles. I hope.

More Putty and Primer [May 19, 2013]

It won't be long before I can quite primering, puttying, and sanding and to begin painting a finish coat. The surface of the woofer boxes is getting very smooth. Most of the wood grain is being filled in. Stubborn spots get an application of quick-drying spot putty, and are then sanded flush. The 320 grit Abranet sanding mesh mounted in the random orbital sander takes just seconds to level an area once the putty dries. [As long as the sander can reach the spot!]

I intend to use General Finishes Enduro water-based primer again on future projects. I like it. It dries quickly, cleans up easily with water, and sands nicely. It dries a very flat black, but the first touch of sandpaper makes it gray so it is easy to see where I've been. The only drawback is the black dust that gets everywhere from overspray and from sanding. I'm in a garage, so I'm not too concerned. It would be nice to have a dedicated painting area though, especially if it is separated from the house. I've been tracking the black dust into the kitchen when I need to fetch something from inside the house. This undercoat also comes in white which should make the dust less offensive. For an up-charge, you can have it custom tinted too.

While the primer dries to a very flat finish, it still shows a sheen in glancing light. I will probably begin applying

topcoat paint after one more coat of primer. And one more sanding. Today's application is the 5th coat of primer. The boxes are looking very nice, and the 6th coat of primer will be a little insurance for when I get into the glossier paints.

I will not try for gloss inside the box - maybe a satin or matte clear coat. I might even use satin finish on the outside too depending on how well things progress. Glossy is such a labor-intensive finish, and reveals the smallest flaw. It can drive you crazy.

I retrieved an earlier picture of the Baltic birch surface after its initial coat of primer, and added a current photo of the same area after five coats of primer. You can see that the wood grain, so prominent after the first coat, has disappeared after all the work. There's much sanding between coats, and that takes more time than the painting itself.

The end result should be a smooth finish, regardless of whether I choose satin, glossy, or something else.

Testing Fit and Finish [May 21,2013]

I placed another order with Homestead Finishing for some Enduro clear Poly in satin to coat the inside of the woofer box, and possibly for the outside too. In the meantime, I decided to do a stack fit of the parts to determine how a non-gloss would look compared to the high-sheen semi-gloss of the wooden parts. It was also a test fit of the bridge to woofer box. The fit passed with flying colors.

I like the appearance even now, and could live with a matte finish similar to the black Enduro Undercoat primer that you see here. Even matte looks tidy. I will add paint and clear coat though - the primer is way too soft as-is. Satin is easy to do, and will take the sheen up a notch.

I did order some very fine 800 git and 1000 grit Abranet sandpapers for my random orbital sander, and Menzerna German-made polishing compounds for the achieving a high-gloss on the woofer box exterior if I choose to do that. I now have options to consider.

I must confess that with the end of this project in sight, I am getting a little impatient with all the finishing steps required.

Paint, not Primer - Finally! [May 26, 2013]

My plan is to spray some glossy black that was meant for the Orions, then to topcoat that in a satin clear coat. The final coat determines the sheen of the surface, so the glossy sheen of the black being applied now doesn't matter - except for the color. It's a good test of spray painting skills too because every little problem shows with a high-sheen paint. I managed to get three coats of the glossy black sprayed in the last two days.

It's building slowly. I applied one coat to everything yesterday. Today I began by sanding [which takes a couple of hours to do all the black parts], and applied two coats of gloss black with a minor scuff-sanding between them. This waterborne paint takes a few hours to dry enough to sand.

I used a smaller 1.5mm nozzle/needle on my spray gun because the paint is much thinner than the primer used before. Because it's thin, it thereby must be applied thinly, I've discovered that this thin paint telegraphs sanding scratches if they are deep enough, so I've moved up to finer 600 grit Abranet sanding disks.

Painting inside the box is difficult. There are all sorts of blind corners into which I want to paint, but much of the spray comes bouncing right back at me. There's no way to get the desired right-angle spray direction onto some of the interior surfaces, and I'm getting a lot of overspray landing on some interior panels. The last picture in this group shows the gritty appearance of overspray on the front baffle - the most visible one! I'll explore ways to get around that problem, but in the meantime, it means more sanding to smooth it out. By the way, the photo was made while the paint was still wet, so it won't look as bad after drying.

I have two turntable-bearing support surfaces to hold items to paint, but I wish that I had more. The little

pieces are merely resting on empty cardboard boxes, and getting around them to spray edges is not easy. It's also difficult to see when the light isn't glancing at the correct angle.

