Easy-to-build Active Hifi Bookshelf Speakers

with Optional Subwoofers

Part 2 – by Phil Prosser

Last month we introduced this fantastic new active speaker system, which looks and sounds great but doesn't cost a lot to build. Nor do you need extreme skills or specialised tools. We described the cabinet design, driver choice and performance last month. In this second article, we have the complete main speaker assembly details.

We decided to make these speakers out of plywood because, with a little care, they can be made to look really nice. But it's still a relatively cheap and stiff material, and quite easy to work with.

As explained last month, we're using two types of Altronics drivers (or three if you build the optional subwoofers), all of which are quite reasonably priced while giving excellent results.

All that's required to achieve high fidelity performance are two carefully designed crossovers, the construction of which is described below.

We'll also describe how to put together the two 'plate' amplifiers which make these active speakers (they could also be used for other speaker designs). These are based on pre-built Class-D amplifier modules, so the assembly is quite straightforward.

Building the passive crossovers

You will need to assemble two passive crossovers for each system, ie, one per bookshelf speaker enclosure.

The passive crossover is built on a PCB coded 01101201, which measures 137 x 100mm. Use the PCB overlay diagram, Fig.12, and matching photo as a guide when fitting the components.

There are only three capacitors, none of which are polarised and three 5W resistors. All should be marked with their values, so simply fit them where shown.

While not critical, it's a good idea to fit the resistor bodies a few millimetres above the top of the PCB, to allow cooling air to circulate.

Then mount the three identical two-way terminal blocks, with their wire entry holes facing the nearest edge of the PCB. That just leaves the three large air-cored inductors, which are simply "made" from whole reels of enamelled copper wire.

To make these inductors, remove the stickers that are on each end. You will see 1-2cm lengths of wire in the middle of the reels. Prise these out and then scrape the enamel off with a sharp blade. You need to be quite firm in doing this, and you will see the bright copper exposed.

Extend this wire by soldering a few centimetres of tinned copper wire to the exposed end. All the reels we purchased had 1-2cm of wire inside the reel, which is insufficient to reach the PCB when the reel is laid flat.

Next, drill a small hole through the side of the plastic bobbin, to allow you to pull the other end of the copper wire through, and secure it with hot melt glue or sealant. Make sure to pull the wire tight on the reel, so nothing can shake and move around. Scrape the end of this wire clean of enamel, too.

We chose to liberally paint the wire on the reel with lacquer. This sets hard and holds everything tight, so it can't hum or vibrate. That is an optional step, though.

While we used hot melt glue to hold the inductors to the PCB after soldering their leads, we realised after doing this that it wasn't such a great idea. Hot melt glue is quite effective for assembly

