Hemisphere Speaker Construction Manual

Spring 2014

Zach Zubow, Ph.D.
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**Introductory Statement**

The construction of eight hemisphere speakers began at the University of Iowa in the 2014 spring semester. It was made possible by a generous award from the University of Iowa’s Student Technology Fund and the tireless effort of Dr. David Gompper, director of the Center for New Music. Doctoral students in the program at UI constructed the speakers using this manual throughout the semester and saw the introduction LOUI (Laptop Orchestra at the University of Iowa), the new laptop ensemble utilizing the eight hemisphere speakers. LOUI’s first performance on 27 April 2014 featured new works written by graduate composers at the University of Iowa. The hemisphere speakers were premiered at this performance and have been used in numerous concerts since.

**Manual for Construction**

This manual is a step-by-step guide for construction of a complete hemisphere speaker that includes six speakers, housed in a wooden bowl. The materials used for the entire product are all listed below. If the materials below are not available or have become discontinued for any reason, a substitute product will suffice. This may be especially true for the wooden salad bowl that was purchased at IKEA. Any salad bowl that is at least 11" in diameter with a depth of 9" will suffice. Any modifications to the speakers will need a matched power amplifier and all component hardware (toggle switch, DC power jack, etc.) can be interchangeable with whatever is available to the builder.

The tools that are listed below will all be necessary. If a cell phone with a compass feature is not available, the placement of the speakers can be distributed by placing the center of each speaker 72° from the center point of the top speaker. It is recommended to use the rope to make these calculations as the curved bowl makes for a difficult measurement for the location of each speaker. The construction of the hemisphere speaker requires the use of power tools and a soldering iron. Special care must be taken when using each of these in order to avoid any serious injury. A well-ventilated space should also be sought when doing the soldering.

Taking special care through each step is imperative. If one follows each step-by-step instruction, the process should take between 10-12 hours (not including gathering materials). Creating strong connections and testing each component while the construction process is underway will also alleviate any issues of having to redo particular steps. Another added feature that may be worth creating is a custom cable for mono signals to the hemisphere speaker. It would be an 8mm TRS to 6-1/4" TS cables for the output of a laptop’s headphone jack. This would be a custom cable that must be created using additional components and materials.

**Zach Zubow, Ph.D.**

Zach Zubow completed his Ph.D. in composition from the University of Iowa in 2012. While completing his doctorate degree, he was the Assistant Director of the Center for New Music and the Assistant Director of the Electronic Music Studios. His research includes specialized recordings of all orchestral string instruments in the Anechoic Chamber housed in the Wendell Johnson Speech and Hearing Clinic that are available for free online. Other projects include: iPhones and wireless technologies in music; motion sensors; spacialized installations; and Arduino technology and components using Max.

Dr. Zubow currently teaches the core music theory sequence, counterpoint, composition, and composition seminar at Coe College in Cedar Rapids, IA. He has also served on the faculties of Grinnell College and Cornell College teaching composition and music theory. Conference performances of Dr. Zubow’s electronic compositions include SEAMUS, Electronic Music Midwest, and the International Computer Music Conference in Athens, Greece. For more information, please visit www.zachzubow.com.