I will build several more coats of the glossy black before I switch to the clear satin topcoat.

I'm fighting weather a bit. After the storm system that left Moore, OK in ruins passed though here, we had several days of rain and high wind. Thankfully, nothing in the way of damaging weather, but enough wind, rain, and cold temperatures to postpone painting. There is some rain forecast in the next three days, so I might be working around that. That's all part of the garage painting "game".

By the way, the gloss black paint is actually a General Finishes Clear Poly topcoat with black colorant added into it. The gallon bucket was ordered from Homestead Finishing and custom mixed there at the suggestion of Jeff Jewitt, the owner.

Another Decision About Paint [May 28, 2013]

Looking at the gloss black paint on the bracket made me reconsider my initial choice to go with a satin sheen on the bracket (not the woofer box!) The glossy paint, although not glass smooth, looks very fine. Waterborne paints never achieve the gloss that solvent lacquers can provide off the gun. If you want glass smooth with waterborne, you must rub it out with abrasives. However, I thought that this sheen looks very good as-is, especially for just a bracket.

I thought that I could do better on the finish, so these were sanded after the photos were made, and another coat was applied. I got one #@& run in the paint. I'll sand that again, and maybe the third coat will be OK. I see a faint telegraphing of the plywood layers through the paint on the bracket in certain light. I don't know if that will ever go away because of the differential expansion and contraction of the wood layers, depending upon their orientation. I'll certainly see if more paint helps though.

Being somewhat impatient, I just thinned some GF Lamp Black Milk Paint [200ml paint:14ml distilled water] and painted the crossover mounting pieces and the tweeter sub-baffles. One coat, and they look good. They are done.

The woofer boxes remain the biggest finishing task ahead. They were sanded yesterday after the first coat of black gloss. It was too windy today to tackle painting them, so they await in the garage for a calmer day.

By the way, the hex bolts on the front of the brackets shown in these photos prevent the internal 1/4-20 threads from becoming fouled with paint. The bolts will be tossed when the painting is done.

Crossover Work [May 29, 2013]

I added a coat of paint to some items today. While the paint cures awaiting some sanding, I experimented with mounting of the passive crossover components. I knew the general direction that I wanted to take, but as everyone knows, the devil's in the details.

I was a little concerned about vibration of the electronic parts against the bracket, so I used some self-adhesive felt to damp vibrations. On the capacitor, there's a 1/2" strip adhered to its side where it comes in contact with the crossover mount. I also put three dots of the felt on the bottom surface of the cap where it rests on the mount.

I flattened the coil bobbin flanges on the bottom where they contact the mount to prevent rolling, and used a cable tie to bind it tightly to the mount.

The fit inside the bracket is very tight. I had attempted to cable-tie the upright capacitor to the mount upright, but the extra width prevented the assembly from fitting inside the bracket. I removed that cable tie.

I tried two dots of felt on either side of the cap to bear against the bracket sides, but even 1/16" felt was too thick. I might revisit this and place the felt dots further around the circumference to reduce the total profile.

The crossovers should look very tidy when finished. All the wiring connections will be placed under the crossover mounts and be out of sight. Wires to the drivers will emerge vertically at the opening that remains

between the crossover mount and bracket.

Waiting to Clear Coat, and Decorative Time Wasting [June 1, 2013]

The last coat of glossy black paint has been applied. The woofer boxes are suitable for use as-is, but I want to clear coat them with a satin finish. The "glossy" paint is more of a semi-gloss, and looks a little "brassy" on large items like these boxes. There's much wind today, and storms are forecast, so I have to wait a day or two. I am pleased with their appearance so far.

In what might be the biggest time-waster in diy audio, I chucked up the connector bolts in my drill press, and sanded, then polished the heads of them to a high sheen. Ordinary connector bolts work just fine, but they look rough and industrial with their dull, burr-laden heads. In the drill press, I started sanding with 220 grit wet-or-dry silicon carbide sandpaper, moved up to 400 grit, then used Happich Simichrome polishing paste on the heads to produce a near-mirror finish. Then I used some gun blue paste on the shiny metal, 3 coats, to produce a black-chrome appearance. This work took about an hour for 8 screws.

