easy to build Salad Bowl SPEAKERS

These speakers are retro, stylish and surprisingly good performers. They're also pretty easy to make and don't cost the Earth. My wife liked them so much that she actually wanted me to put them in the living room!

By Phil Prosser

Here is our take on the IKEA salad bowl speaker concept that has been spreading around the internet, which we think came out really well. This article describes a fully functioning pair of desktop/bookshelf speakers and gives some suggestions for tweaking the design to suit your needs.

What initially attracted us to this idea was the mix of an old-school spherical speaker with extreme ease of construction. While the initial motive for building these was style and looks, it quickly became apparent that these little cuties had more to offer than that.

Those who make speakers will be quick to comment that a sphere should be highly resonant; however, our tests show this is not the case. The fact that the driver forms a significant portion of the surface area of the sphere results in the Q of the internal resonance being relatively low. As a result, our measurements don't show resonant peaks in the response.

Another benefit of a spherical speaker is that it has no edges. Or is it all one edge? Either way, concerns like edge diffraction and baffle effect are avoided. The fact that these speakers are spherical makes them extremely rigid.

Edge diffraction is the effect of sound waves propagating from the driver across a speaker's front panel, then hitting the edge, which forms a discontinuity from propagation in 'half space' to 'free space'. This change causes diffraction at the speaker edges, affecting the frequency response and off-axis behaviour.

There are many ways a spherical speaker can be mounted. Without creating a solution to this, they will tend to roll around! We have come up with a couple of options, including feet for the desk version and "rocket" floor stands, both shown in the photos. The desktop version uses three small doorknobs as feet.

The loudspeaker driver used is the SB Acoustics SB12PFCR25-4-COAX, a bass/mid driver with a coaxial tweeter (mounted in the centre). This allows us to achieve really good performance from about 70Hz upwards. These work brilliantly as desktop speakers and would also match well with any of our subwoofers crossed over at 80-100Hz.

If you're interested in matching these speakers with a subwoofer, check out my Tapped Horn Sub design (September 2021 issue; siliconchip.au/Article/15028), which is inexpensive and easy to build. You could also consider the very high-performance Active Subwoofer (January & February 2023; siliconchip.au/Series/390).

We chose this specific SB Acoustics driver because it incorporates the tweeter, and neatly addresses the challenge of finding somewhere to mount the tweeter. The only other solution we could think of was to mount the tweeter externally, which we did with the floor-standing version, but it was a real hassle.

We have added a port to our enclosure. This allows us to extend the lower frequency response to about 70Hz, with some useful output below that. That is a good result for such a small speaker and is reasonable in its intended applications of desktop usage or placement in a small room. Don't try to run a dance party using these speakers, though.

There is a bit of a hump in the frequency response in the 100-200Hz region. This is a result of the port and helps fill out the bottom end, given the roll-off below 80Hz. The black line in Fig.2 shows the low-frequency response you will achieve

Features & specifications

- *Compact full-range loudspeakers with a unique appearance*
- *Simple construction*
- *Spherical enclosure minimises diffraction*
- *Coaxial tweeter for good off-axis response*
- *Can be desk or floor mounted (the latter with a simple stand)*
- *Frequency response: 70Hz to 20kHz (±3dB typical)*
- *Power handling: 50W RMS per channel*
- *Impedance: nominally 4Ω*
- *Relatively low total cost*

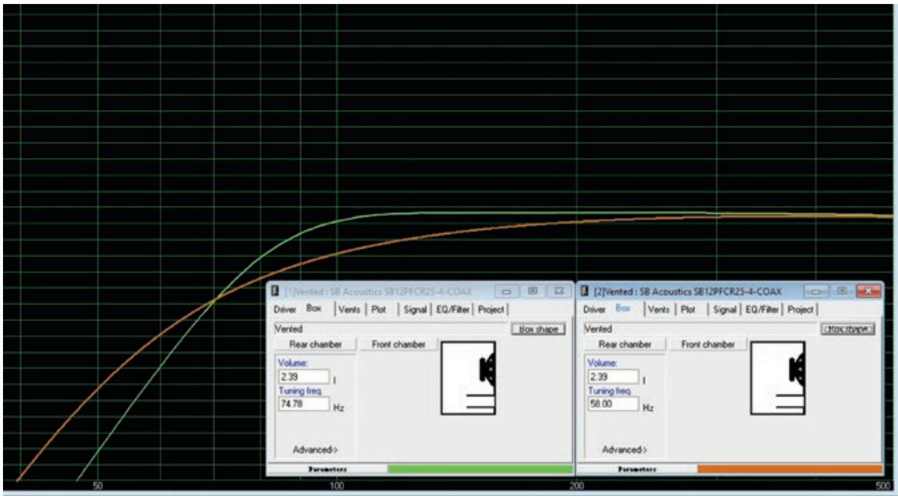


Fig.1: the modelled response of these Speakers with a 90mm port (green curve) or tuned for 58Hz with a 160mm port (orange curve). The longer port gives more output below 70Hz, but trades that off against reduced output between about 70Hz and 200Hz.

if you simply omit the port. If you use these on a desk backed up to a wall, omit the port.

We used a 25mm port from Wagner Electronics, cut to 90mm in length. This tunes the system to resonance at 74Hz. In practice, the vent ends close to the driver magnet, so its effective length is over 90mm. This tuning gains us a couple of decibels of extra bass in the roll-off region.

In an ideal world, this port would be 160mm long, tuning the enclosure to 58Hz, but there is not enough room in the enclosure for that - see Fig.1.