**Special Thanks**

This project would not have been possible without the help from graduate students at the University of Iowa that include Nima Hamidi Jason Palamara, and Leonid Iogansen. In particular, Dr. Will Huff was an immeasurable asset to the research, construction, and implementation of the hemisphere speakers into the composition department. Dr. David Gompper’s stalwart dedication to his students and the composition program at the University of Iowa is the reason for this manual, the hemisphere speakers, LOUI, and many other aspects within the School of Music. His commitment and contribution to the greater music community is greatly appreciated my many.
### Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>11&quot; IKEA Salad Bowl</td>
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</tr>
<tr>
<td>12&quot;X12&quot;X3/4&quot; Wood</td>
<td>1</td>
</tr>
<tr>
<td>12&quot;X12&quot;X1/2&quot; Plywood</td>
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</tr>
<tr>
<td>Polk 2-way db401 4&quot; Coaxial Loudspeakers</td>
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</tr>
<tr>
<td>Pyle PFA300 90-Watt Class T Hi-Fi Stereo Amplifier</td>
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</tr>
<tr>
<td>8&quot;X1/4&quot;-20 threaded rods</td>
<td>4</td>
</tr>
<tr>
<td>1/4''-20 nuts</td>
<td>28</td>
</tr>
<tr>
<td>1/4&quot; Mono TS Female Audio Jacks</td>
<td>6</td>
</tr>
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<td>DC Power Jack, Circular for 12V, 3A Supply</td>
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</tr>
<tr>
<td>RCA Male to Male Cable</td>
<td>2</td>
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<tr>
<td>Power Switch, ON/OFF Toggle</td>
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</tr>
<tr>
<td>Braided Speaker Wire</td>
<td>5'</td>
</tr>
<tr>
<td>Braided Wire</td>
<td>5'</td>
</tr>
<tr>
<td>Deadbolt Strike Door Filler Plate</td>
<td>5</td>
</tr>
<tr>
<td>9&quot;X2&quot; Metal Plate</td>
<td>1</td>
</tr>
<tr>
<td>U-Style Wall Mount Holders</td>
<td>3-6</td>
</tr>
<tr>
<td>1&quot; Wood Screws</td>
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<tr>
<td>1/2&quot; Wood Screws</td>
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<tr>
<td>Lead Free Solder</td>
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</tr>
<tr>
<td>Electrical Tape</td>
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</tr>
</tbody>
</table>

### Tools

- Drill
- Jig Saw
- Soldering Iron
- Multimeter (with Ohm detector)
- Needle Nose Pliers
- Philips Head Screw Driver
- Hack Saw
- Wire Cutter
- Wire Stripper
- Philips Head Drill Bit
- 1/16" Drill Bit
- 1/4" Drill Bit
- 5/8" Drill Bit
- 1/2" Boring Drill Bit
- 3 5/8" Saw Bit
- Rope
- Cell Phone with Compass
- Pencil

### General Safety

Most of the equipment is very safe, but it must be noted that these tools and items can cause serious injury if care is not taken while building the hemisphere speaker. Be sure that all fingers, hands, toes, and other extremities are clear of any equipment before using the tools!
Hemisphere Speaker Base

1. Trace the outer edge of the bowl on the 12"X12"X1/2" Plywood.

2. Use the Jig Saw to cut out the base of the hemisphere speaker.

3. Trace the outer edge of the bowl on the 12"X12"X3/4" Wood (exactly as before).

4. Measure a 9" section of the outer circle (for the opening).

5. Trace a circle about 1" inside the previous circle.
6. Use the Jig Saw to cut out the wood. (It should look like a letter “C”)

7. Once both pieces are cut out, the C-shaped piece will sit on the base to add additional height.
**Speaker Housing Unit**

1. Make a mark centered on the bottom of the salad bowl. Drill a hole on this mark using the 1/4" drill bit.

2. Using the 3 5/8" Saw Bit and Bit Guide, make a small depression into the salad bowl. (Note: the Saw Bit will work much better if the bit is already spinning before contacting the bowl.)

3. Cut a piece of rope about 20" Long. Tie a knot on one end and feed it through the 1/4" hole in the bottom of the bowl. It should hang as the above picture.

4. Make a mark on the string where it crosses the Saw Blade depression and where it reaches the bottom of the bowl.

5. Remove the rope, fold it in half, and match the two marks together. Make a mark where the rope is half the length between the two marks. Feed the rope back through the 1/4" hole.

6. Make a mark on the bowl where the middle line of the string falls. Place the compass on top of the bowl and spin the bowl so that 0° North is parallel with the string.
7. Without moving the bowl, spin the compass and string so that it reads 72°, keeping the string parallel with the arrow on the compass. Make a mark where the middle line falls on the bowl.