The blued-steel heads, if left unprotected, will rust very quickly. I used some Sheath Rust Preventive to apply a coating to them. It's essentially a wax dissolved in solvent. When the solvent evaporates, the wax coating remains behind to reduce rusting. If I didn't have this particular product, I'd look at Boeshield because of its stellar performance in published corrosion tests.

I must admit that this is certainly not essential to the sound or structural integrity of this project. It's merely mindless work that keeps me occupied while paint dries.

I still have to test the ASP boards and install them into the case. I still need to complete the passive crossover wiring. I probably should be doing that work instead of decorative work like polishing screw heads!

I observed something curious when I was close to the bracket for this photo in streaming sunlight. I noticed the the black paint has many thousands of tiny flakes embedded within it. It reminded me of a 1960s metal-flake paint job, except on a much smaller scale. If you click on the next-to-last photo in this group to view it larger, you'll see what I'm talking about. The photo almost makes it look like a rough surface, but it is completed embedded within the coating and it shimmers as you move your head around. I noticed that the light source must be very specular - like direct sunlight - to see it.

Like my nephew says...Cool!

Update: I did not clearcoat the woofer boxes. I decided that the gloss black finish looked good enough to stand on its own. It's more of a satin than glossy anyway.

Wiring the Tweeters [June 2, 2013]

The weather continues to delay the final spraying of clear coat on the woofer boxes, so I spent time wiring the tweeters into the baffle. The work was a bit delicate because of the two tweeters and two sub-baffles that must

be coordinated. A spatter of hot solder flux in the paint wouldn't be appreciated either.

With lots of paper towels and an old carpet remnant to protect items during this work, it wasn't difficult. I went slowly and very carefully not to spoil work that had already been done in finishing.

I used Radio Shack 24-gauge speaker wire for the tweeters because they will see very little power. It also provided the flexibility needed to bend into tight spaces. The 24-gauge wire runs for only a couple feet, then attaches to a more substantial wire located in the space under the crossover, so the effect of light gauge wire is inconsequential.

Before tightening the tweeters, I rotated them to orient their hex grids horizontally for appearance's sake.

I also began soldering wire in the crossover assembly, but there's not enough work done yet to warrant a picture. I'm awaiting a hot knife tip for my ancient pre-1964) Weller soldering iron to neatly trim the Techflex braided cable sheathing that I intend to use over the wires.

Productive Days [June 3 & 4, 2013]

With most of the painting out of the way, I'm making headway assembling the speaker.

First, I installed 2" x 1/8" synthetic felt strips inside the bridge to cover up the screw heads on the damping metal. This prevents the screw heads from making direct contact with the finish on the woofer box. It probably adds a little more acoustic damping to the bridge too. I'm sure that this bridge is very acoustically inert compared to other methods of construction. The bridge sides ring much less than the baffle itself does, so it shouldn't contribute to unwanted resonances.

I also installed the drivers into the baffle using #6 x 5/8" self-tapping screws (upper midrange) and #8 x 5/8" screws (lower midrange). Nothing fancy. The fit nicely into the predrilled pilot holes done months ago before the finishing steps began.

I attached the baffle onto the bracket using 1/4" x 1-1/2" machine screws. They engaged the brass inserts placed inside the bracket before it was assembled. I also placed a gasket of very thin polyethylene foam between the bracket and the baffle. I had purchased a huge roll of the stuff for my Orion project to place between the sides and the baffles, but never used it. This was a good application for it.

There was a short moment of panic when I realized that the connector bolts that I had so carefully polished would not install because of the short space under the baffle. The solution of course is to loosen the baffle screws first and shift the baffle forward. That provided enough room for the bolts to drop into position. I'll use an Allen wrench to tighten them (the screwdriver tool won't fit), but it is one design item that verges on a mistake. I wish I could foresee all the issues completely before I start fabricating parts.

The wiring of the drivers was started. I wanted the wiring to be unobtrusive. There are some baffles that are machined to hide wires, but it's difficult with a solid wood baffle to do that. I believe that the routing of wires combined with a 1/4" and 1/2" Techflex looks tidy. It's not completely done because the crossover shuttle still needs to be incorporated. It's installation will route and hide wires further.

It has been a productive couple of days.

Crossover and More Baffle Wiring [June 7, 2013]

In response to a comment about the wiring potentially shading the sound from the rear of the woofer, I slightly rerouted the cabling to position it behind the spider ring casting. It took 3 cable ties to get the wire into position - one tie placed fore of the ring, one aft, and then the tie for the cable itself looping into the other two. It places the speaker wire bundle almost completely in the "shadow" of the spider, leaving the area around the cone mostly unobstructed. At this point, I'm not that concerned. After all, photos of SL's speaker show wires routed in a similar fashion. The first photo of this group shows at least two of the ties at the affected point.