Cost

While these speakers are designed to be relatively inexpensive, we are using high-quality drivers from SB Acoustics that cost around $90 each. We also can't avoid some relatively expensive air-cored inductors in the crossover, meaning the total cost to build these speakers will be about $350. Still, it's hard to buy a decent pair of speakers for less than that.

You might be able to build a pair for around $300 or perhaps a bit less if you take some shortcuts, eg, if you come up with alternative feet and wind your own air-cored inductors.

Crossover

The crossover we're using is based on that recommended by SB Acoustics with some minor modifications. This is a third-order electrical crossover at 2.2kHz. Third-order is a higher order than we would generally want to use. Still, given that the tweeter resonance is at 1300Hz, it's necessary for the crossover to occur at a sensible frequency.

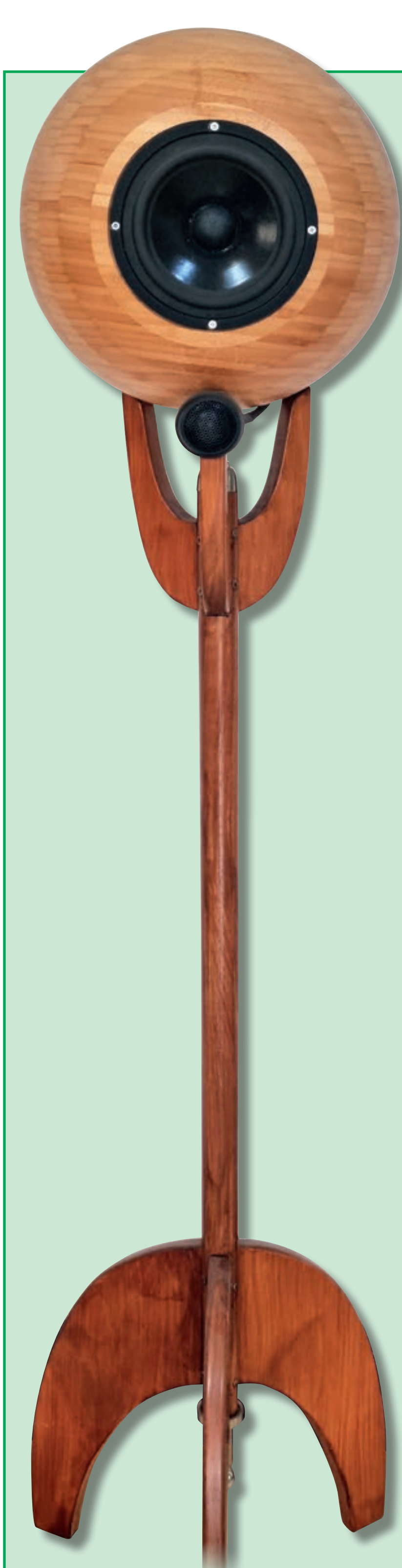
Our measured frequency response of the driver in the spherical enclosure (Fig.2) is very close to that SB Acoustics provides. The only notable difference is that our tweeter was 1-2dB less sensitive than theirs.

Fig.2 is a raw measurement of the driver with no processing at all. We are looking for spikes and dips that, if present, will colour the sound. Happily, the response is actually very smooth. We will discuss that chasm at 12kHz or so later; the short answer is that it disappears off-axis. Those wobbles in response at the bottom end are due to floor and room interactions.

We were about to start a fresh crossover design when we noticed that SB Acoustics published a recommended crossover circuit. When a manufacturer publishes a reference design, it is usually a great starting point. We duly tested it.

Given the tweeter's small diameter, a third-order design was appropriate. It is important to drive as little energy at 1.2kHz into that tweeter as possible. The woofer also has a third-order crossover, which makes sense from a symmetry perspective. This driver is well-behaved, as shown in Fig.2. So, if not for the tiny tweeter, a second-order crossover may have been better.

The resulting system response is shown in Fig.3. This is very flat through the main audio range, up to 10-15kHz. The dip between 10kHz and 20kHz can be seen to move as you



You could repurpose a couple of coat racks as speaker stands since the Speakers are small and light, or build similar stands from MDF or other timber. We used a driver without a coaxial tweeter and mounted the tweeter under the enclosure, but it doesn't look great and is fiddly to assemble. We therefore recommend you stick with the coaxial drivers.

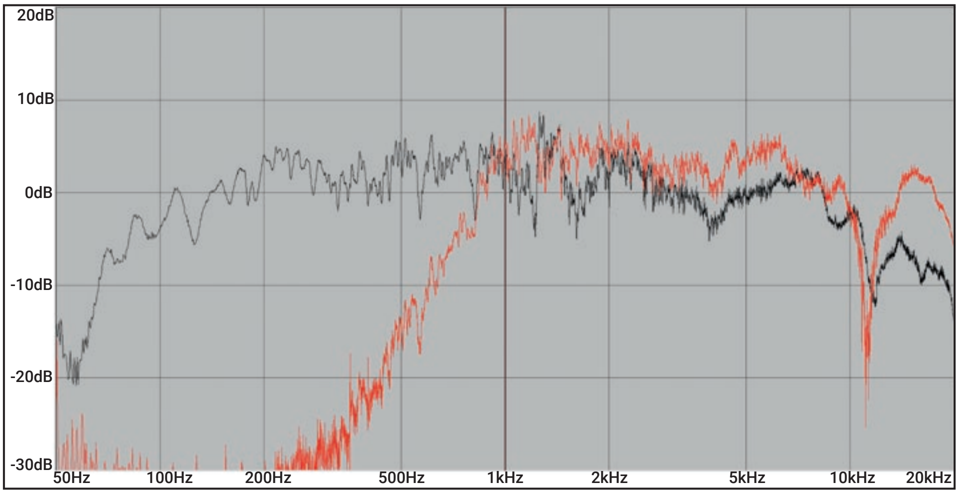


Fig.2: the measured frequency response of the SB Acoustic SB12PFCR25-4 driver without any processing or smoothing. The woofer response is in black, while the tweeter is in red. The dip above 10kHz is discussed in the text.