8. Spin the bowl without moving the string or compass until the string and compass arrow (at the new position) reach 0°.

9. Repeat steps 7–8 until there are 5 marks on the bowl. Each mark should be evenly spaced from each other. Check the marks before moving on to next step.

10. Drill holes on each of the new marks using the 1/4” drill bit.

11. Use the Saw Blade to cut out each hole for the speakers.
Preparing the Speakers

1. Remove the speakers and hardware from the packaging (you will use the screws from the hardware bag).

2. Use the needle nose pliers to slightly bend the mounting plate around the outside of the speakers. (This is to help the speaker meet the contour of the bowl.)

3. Make six 2-foot lengths of the braided speaker wire. Split the ends so that each side of the wire is free from the other.

4. Use the wire stripper to remove the plastic shielding from each wire. Each end should look like this:

5. Insert the Red wire into the positive side (the one connected to the Red wire) and the White wire into the negative side (the one connected to the Red and Black wire). Feed the wire through and spin it around the hole to secure the wire.

6. Melt a piece of solder on each connection.
Installing the Speakers

1. Place one speaker in the top hole of the salad bowl. Use the 1/16" drill bit to make guide holes for the screws.

2. Repeat step 1 for the rest of the speaker holes. Before drilling the guide holes, make sure the speaker is parallel with the opening of the bowl. (Make sure the word “Polk” is spelled left to right.)

3. Use the screws found in the hardware bag and Philips head drill bit to secure each speaker into the salad bowl.
Configuring the Amplifiers Part 1: Prepping the Power Amplifier

1. Remove the amplifiers and all hardware from the package. (You will use the hardware included in the amplifier case).

2. Remove the screws and faceplate from the rear of the power amplifier.

3. Remove the screws and knobs from the front of the power amplifier. (The knobs pull directly off by pulling.)

4. Use the needle nose pliers to remove the 3 nuts from the potentiometers.
5. Remove the faceplate and use the wire cutters to clip the wires connected to the power switch. Make sure to clip the wires as close to the power switch to preserve the length of the wire connected to the power amp.

6. Slide the power amplifier out of the housing unit.

7. Repeat steps 1–6 with the two other power amplifiers.
Configuring the Amplifiers Part 2: Power Supply

1. There are two AC power adapters in the box. Save the adapter with the wall plug to use after the hemisphere speaker is complete. The second power adapter has a red and black wire. Cut this wire about 6 inches from the plug.

2. Separate the two wires from each other so that they are independent. Use the wire stripper tool to expose about a half an inch on each wire.

3. Repeat steps 1 and 2 for the other power amplifiers. The final product should look like this:

4. Cut a piece of red braided wire about 6 inches. Use the wire stripper tool to expose about a half an inch on either side.

5. Cut a piece of black braided wire about 6 inches. Use the wire stripper tool to expose about a half an inch on either side.

6. Gather each of the red wires from the three power adapters. Fray each end just a bit. Take the red braided wire that was cut in step 4 and hold the four wires so the copper braiding all meet.
7. Twist all four wires together so that a secure connection is made between each.

8. Use a liberal amount of electrical tape to wrap around all four wires from the shielded to the exposed part of the wire. I recommend starting your wrapping around the shielded part of the wire and work your way towards the exposed part, then continue to wrap back down toward the shielded part. This is not only securing the connection, but also strengthening the junction in the wires.

9. Repeat steps 6–8 for the black wire. Make sure the fourth wire is the piece of black braided wire.
Configuring the Amplifiers Part 3: Power Switch

Note: You must take special care to be gentle while working with these wires as they are soldered to the power amplifier.

1. Use the wire strippers to remove the shielding from the spot the power switch was removed.

2. Stack the three amplifiers on top of each other so that they are all facing the same direction.

3. Cut a piece of red braided wire about 6 inches. Use the wire stripper tool to expose about a half an inch on either side.