Next up was tackling the crossover shuttle. It was slow going, and in a way, like building a ship in a bottle. There's very little room to position wires inside, and the terminal strip could hold only two heavy-gauge stranded wires at a time. I'm using Madisound's Supra Classic 15 ga. speaker wire. Even though I had punched the wire holes larger for this, the openings were still too small. I had to get creative with the connections, and it became a combination of wire-to-wire and the terminal strip.

It was also awkward because many of the connections had to be made while the crossover was near its final position on the speaker. I had to prop it up using a book in order to work on it.

Once the bottom of the crossover was screwed into place, and the assembly inserted into the bracket, it became satisfying. I still have a little more work to do to route the wires from the speaker more compactly so that the crossover shuttle can sit a little more into its cavity. It still looks tidy though.

I also attached the 4-pole Speakons to the pigtail coming from the crossover, although I have no photo of that yet. It looks as if the main part of this speaker is 99% assembled.

I need to route the cabling in the woofer box and install the woofers, and tend to some long-delayed ASP tasks, then it will be completed.

I'm a little worried about the ASP and what happens with a mains power outage. With the Orion, cycling the ASP power when the power amplifier was on could blow drivers. Here in southeastern Ohio, power glitches are a way of life. Hardly a day goes by without the uninterruptable power supply for my computer kicking in because of a transient glitch. Last week, I was without power for half a day, and last summer, for a week in June. I will probably obtain another battery backup UPS unit for the ASP to keep it powered while the amps are left to the mercy of the power company.

Wiring the Woofer Box [June 10 & 11, 2013]

Before I began wiring up the woofer box and attaching Speakons, I researched the wire positions in the cable to see which combinations produced the least crosstalk between the tweeters and the mids. SL warns about this in one of the OPLUG posts. One member named Drew measured the crosstalk between different pairs of wires in his 8-conductor cable, and published the results. However, the Parts Express 8-conductor wire that I used differed in the color coding of the pairs. I made a chart to correlate it to Drew's sample.

The Speakons have numbered connectors for the wires - 1+, 1-, 2+, 2-, etc. The Speakons mounted at the top of the box had four connectors for the two pairs of wires for the tweeter and mids. The 8c Speakon in the bottom had more connectors of course, and the number included 3+, 3-, 4+, and 4- in addition to the numbers found on the 4c Speakon. I decided to make the tweeter the 1+ and 1- pair, the midrange 2+, and 2- because those numbers are common to both connectors. Because this was in the order of descending height, I carried that convention through to the two woofers on each side. The bottom woofer was thus numbered 4+ and 4-. This system keeps the same numbers for the tweeter and midrange on top and bottom Speakons to prevent confusion when attaching wires to them.

I have the wiring on the right woofer box almost done. There will be left-hand and right-hand boxes, with the Speakon connector positions mirrored on each. I had drilled the wire access hole for the top woofer mirrored too, planning this from the beginning. It will help with the cable runs in the room. The woofer box on the right side, for example, will have its Speakon on the right side of the box, positioning it closer to the right wall. The speaker cable won't intrude into the room as far to connect to the speaker.

I used Wood Artistry Speakon brackets sold for Orion speakers for a clean appearance. They are black anodized aluminum, and that fits nicely with my color scheme.

To attach wires to the Speakon connectors, I used crimp terminals that slip onto the connector's spades. The space for connections is very limited, and there are no holes in the spade terminals into which to hook wires for soldering. The internal speaker wiring I used was the Supra 15 ga. speaker wire sold by Madisound. It has a fairly stout conductor, so crimp terminals appeared to be the best way to attach wires without mistakes. I did wrap electrical tape around the inner group of connectors (all of the the "+" polarity) to reduce the possibility of them touching/shorting the outer group ("-" polarity). However, the mechanical integrity of the connections is good, and it would take a fairly hard blow to force the connectors to touch even without the tape.

I'm using mostly 1/2" Techflex to bundle the 4 separate pairs of wires running into the box. It looks tidy. I was very pleased when it stretched enough to enclose the terminals on the rear of the Speakon.

I also installed the 4-pole Speakon on the top of the woofer box. This allows for a quick and foolproof way to electrically connect and disconnect the bridge assembly.