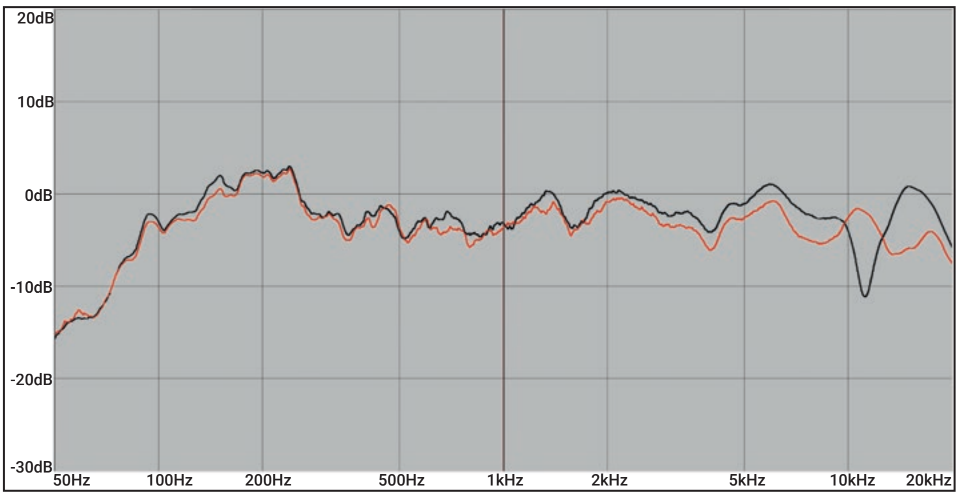


Fig.3: the overall Speaker frequency response with ⅙th octave smoothing, with on-axis response in black and 15° off-axis in red. This is very good for such a simple design. The dip at about 12kHz is a consequence of the tweeter location. As the crossover is optimised for a 15° off-axis response, that dip has disappeared in the red curve.

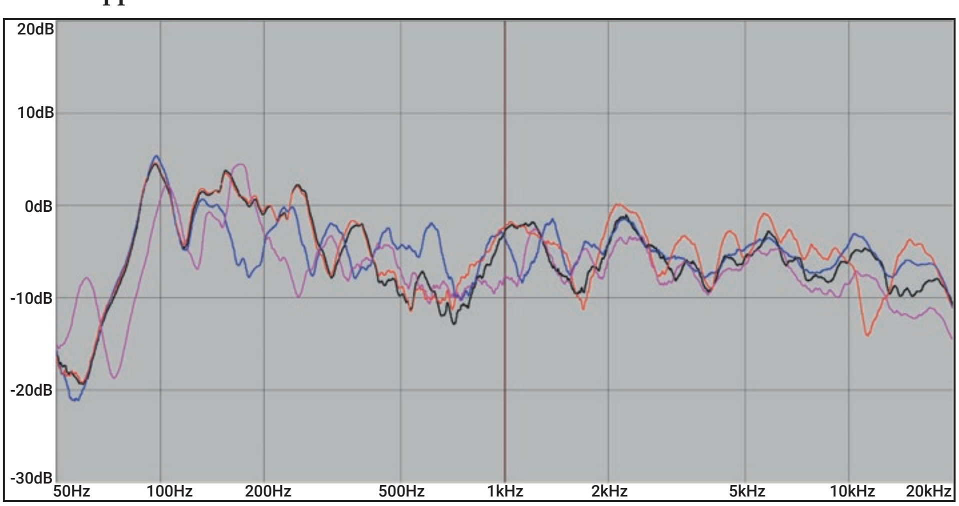


Fig.4: the frequency response of a Salad Bowl Speaker with ⅙th octave smoothing and reflex port installed at various locations. The black curve is about 15° off-axis, red is straight on, blue is elevated about 400mm and again about 15° off-axis, and purple is on the other side of the desk at a similarly elevated location. The low-frequency ripple from the room is very evident.

move off-axis. This is likely a consequence of the coaxial tweeter and varying path lengths from the exit of the coaxial tweeter to the woofer voice coil former.

It is important to note that there is no sign of the crossover at 2.2kHz in the frequency response plot. In short, this crossover works very well with the driver.

The following hypothesis hasn't been proven, but the wavelength of 12kHz is about 27mm, and destructive interference will occur for a path difference of 10-15mm. Given the location of the tweeter cone relative to the coil edge, the dip makes sense. It also explains why the dip changes in frequency and disappears as you move off-axis.

This ripple in response is at a frequency near the limit of what most people can hear, so it is not a big deal.

Our frequency response plot was made 1.2m above the floor at a distance of 30cm, the same distance at which the manufacturer's response plots were made. When used on a desk, as we expect these will be, there is no sign of that dip. It's only apparent when the driver is measured in free space.

There are all sorts of other artefacts in the plots, which, in our test location, resulted from our monitor, keyboard and probably even coffee cup! These peaks and dips move all over the place as you move around the Speaker. Running the risk of being told to clear our desk, Fig.4 shows several measurements of the Speaker in different locations.