4. Cut a piece of black braided wire about 6 inches. Use the wire stripper tool to expose about a half an inch on either side.

5. Similarly to what was done in “Configuring the Amplifier Part 2”, you will be connecting all power switches of the three power amplifiers together. Gather each of the red wires from the three power adapters. Fray each end just a bit. Take the red braided wire that was cut in step 4 and hold the four wires so the copper braiding all meet.
6. Twist all four wires together so that a secure connection is made between each.

7. Use a liberal amount of electrical tape to wrap around all four wires from the shielded to the exposed part of the wire. I recommend starting your wrapping around the shielded part of the wire and work your way towards the exposed part, then continue to wrap back down toward the shielded part. This is not only securing the connection, but also strengthening the junction in the wires.

8. Repeat steps 5–7 for the black wire. Make sure the fourth wire is the piece of black braided wire.

9. Unwrap the power switch and turn the power switch so the two connections on the back of the toggle switch are on top.

10. Feed the red wire through the right connector and the black wire through the left connector. Wrap the wire around a bit to secure the connection.
11. Drop a small piece of solder on each connection. The final product should look like this:

Note: Make sure there are no stray wires making a cross connection.

The end result should look like this:
Making the RCA to TS Connectors

1. Cut the ends off of an RCA cable and leave about 10 inches of wire from the jacks. Cut a second RCA cable at the same length from the jacks. You will need one whole cable (to create two pair of jacks) and one half of another cable (for the third pair of jacks).

2. Separate the two wires so the two cables are independent from one another.

3. Use the wire stripper to remove the outer shielding from each wire.

4. You will see a braided set of copper wires surrounding a small wire. The braided set of copper wires is the ground and the inner cable carries the signal. Separate the ground wire from the signal wire and use the wire stripper to remove about 1/4" of shielding.

5. Repeat step 4 for all six cables.

6. Connect the modified end of the RCA cable to the TS female jack. When looking at the TS female jack, feed the cables through the side of the jack that has more of an elevation (tall side). The inner cable should be fed through the connector furthest away from the opening of the jack. The outer braided wire should be fed through the connector closest to the opening of the jack. Twist each wire to secure the connection.

7. Repeat these step 6 for each of the six RCA jacks.

8. Drop a piece of solder on each place the wire was fed through the TS jack to secure the connection.
Securing the Amplifiers

1. Set the power amplifiers on the base plate as centered as possible. Outline the bottom amplifier with a pencil.

2. Make four marks on every side of the power amplifiers where it is free of any connection to the motherboard.

Note: The indication marks in the pictures above are estimates. Make sure to leave a bit of clearance on each board so that the bolts and nuts, which secure the power amplifiers, do not touch any connection on the power amplifier. Failing to do this will blow the unit!
3. Use the 1/4" drill bit to make holes at every location below.

4. Measure the height of the stacked amplifiers with the 8"X1/4"-20 threaded rod. Add about 1 1/2" to the total height of the rod and cut four pieces.

5. Use the 1/2" boring drill bit to hollow out a small portion of the hole on the bottom of the base plate. This is to recede the bolt on the bottom of the base plate so the hemisphere speaker will sit flat on the ground.
6. Feed the threaded rods through each hole and secure a 1/4"-20 nut to the bottom of the base plate.

7. Secure the rods by placing a nut on each rod on the inside of the base plate.
8. Place the first amplifier on top of each bolt. Secure the amplifier with a nut on the topside of the motherboard.

9. Tighten the nuts so the power amplifier is secure.

10. Screw another nut onto each threaded rod above the first power amplifier. Each should be at the height of the first amplifier.
11. Place the second amplifier on top of the new set of nuts and secure the amplifier with new nuts.