On another note, and one that is not as happy, I'm having a little trouble with my ASP circuit boards. The initial check for +/-12 volts worked fine on both boards, but after stuffing the op-amps into place, I encountered trouble. The gain numbers for each stage, except for the midrange, are significantly off. I ordered some connectors to be able to run ARTA with my sound card to assess the condition of the boards, but failing the spot checks was disheartening. I had no trouble at all assembling Pluto and Pluto+ circuit boards, so I'm in unfamiliar territory right now.

I'm mechanically inclined, but I'm not a sparks and wires wizard.

[UPDATE: This issue was quickly ironed out after learning ARTA software. The culprit was two missing resistors, one per board, that were not on hand when I stuffed the boards. I had forgotten about not having the resistors, and that they were missing. A thread describing the troubleshooting is posted in the LX521 Resources area of the OPLUG. The thread is titled *ARTA testing of ASP* . Note that this section of the web site is available to owners of LX521 plans, but not to the general public.]

The Woofer Box [June 12, 2013]

The woofer box should be called the "black hole" for a couple of reasons. Like a black hole, the gravity around those massive drivers is profound. They are very heavy. Next, any tool that comes within 4 inches of the magnet gets sucked right to it. I had to be very mindful of that while working. Finally, it's very, very black inside, making visibility poor for seeing black fasteners, attaching wiring, and even photographing. The

exposure range from highlights to deep shadows exceeds what my camera can handle. My old eyes are even worse.

I installed the drivers by myself, and found that laying the box sideways was easiest. For me, installing the top woofer was easier than the bottom one. I took advantage of the access port that I installed into the top of the box, and that helped for securing fasteners for the top woofer. The port's job is done.

I used 8mm quick-connect terminals from Madisound for attaching the wiring to speaker terminals. The wires were crimped onto the connectors, then soldered to them for an extra secure joint. The connectors were then pushed onto the woofer lugs. They look very secure. I'm glad I did it this way because a soldering iron would certainly have been drawn to the magnet, resulting in melted spot(s) on the rubber boots.

I have one woofer box completely done, and the other is scheduled for tomorrow. This one is sitting under the left speaker right now, and it looks very handsome. One speaker is done.

I dread lifting the woofer boxes up the stairs for a photo session once everything is complete. They are truly back-breakers.

Update June 13: The other woofer cabinet is now done. That completes the non-electronic part of this project, and I'm very pleased with how they look. Wife says they have personality. Keep in mind that she likes my Plutos, and was elated when I said that the Plutos may be moved upstairs to the TV room.

She also looked at the inductor on the back crossover, and wondered what the "roll of tape" was doing there. I had removed the Madisound masking tape wrap and replaced it with a nice, white Tyvek wrap to hold the coil of copper wire in place. It was an effort to make the the coil look a little better, but if she's thinking it's roll of tape, I missed the mark!

Now it is back to work on the electronics...

Some Photos [June 14, 2013] and **Listening Impressions** [June 21, 2013]

As always, click on any thumbnail picture to get a larger view.

It's difficult photographing these in a small room. In order to convey texture and sheen, the lights almost always need to be positioned where walls and furniture are in the way. The heavy speakers, each in two parts, aren't easy to shove around either.

Already, there are things that I'd try differently next time...

1. I'd add paperbacked veneer the top of the woofer boxes to prevent telegraphing of butt joints through the paint. A few faint lines are now evident where the pieces are joined because of humidity-related expansion/contraction. Thankfully. because the boxes are black and mostly hidden by the bridge, you have to look hard to find them.
2. I'd probably install the baffle screws from the rear in the next build. I'm not crazy about the appearance of the four 1/4-20 flathead screws that attach the baffle to the bracket now. But it's not a big deal.
3. I'd make the baffle bracket rotatable. It's becoming clear that being able to toe-in the baffle compared to the woofer box allows valuable acoustic tuning in the room.
4. I spent nearly $60 for the #10-24 black locknuts for the woofer mounting screws. That's crazy-expensive, and something I'd revisit. I hit "Buy" in a weak moment. Also, their turning resistance made spinning them down slow. I had to use tools all the way down. But they look nice.

And some things that I'd not change...