Subjective evaluation

These speakers sound pretty darn good using the standard crossover. We did make two minor changes, though. Firstly, we reduced the tweeter attenuation resistor to boost treble by 1dB. Also, the OEM design used a 0.4mH series inductor for the woofer. We had a bunch of 250μH units available, and calculations showed it would make a negligible difference, so we went with that.

Given how well these measured, we shelved any idea of redesigning the crossover. Why break something that works? The final crossover is shown in Fig.5.

The change from 2.2Ω to 1.5Ω for the tweeter series resistor will increase the tweeter output by about 1dB and slightly improves damping. Given the

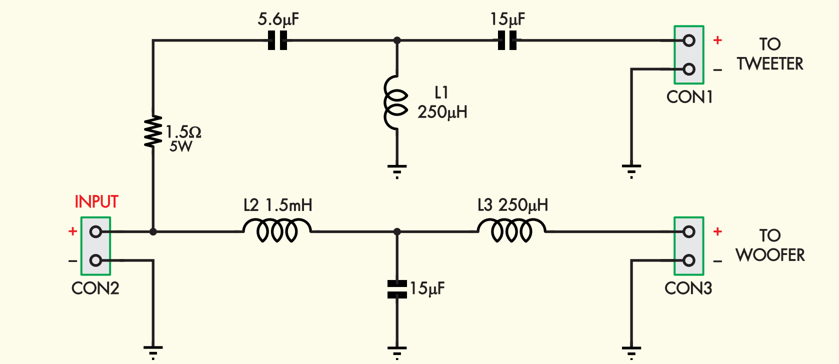


Fig.5: the crossover circuit provides a third-order high-pass filter (HPF) for the tweeter and a third-order low-pass filter (LPF) for the woofer, crossing over at about 2.2kHz. There is no phase inversion. We have made the resistor 1.5Ω as that provided better balance in our speakers than the suggested 2.2Ω. Still, if your tweeters are less or more sensitive than ours, you may wish to tweak its value.

frequencies involved, it is not likely that the reduced sensitivity is a consequence of the spherical enclosure; it could be that our samples are slightly less efficient than average (or the ones they tested were above average in efficiency).

When building yours, consider experimenting with values of, say, 1Ω, 1.5Ω and 2.2Ω to see which results in the most natural sound in your application.

Practical considerations

The mounting location for the crossover was a bit of a head-scratcher. Usually, we would make a PCB and screw it to the enclosure. That is not an option here as, being spherical, there are no flat surfaces to use. There is also precious little room to play with.

So we made a PCB with rounded edges that you can glue into the speaker base. It just fits through the driver hole, and we have placed the 1.5mH inductor so that you can snug this up against the port and glue them together – see Photo 1. We used neutral-cure silicone sealant to glue the crossover PCB to the enclosure, as it will stick to just about anything, and once it sets, it is very resilient.

Building the speakers

The sole 'tricky' part of building these speakers is cutting the bottom off one bowl to accommodate the driver. If you have a router or can borrow one, it will be much easier than you might think. We reckon it would be possible to use a tenon saw and do this by hand if you clamp the bowl well, as the bowl wall is only 8mm thick.

When we cut off the bottom of the bowl to accommodate the speaker driver, we need sufficient material left to screw into. To achieve this, we took an MDF off-cut and cut it into two 120mm circles using a jigsaw. We then used an 80-grit sanding disc in a drill to get them to be rough fits to the bowls – see Photo 2. The fit does not need to be perfect; we will glue it in with acrylic filler.

Use an N95 mask and work outside (if possible) when cutting and sanding MDF. Having a vacuum cleaner pick up the sawdust as you make it is also a good idea. MDF dust is a health hazard.

Once you have roughed the wood so it fits with a gap under, say, 5mm, apply acrylic filler liberally around the sloped section and squeeze it into the bottom of the bowl, as shown in Photo 3. It is a good idea to drill a hole in the middle of the MDF to allow air out as you stick it in. Leave it for a week to really set.

Routing

We used our circle jig (described on page 61 of the January 2023 issue) and a router to expand the flat portion of the bowl base to an outer diameter of 122mm, matching the diameter of the SB12PFCR25-4-COAX driver. We placed the bowl top-down on the workbench and drilled a hole in the middle of the base to centre the router. Make this route in two or three cuts, and do not cut too deep.

Briefly, the circle jig is a length of aluminium bar with holes drilled in it to allow it to be bolted to the router. There are other holes drilled in it at various distances from the router.

Photo 1: you can see how the port, driver and crossover fit into the spherical enclosure that was made by gluing two salad bowls together. You can also just see the MDF reinforcement ring behind the circular driver cutout.

Photo 2: we roughly cut two 120mm MDF discs from off-cuts (left), then used an 80-grit sanding disc in a cordless drill chuck to shape it to fit in the bottom of the bowl (right).

Photo 3: the reinforcement disc is glued into the bottom of the bowl using acrylic gap filler. Before doing this, ensure it is a close fit, leaving gaps less than 5mm wide all around.

After loosely screwing one of these into a centre hole drilled in the bowl, the router will rotate about that point and make a perfect circle.

We are pretty sure that a steady hand, some clamps and a tenon saw would do the job, and might actually be easier and make less mess.

Cutting the speaker hole

The driver fits into a 102mm hole in the base, visible in Photo 4. Mark this with a compass and cut it with either a handsaw or jigsaw. The hole is fairly small, so only a little elbow grease would be expended doing this by hand. Check that your driver fits, and if necessary, fettle (a fancy word for bodge) the cutout so that the terminals do not interfere with the hole.