12. Repeat steps 10 and 11 for the third amplifier.

Note: **DO NOT USE WASHERS.** The pictures above have washers between each set of nuts. Using washers increases the surface area of the rod to motherboard connection and will cause the amplifier to blow from shorting these connections. There is not much room on each motherboard to secure the power amplifiers, so care must be taken when securing them to the threaded rods.
Making the Faceplate

1. Make 8 marks in the middle of the faceplate every inch starting one inch in on the 2” of the 9”X2” Metal Plate.

2. Use a hammer and nail to pound in a small notch on each mark. This is to keep the drill bit from slipping off the mark when drilling the holes.

3. Use the 5/8” Drill Bit to drill each hole. When doing this, put the faceplate on a piece of wood, on the ground using downward force for leverage and to avoid drilling into the floor.

4. On every corner of the faceplate, drill a 1/4” hole for securing the faceplate using the same techniques in steps 2 and 3.
Faceplate Configuration

1. The power supply is the first component attached to the faceplate. This is because the external power supply must be inserted into the faceplate BEFORE soldering the power supplies from the power amplifiers. Secure the external power supply into the faceplate with the exposed end toward the inner part of the faceplate. Using the single red and black wires from the combined red and black wires in the steps, “Configuring the Amplifiers Part 2: Power Supply”, solder the red wire to the long end of the power supply and the black wire to the inner part of the power supply.

2. Secure the six RCA connectors to the faceplate by unscrewing the nut, removing the washer, and inserting the TS cable into the faceplate. Replace the washer and nut to the TS cable once it is in place with the insert end facing the same direction as the external power supply.

3. Secure the power switch to the faceplate by unscrewing the nut, removing the washer, and inserting the toggle switch into the faceplate. Replace the washer and nut to the power switch.

4. Plug in each DC Power supply from the external power supply to the power amplifiers.

Configuration of each component:

(Toggle Switch) (TS Insert 1 (Top Speaker)) (TS Insert 2) (TS Insert 3) (TS Insert 4) (TS Insert 5) (TS Insert 6)

Power Supply

(This is just a suggestion. Any configuration is possible, but for organizational purposes, make sure that you are mapping your speakers and RCA cable to the intended destination.)
Connecting the TS Inserts

1. Connect the RCA cables to the power amplifiers. Follow the map below:
Connecting the Speakers

1. Connect the speaker wires from “Preparing the Speakers” to the Power Amplifiers. Follow the map below:
Configuring the Gain on the Power Amplifiers

1. To adjust the level of the Power Amplifier before closing the hemisphere speaker, you must first configure each attenuator on the amplifiers. To do this, locate the attenuator on each amplifier and notice the two openings underneath each attenuator.

(The shadow of the attenuator knob covers the middle hole in the left picture above.)
2. Place the Red measurement tool in the far left opening and the Black measurement tool in the middle opening. Use the multimeter to adjust the Ohms so that the knob output is half of the maximum output.

(Example: if turned all the way up it reads 22 Ohms, reduce the knob so it is left at 11 Ohms.)
Finishing

1. Double check to make sure all connections are secure (DC Power Supply, RCA Inputs, Speaker Inputs). Try plugging in all components to test each connection using a phone for sound or something else that is portable.

2. Secure the faceplate to the speaker base and secure any loose wires using the U-Style Wall Mount Holders. You will have to bend the faceplate in order for it to wrap around the speaker base.

3. Carefully, place the hemisphere speaker on top of the speaker base. Make minor adjustments left or right to make sure the speaker housing bowl fits flush on top of the speaker base.
4. Secure the top two screws of the faceplate to the speaker housing unit.
5. Use the Deadbolt Strike Door Filler Plates to secure the speaker housing unit to the speaker base around the entire hemisphere speaker. 4-5 filler plates will suffice for securing the two units together.
Finished Hemisphere Speaker

This is what the finished product should look like. Some manipulation of hardware or placement of components may be necessary, but be sure to test everything before buttoning up the final unit!