1. The small screws securing the tweeter sub-baffles don't bother me at all - probably because they are black-on-black.
2. I'd continue using Techflex on exterior wiring on rear of the baffle. The Techflex braid sheathing looks very professional. Inside the black woofer box, the Techflex-covered wires blend right in.
3. The milled chamfers on the bracket and wooden bridge pieces add a feel of finished woodworking. Chamfers or roundovers are easy to cut using a router, and a little time spent here adds significantly to the appearance.
4. The paints and wood finishes I found are ideal. If anything, I might spray a clear satin over the semi-gloss black on the woofer box to reduce visibility of small flaws. However, I don't have much to complain

about right now. The flaws are very small, and better than what I've seen on some commercial loudspeaker offerings.

5. I like the Wood Artistry Speakon brackets. It's a good product. I'd also continue mounting them mirror-imaged left and right on the two speaker boxes. I think it makes for more tidy wiring inside the box, plus I have the connectors and speaker cables closer to the walls.

My first impressions are:

- They need no subwoofers. These loudspeakers dig deeper than I ever expected they would. I usually take "no subwoofer needed" statements with a grain of salt, but there's no mistaking the bass authority delivered by the SEAS L26RO4Y drivers in the bottom. Color me surprised - and pleased.
- They image nicely. The sweet spot in which to listen is a bit smaller then for my Plutos. There's less room to move left or right before the soundstage collapses. My listening room is narrow though, and I'm unsure about how the soundstage would fare in a more ideal space.
- While the Plutos are no slouch for quality music reproduction, there's *much* more "micro-detail" apparent in the sound of instruments in the LX521. I suspect that the high-quality of the SEAS drivers contributes to this. It doesn't hurt that many of the drivers were custom engineered for the LX521. The low-cost AURA tweeter of the Pluto is likely its Achilles heel. I'm very pleased with the fine detail delivered in music with the LX521 compared to my Plutos.

I've added more listening impressions below after listening to them for a few days, and after doing some experiments with positioning. However my listening room is not ideal. The next section explains why. Consider it an important preface before diving into my subjective impressions.

Speaker Placement and My Room's Limitations [June 28, 2013]

The LX521 speakers are heavy, and are comprised of two components which makes moving them cumbersome. I made a pair of flat dollies using some inexpensive Lowe's casters attached to 16"x19"x3/4" MDF. Placed under the speakers, I could easily experiment with speaker positioning. I considered making the dollies a permanent accessory, but they lift the already-tall speaker by another 2" to 3". In my low-slung Ikea Poang chair, the dolly raises the speaker so that the bottom of the lower midrange driver is at my ear height. By raising up a few inches from my seated position, the sound gets better. This indicates that the dollies won't work long-term. Or I need to modify my chair.

I'm finding that placement for ideal sound is going to be a compromise in my listening room. It's the largest finished room in the house, and it's still not quite wide enough with the current furnishings in place. Being located in the basement, my ceiling is also 5" lower than in a normal room.

The picture on the left shows the current configuration. Some furniture is higher than other pieces, so I coded their relative height with gray tones. White is at floor level, black is at the ceiling, and a percentage of gray is in between. Taller furniture will be shown with a darker shade than shorter pieces.

Linkwitz specifies room parameters to maximize performance of these loudspeakers. My room fails on two key points.

His key specifications are:

- Lateral symmetry of the loudspeaker and listener setup with respect to large reflecting surfaces.
  I **fail** this requirement. Click the room layout thumbnail on the right to see my current situation. I listen on an angle to the room.
- Loudspeakers must be placed at some minimum distance from those large surfaces in order to delay specular reflections by more than 6 ms (sound travels 2 meters in 6 ms).
  I **fail** this requirement. I've done my best here without moving heavy furniture. In an attempt to mitigate the effects of nearby objects, the right speaker is positioned near a doorway, the left near a fireplace opening.
- The wall behind the loudspeakers should be diffusive in order to not lose the rear radiated sound from the LX521.
  OK
- The wall behind the listener should be lossy or open.
  OK
- Cloth wall hangings, rugs, pictures, upholstered chairs, open cabinets, plants and other decorative elements are all that is needed to interface a dipole loudspeaker with the room.
  OK

All this means that I cannot hear this speaker at its very best in my current room. However these speakers still produce an overall sonic improvement over my Plutos. I am sure that I lose a little imaging precision because of these limitations, but it is still far better than the majority of systems I've heard in other homes.

Listening to the LX521

(Note: see discussion of my room limitations above, and consider their effect on my listening impressions.