Fitting the port

If we were using these on a desk, pushed back against a wall, we would omit the port. The boost in low frequencies using the Speaker in a corner will be sufficient, and you will be better off without the port. If you've already added the port, you could put a sock in it for such use cases.

If you will use the speakers in more 'free space' and without a subwoofer, include the port, as the low-frequency output will benefit from it.

If adding a port, drill the hole now. We used a 32mm hole saw and filed the hole to the required 33mm. We centred the hole 50mm below the centreline of the bowl see (Photo 5). This results in the port pointing upwards inside the Speaker.

You need to cut 10mm off the Wagner 25mm port to make it 90mm long; otherwise, it will interfere with the speaker magnet later. We made the hole tight enough that we had to push the port in forcefully. If your hole is too big, glue the port in using some acrylic filler.

Speaker connectors

We used very simple combo banana/binding posts. The speakers' power handling does not warrant anything massive, but we think these are better than the cheap spring-loaded terminals. The location of the connectors is largely a matter of convenience; ours are shown in Photo 5.

These need an 8mm hole, although we prefer to start smaller and use a file to get a good fit with the chamfered keying on the threaded section. That stops them from coming loose and spinning.

Our experience building the prototype showed that it is possible to solder to these terminals once they are in the assembled Speaker, but it is fiddly. We recommend you pre-install the input wiring to these terminals. Solder 300mm lengths of black and red wire to each pair and add 6mm diameter heatshrink tubing over the solder joints. You can trim the wires to length once you have attached them to the crossover.

Adding feet

As mentioned earlier, they need feet for desktop use. We used brass knobs because we thought they looked nice and were easy to fit. They are not individually that expensive, but there are six, so it does add up. You might come up with your own solution.

The feet are visible in Photos 5 & 6. They fit through 4mm holes drilled as shown in Fig.6. Whatever feet you choose, make sure you place them so the Speaker is stable; their placement must consider the centre of gravity being pulled forward by the weight of the driver magnet.

The Bunnings knobs come with long bolts that you can cut and then file the ends smooth to ensure they thread onto the knobs without sticking. You can use a metal file to do that.

Gluing the pieces together

Sticking the two salad bowls together is as simple as it sounds. We used 120 grit sandpaper to take the gloss off the rim of the bowls and around the inside of the bowls. This ensures there is a good surface for the glue to adhere to.

We then mixed five-minute epoxy (Araldite), a teaspoon full or less per bowl. Use a piece of thin wire, 1mm in diameter or so, to apply a small bead around the top rim of the base bowl. Our tips are:

- Do not use too much glue, or it will ooze out around the joint.
- Get everything ready before you start applying the glue. It will set in less than five minutes, so you don't have time to muck around.
- Be ready to clean up spills; have cloths and isopropyl alcohol/white spirits ready.

Photo 4: the result of cutting a 102mm diameter hole in both the base of the bowl (already routed to have a larger flat area) and the MDF reinforcement disc, leaving just a ring.

Photo 5: the flat part of the base opposite the driver cutout provides a place to mount the two binding posts, while the port is offset so it fires downwards and clears the internal crossover assembly.

Photo 6: the finished speakers look classy, if a bit unusual. Fans of post-modern art could paint them white and add red wiggly radial lines around the drivers to make them look like eyeballs!

• Know how you want to align the bowls. Ours were so random that we kind of gave up, but you might be more discerning than us.

Once you have a thin bead on the bottom bowl, gently place the top bowl over it. Very gently wriggle it to ensure both sides are wet, and check that everything is aligned. Set it aside for a while.

Once the main joint is set, mix another batch of glue and, using an icy pole stick or similar, run a bead of glue around the joint inside the glued bowls to ensure the final result is airtight. With the roughened surface, the epoxy bond will be extremely strong.

Assembling the crossover

The crossover PCB with chamfered corners is coded 01109231 and measures 98 × 104mm – see Fig.7.

We etched the PCBs shown in the photos ourselves as the design is simple. PCBs for sale will be the usual green commercial products, but otherwise identical to these.

Our photographs show yellow polypropylene 15μF capacitors, which are overkill; we simply used them as they were on hand. We have specified 15μF 100V bipolar electrolytic capacitors as they will work perfectly well and are what we would buy if building another pair of speakers.

We have left room for a 400μH inductor to be used in place of the recommended 250μH inductor. All testing was done with 250μH, but you can experiment; we don't expect much difference in performance over the range of 250μH to 400μH.

If you want to experiment, run wires from the drivers out through the port to the crossover. Get the crossover as you want before gluing it into the Speaker.

Assembly is straightforward. Fit the screw terminals first; still, you might want to simply solder flying leads and save on this cost. If you choose to do this, solder 300mm flying leads to the bass and tweeter connectors and label them so you know what goes where. The input wires should already be soldered to the input connectors.

Next, mount the resistor. This does not need to be proud of the PCB, as if this is getting hot, your tweeter will be in serious trouble. So it's OK to push it down flat before soldering and trimming the leads.