***Mike Garson's Jazz Hat*, Reference Recordings, 2008 - Jazz**

The first selection I played was a favorite CD played often on the Plutos. The recording is excellent. There was always a special synergy between my Plutos and this CD. Track 2 in particular is a selection that truly made me appreciate the Pluto speakers when I first built them, and it's a track that I always played for visitors. I wanted to see how the two speakers compared playing it, and it was first up.

Track 2 has some sonics that are a good test of a speaker's performance. The LX521 rendered the saxophone more cleanly than the Plutos, but in my compromised listening room, I believe the Pluto pinpointed the instrument in the soundstage better. My room width, with some intruding bookcases, is too small for dipoles, and I know from reading Linkwitz' web site that this adversely influences imaging. It probably explains why the Plutos held their own imaging-wise.

About seven minutes into track 2, there's a series of taut bass string plucks recorded so well that you can almost see them. The LX521 handled this detail very well. About now is when I start paying attention to the accuracy of the recorded sound, and I conclude that the LX521 renders the fine details very, very well. It exceeds the Pluto in detail, on every track. Everywhere.

The LX521 won on detail, the Pluto for precision pinpoint imaging. I wish that my listening room was about 5 feet wider for a more valid comparison. This reinforces Siegfried Linkwitz's statement that Plutos are nicely suited for small rooms.

Wayne Horvitz, *Sweeter Than The Day*, Songlines, 2001 - Jazz

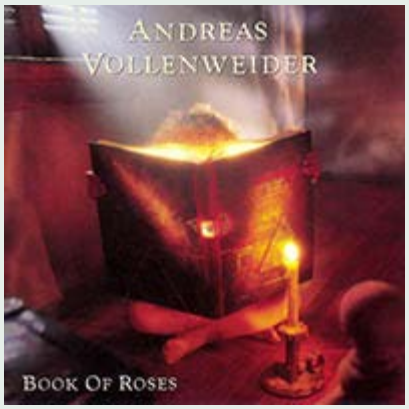
This is a very well recorded SACD disk. Track three has some moderately strong bass, and I curious about how well the dipole bass configuration of the LX521 could render it. This is when the LX521 starts to show a considerable advantages over the Pluto. I hear improvements in bass clarity and the LX521 gives up nothing in volume to the two 10" sealed woofers of the Pluto+. Nice! The LX521 pulls ahead of my Plutos on detail and bass reproduction (depth and quality).

Yello, *Touch*, Polydoor/Universal, 2009 - Electronic

Intrigued by the bass depth that I heard in the previous album, I play a bass-rich recording (track one) to test the dipole handling of low frequency electronic bass. The result was stunning. The LX521 appeared to go much deeper, and played the deepest tones with more volume than the Pluto+ could ever muster.

This was a knockout advantage for the LX521. I replayed track one again just for grins. It is amazing how well the SEAS L26RO4Y drivers can do on subterranean program material. Even though I had planned to add Thor subwoofers in the future, this performance eliminated my interest in building them. That's a bit sad because I have all the parts (two 12" Peerless XLS 830500 drivers, plans, circuit boards, electronic components) to build two THOR subs. However I'm secretly pleased because I was always concerned about the space that two 12" subs would occupy in my room.

I did not judge soundstage with this recording. It is mixed and synthetic, so it doesn't have much in the way of realistic soundstage to evaluate. It was merely bass "candy" to flex the muscles of the woofers.



Andreas Vollenweider, *Book of Roses*, Columbia 1991 - Electracoustic harp, contemporary/experimental

This is one of the best albums that I own regarding mastering and sound reproduction. This album's genre is a little hard to characterize, but it has never ceased to impress me with how well it is produced. There are some recorded ambient sounds that are played between tracks to tie them together, and they sound very realistic. For example, there are some crows calling in the distance when the disk begins, and they sound as real as the crows that are around my housel.

Track seven features an a cappella track by Ladysmith Black Mambazo. It may be familiar to builders of Linkwitz Plutos because it's included on the test CD for them. It is very well recorded and a delightful test of a loudspeaker on male chorus. There's a dominant singer on the left, with the rest of the chorus centered. The electric harp occupies the right side of the visual scene. This is exquisitely reproduced, and is enjoyable music, not just a test track.

I hope that no "remastering" has reduced the quality of this recording for current purchasers. My disk is quite old now, and cherished.

Giuseppe Verdi, *Requiem*, Telarc, 1987 - Opera

The LX521 stomps my Plutos on this very dynamic recording - especially on how well it handles the range from low to high volume in some passages. With the chorus singing full volume in *Libera Me* (track 3, disc 2), and having soprano Susan Dunn raising her powerful voice to be heard above them clearly is spectacular. Parts of the selection are very quiet, then within a few seconds, a crescendo. High volume favors larger driver area, and the LX521 doesn't strain with high SPL.

There are also places where a powerful tympani is reproduced very accurately in this recording. Instead of merely a distant "thud", the instrument overtones are beautifully reproduced together with the bass impact to give the sound its unmistakable realism.

This recording is emotionally engaging for me, and always gives me shivers toward the end of *Libera Me*.

I have noticed that the recording is still available, but in newer packaging. Once again I hope that the mastering has not been changed because the first edition is a winner.

Phoebe Snow, *Phoebe Snow*, The Right Stuff, 1995 - Jazz vocal

This is another well-recorded and familiar album. I play track 2, *Harpo's Blues*, to evaluate a loudspeaker. The LX521 rendered her voice more cleanly than the Plutos did, although the difference is small. My Plutos always added a slight emphasis on the lower tones of the female voice (not just on this album), and the LX521 did not. The feeling that she is present in the room is more believable.

There's a saxophone in track 2 that the Pluto placed in pinpoint precision on the front wall well beyond the speakers, and the LX521 does almost as well. Again, (and in my space-limited room - an important point!) the Plutos did a little better. The sax advances forward from the front wall that is about 10 feet away, and it pulls forward to the left LX521 speaker somewhat more than the Pluto. Certainly this is because of room acoustics. The synergistic combination of the Pluto with this recording was something that worked well, and that's why I chose this album to compare.

I can live with the changed position of the saxophone because Phoebe's voice is so alive and real coming from the LX521.

[Update June 30, 2013]
I have experimented some more with speaker placement, in particular the right speaker that's very close to a large bookcase. When I pulled the right speaker into the center a few inches away from the bookcase, and then significantly reduced its toe-in, imaging precision improved. It now images specific instrument locations in the sound stage just like my Plutos did, but with the improved quality of sound of which the LX521 is capable.

I'm very happy with this improvement, While a having a larger room that meets specifications would have been the best option, this adjustment delivered a worthwhile improvement. The amount of toe-in is now different between the left and right speakers, but it works.

Technically I'm not sure what caused the improvement, but the axis at right angles to the speaker now points toward the open doorway on the right wall, and the nearby bookcase/wall junction is hidden behind the baffle (as seen from the listening position). Perhaps hiding this early first reflection surface behind the speaker helped suppress its influence . It also may help that the major axis of dipole radiation is now painting obliquely down the front of the objects against the right wall instead of being pointed into the nearby bookcase/wall junction.

For another impression of the LX521 loudspeaker, experienced listener Charles Port has a web page describing his findings. His listening room is larger and better suited for these speakers than mine. He can use their full capabilities.

Conclusions

These are better than my Plutos in many ways, and they ought to be considering the difference in cost and size. The sound is more accurate, no doubt due in some part to the better drivers employed. I'm still impressed with how well the inexpensive Pluto+ system held up. In the end though, the LX521 is superior. There's no going back for me.

Bass from the LX521 is better in several important ways than the Pluto+ subwoofer system. First, the LX521 goes deeper, and does so with more volume if that's part of the recorded program material. The LX521 plays bass with better definition too. Some of my impressions about bass may be due to how dipoles load the room resonant modes differently. There should be fewer problems with dipole bass.

Limitations? Yes indeed. There is no free lunch.

- **Cost:** They are not inexpensive. While the cost of this system isn't cheap, it will compete with speakers costing 10x as much. If you put in the time needed to achieve a nice finish, they can look ultra-high-end too. In the final analysis, they are affordable for what you get in return. That's what matters.
- **Size:** They are fairly large speakers that are awkward to move. If you need to move a speaker into and out of position daily, you'll need wheels. Or lighter speakers.
- **Placement requirements:** They make demands of the listening room. If the speakers must be placed too close to large reflecting surfaces (walls, bookcases, etc.) you'll lose some of the potential advantages, especially in imaging precision. Remember though, the precision is reduced, not lost, and experiments with toe-in and placement may offset some of the problems. Linkwitz has provided a graphical example on his website for placement considerations in simple room geometries. Also remember that just about any loudspeaker, not just the LX521, is bound by room restrictions.

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