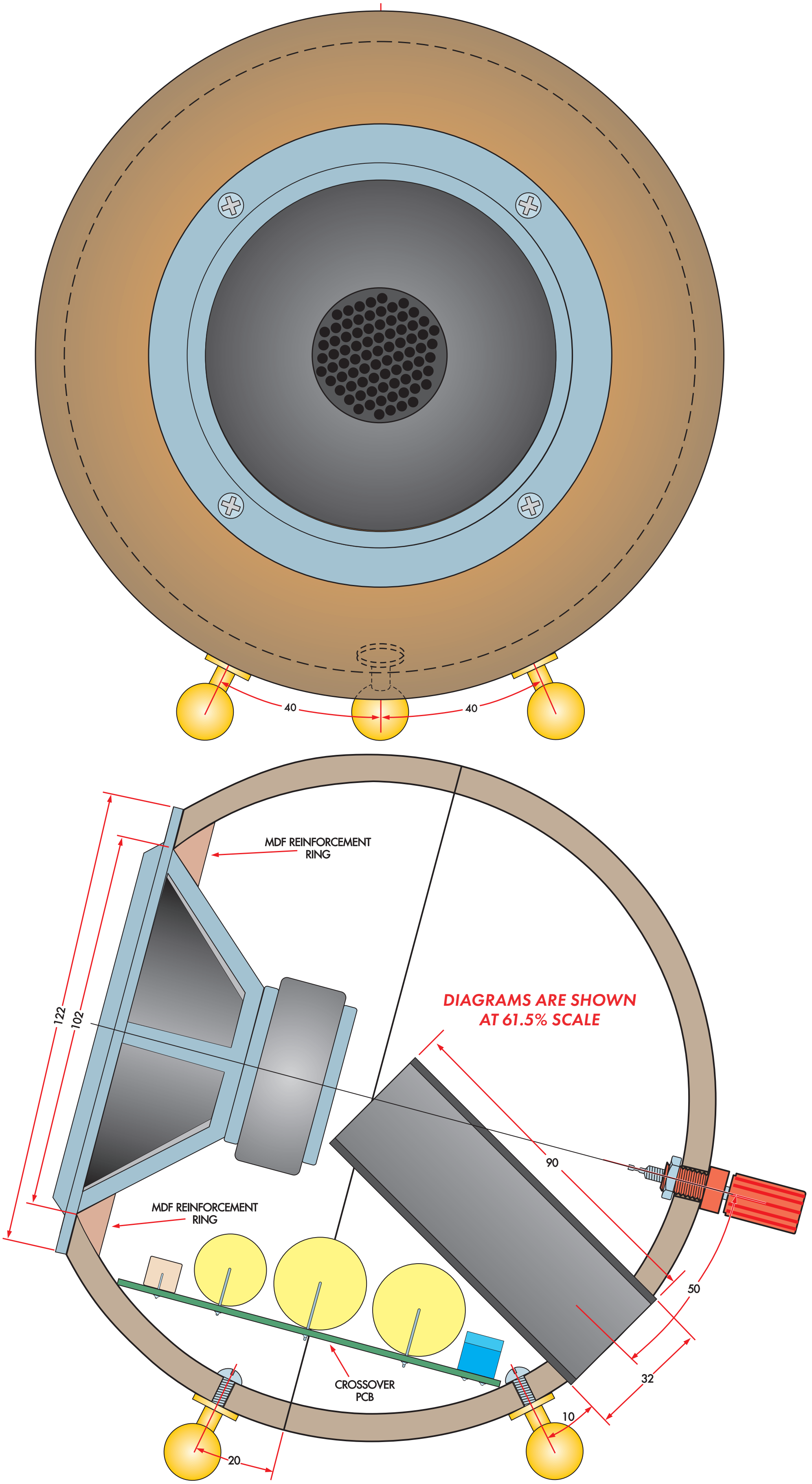


Fig.6: these views of an assembled Speaker should give you a good idea of the relative locations of the driver, feet, port, crossover and terminals. You could vary some of these slightly but we feel our design is pretty close to optimal.

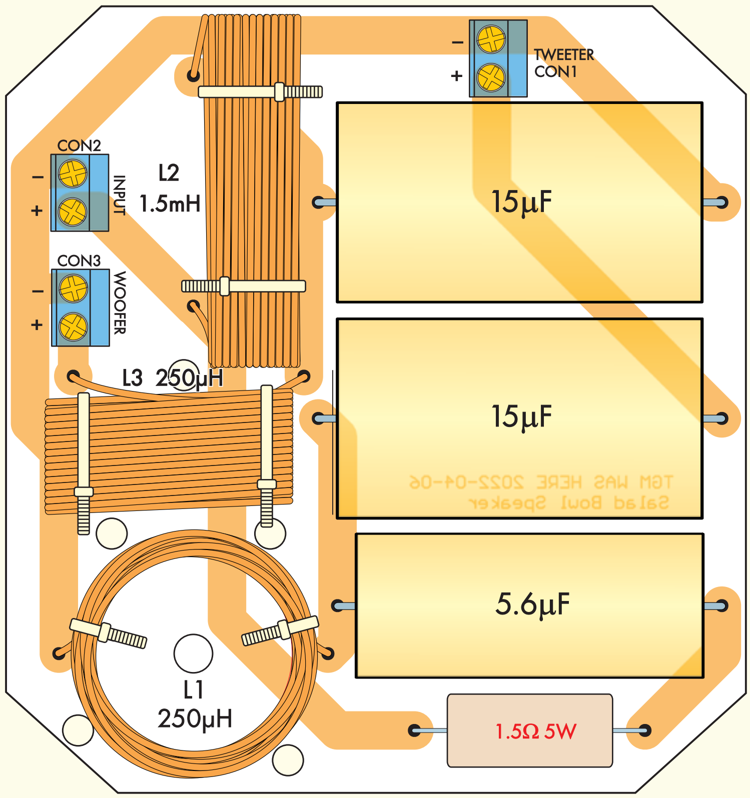
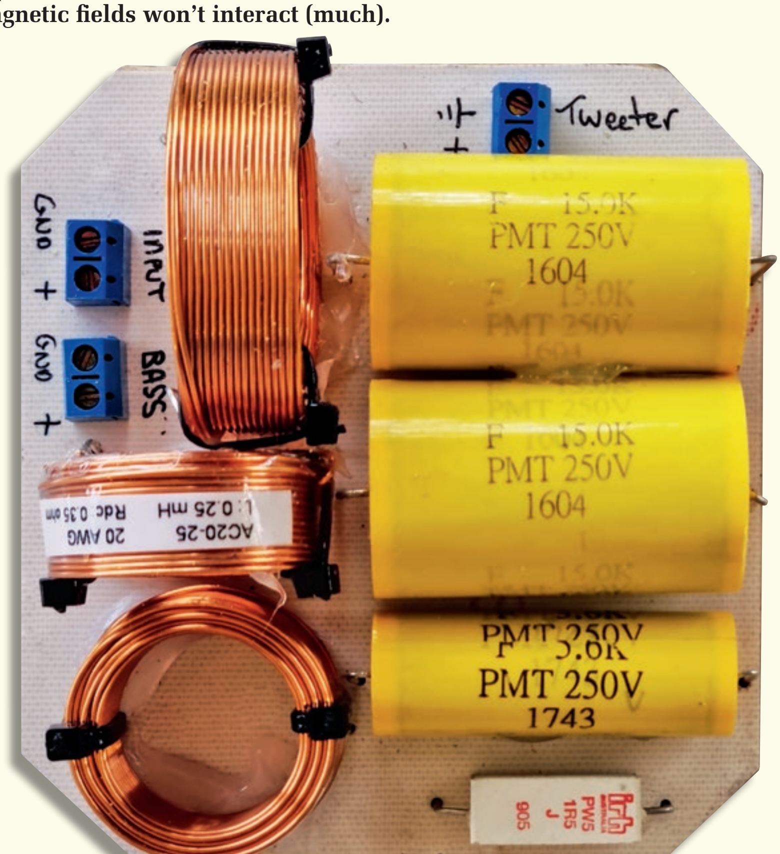


Fig.7: the crossover PCB is straightforward to assemble. While we're showing the capacitors as axial polyester types, axial crossover bipolar electrolytic capacitors are considerably cheaper, especially for the 15µF cap, and will work fine. Ensure the inductors are mounted as shown so their magnetic fields won't interact (much).



The prototype crossover was simple enough that we made the PCB ourselves. We recommend using electrolytic crossover capacitors instead of the two large 15µF polypropylene capacitors shown here.

Install the capacitors next, none of which are polarised. Put a dab of neutral-cure silicone sealant under each to stop them from vibrating.

Finally, solder the inductors in place. Note that these are all at right angles to the others to ensure the magnetic fields don't interact. Make sure you stick to this arrangement. Again, glue each in place with a solid dab of neutral-cure silicone.

With all the components mounted, check your soldering and that everything is in the right place before moving on. Let the silicone cure before moving on to final assembly.

Final speaker assembly

Before you glue everything in place, let's check that everything works, as it is diffcult to remove the crossover afterwards. Do the following on the bench. Strip a short length of all the flying leads and connect the leads from the input connector to the input terminals.

Next, connect the bass driver and tweeter to their respective inputs on the crossover but connect only the ground wires at the driver end at this stage. We want to just touch the positive wire for the test. You can tell which is which as the bass driver connections have heavy-duty tinsel going into the spider on the driver while the tweeter connections run to thin wires going to the rear of the magnet assembly.

Apply a signal to the inputs and touch the positive bass wire to the terminal on the driver. You should only hear the lower-frequency parts of the test signal. It won't have any real bass with the driver on the bench.

If you hear treble instead, or nothing, check your connections.

Next, touch the tweeter positive wire to the terminal on the speakers. You should hear 'hissy' treble. It will not be loud. If there is nothing or all you hear is muted sound, check your wiring and component values.

Assuming that it all checks out, test-fit the crossover into the enclosure. Photo 7 provides a pretty good view of how to install it. You need to align the thin axis with the hole and put the 1.5mH inductor in first, as we need this at the back to make room. We also need the weight at the back to improve the balance of the Speaker.

Once you are sure you know how

Parts List – Salad Bowl Speakers

Pair of desktop speakers

2 SB Acoustics 120mm coaxial speakers **[Wagner SB12PFCR25-4-COAX]**
2 25mm diameter, 100mm-long PortBASS reflex ports **[Wagner PORT1X4L]**
4 IKEA salad bowls
[BLANDA MATT 20cm bamboo serving bowl, 002.143.41]
2 16mm MDF sheets or off-cuts, at least 120×120mm each
2 red captive head binding posts for speaker terminals **[Altronics P9252]**
2 black captive head binding posts for speaker terminals **[Altronics P9254]**
6 doorknobs for feet **[Bunnings Prestige 15mm Brass Ball Knob, 4021268]**
3 2m lengths of heavy-duty hookup wire (white/blue, black and red)
[Altronics W2270, W2272 & W2274,
Jaycar WH3050, WH3052 & WH3040]
1 100mm length of 6mm diameter heatshrink tubing
8 6G × 20mm countersunk head wood screws (ideally black)
2 400 × 150mm (approximately) pieces of 50mm-thick acrylic wadding or similar
1 small tube of 5-minute epoxy **[eg, Araldite]**
1 310ml tube of White SikaSeal Acrylic 100 Gap Filler **[Bunnings 1670226]**
2 crossover boards (see below)

Crossover board – parts to build one board

1 single-sided PCB coded 01109231, 98 × 104mm
2 250μH air-cored crossover inductors (L1, L3) **[Wagner AC20-25]**
1 1.5mH air-cored crossover inductor (L2) **[Wagner AC201-5]**
2 15μF 100V non-polarised electrolytic crossover capacitors
[Wagner 15RY100, Jaycar RY6910]
1 5.6μF 100V metallised polypropylene crossover capacitor
[Wagner PMT5.6, Jaycar RY6955]
3 dual mini terminal blocks, 5.08mm pitch (**optional**; CON1-CON3)
1 1.5Ω 5W 5% resistor (can be varied to adjust treble balance; see text)

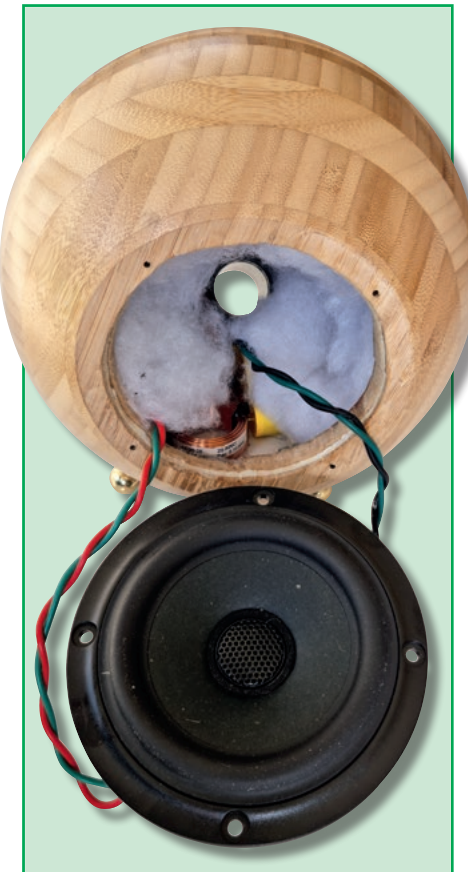


Photo 8: the Speaker just before we finally attached the driver, with acoustic wadding loosely stuffed inside.

you will get things in and out and that there is room (fettle the hole if necessary), we are set to finalise the wiring.

Trim the input and output wires so that, with the driver in front of the enclosure, you have sufficient length for the crossover to be glued in place. Solder the connections for the bass, tweeter and input. It is important to put some 6mm heatshrink on the speaker terminals when you connect the wires. These terminals are close to the crossover, and we do not want them shorting to it.

Now put solid dabs of neutral-cure silicone sealant on the underside of the PCB at each of the rounded corners. Then install the board, with some tissues/rags handy to clean your fingers. Carefully insert the crossover into the Speaker enclosure. As you will have found, it is a little like a puzzle, but it does go in and sits alongside the port.

Make sure there is silicone still under the PCB, and where you inevitably rub some onto the enclosure, clean up immediately.

We used a long screwdriver to add some extra silicone between the enclosure wall and the top of each corner of the PCB to ensure it won't move later.

Leave it to cure; don't be tempted to rush this, as silicone has no strength until it cures. We used a small piece of leftover acrylic wadding as damping for the Speaker, as shown in Photo 8.

Anything like open-cell foam, acrylic wadding or the contents of a disused cushion would do. Lightly stuff the enclosure and ensure the port is not completely blocked. Now where did that cushion go?

Finally, install the driver. We mounted the driver with the terminals horizontal. This ensures that the terminals cannot rub against the crossover components.

Ensure each driver has the same rotation so the screws line up. They will look silly if the screws are all over the place. We drilled a 1.5mm pilot hole for each screw and used 6GA wood screws. Do these 'gently hand tight'. These simply need to secure the driver well enough to achieve an air seal.

Testing and setup

Now for the fun! You will note that the acoustic output is night and day between the driver on the bench and in the enclosure. We were surprised at the bass output these little speakers deliver.

Start gently and play some program material, verifying that there is output

Photo 7: this close-up shows how the crossover board is orientated so the closest inductor just misses the port tube.

The Salad Bowl Speaker (not shown at actual size).

from the tweeters and bass drivers. If there is anything odd, now is the time to check. Once everything is good, you are set to find where to put them!

Often you have little discretion in the placement of a speaker. Try to find a spot with free space around and behind the Speakers. We found that when placed right up against a wall/desk junction, there was a reinforcement of bass, with a pronounced peak in the bass region. As mentioned earlier, blocking the port(s) should reduce that.

Refrain from facing the speakers straight at your listening position, though this is less of a concern on a desk. The crossover is optimal for a slightly offset listening position.

Observations

Our most ardent critic at home loves the style. We think it is interesting, both visually and in terms of a speaker free from diffraction, and we see this in the plots.

The coaxial driver really met our expectations, with a consistent sound experience at a wide range of angles.

The low end surprised us. It is not a disco speaker but does a fine job for moderate listening. As the measurements suggest, the sound is clean and free from annoying characteristics.

We could hear the elevated bass when we used the Speaker in a corner, so we would use no port in such a location.

While we have rated them at 50W, you should show some discretion if playing deep bass through them. These are intended for small rooms, on computer desks and similar.

While the impedance is nominally 4Ω, they present a fairly benign load with a higher-than-rated impedance over most of the audio range. Any modern amplifier will happily drive them. Our inexpensive, compact Hummingbird amplifier module is ideal (December 2021 issue; siliconchip.au/Article/15126).

These speakers provide useful output from 70Hz to 20kHz and some output below 70Hz. Over the majority of this frequency range, they are quite flat, operating within ±3dB. SC