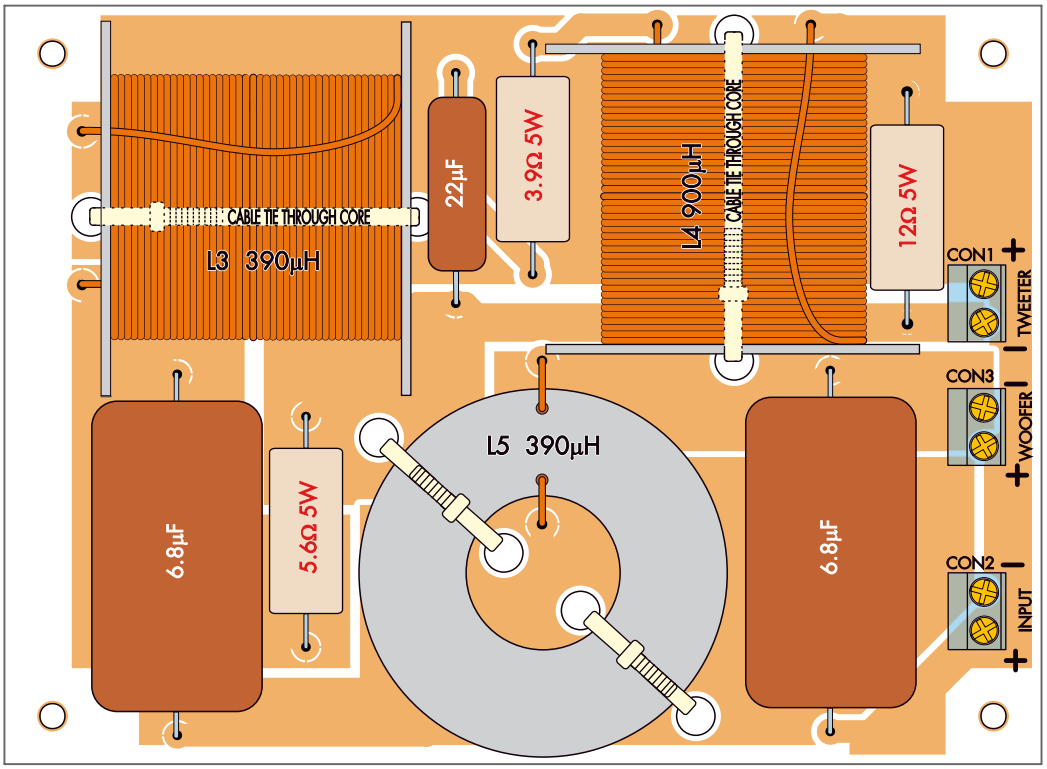


Fig.12: building the passive crossovers is not a huge job since there are only three inductors, three capacitors, three resistors and three terminal blocks. The inductors (which are full reels of copper wire!) are bulky and heavy, so make the sure they are properly anchored using cable ties (as shown here) or acrylic/ silicone sealant.
An early prototype PCB is shown below, a little less than life size. There are some component differences between the photo and the overlay at right. Follow the overlay! Two are required – one for each enclosure. Also note our comments regarding hot melt glue – while it holds the inductors nicely, it can soften and even let go if the coils get hot. Hence the provision for using cable ties, as shown at right.

like this, but can get a little messy if you are not cautious. And it can let go if the board gets too hot during use.

If you use it, watch out that you don't get it on your fingers; it gives terrible (and excruciating!) burns.

Gluing the coils down using neutral-cure silicone sealant is probably a better option but even better, use cable ties.

So the final board has holes to allow you to strap those inductors down using suitable large cable ties, as shown in Fig.12.

Building the monitor enclosures

Fig.13 (overleaf) shows how to cut two 600 x 1200mm sheets of 15mm ply into the pieces you will need to build two bookshelf (monitor) speakers. The piece labelled "Subwoofer 2 front" is only needed if you are going to be building the subwoofers; otherwise, you can leave it as part of the off-cuts.

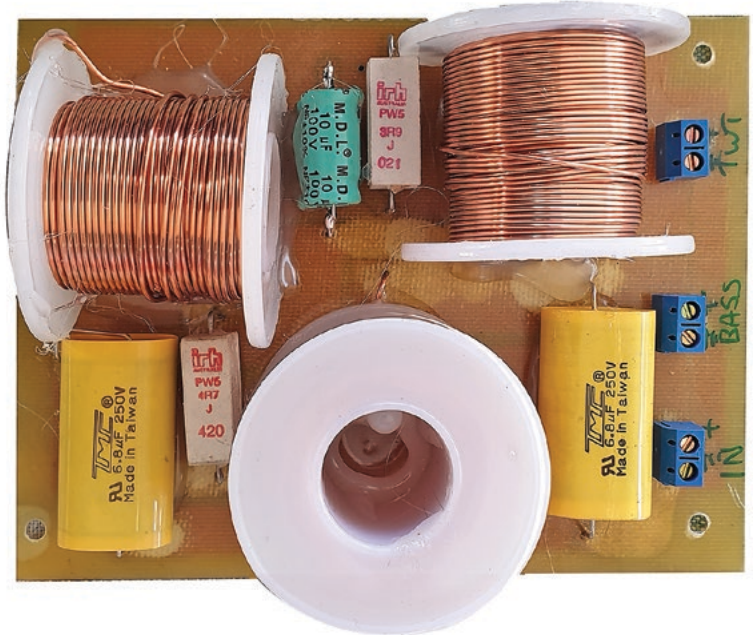
The cutout drawings are also shown. By choosing the speaker depth to be 297mm, you can slice the one sheet right down the middle to get the bottom, sides and tops for a pair of speakers with minimum cost and fuss.

This allows 6mm for the cut. If your pieces end up slightly wider than 297mm, that's unlikely to be a major problem, as long as they're all the same size.

The material we used was 15mm five-ply from Bunnings. This is available from most hardware stores. We chose this based on price and availability.

If you are after a really slick finish, you will benefit from choosing a higher grade timber, hence our suggestion in the parts list to use marine ply.

If you plan to paint the boxes, then MDF would be better as the panels are extremely smooth. Some people may wish to use stiffer or denser material for the boxes. This is a personal choice and if it is your thing, go for it.



Note our comments re the use of hot melt glue: a cable tie through the core of the coil (as shown in the diagram above) is much more secure (especially when the coil gets warm!).

In all the above cases, if you choose to use material that is not 15mm thick, you will need to go over the cut sheets and adjust the dimensions for a similar internal volume. Plus or minus a fraction of a litre is fine.

This is not a difficult chore, but remember, it's better to measure (or calculate) twice and cut once, than measure once and cut twice!

You may wish to wait until the boxes are assembled to cut the holes for the drivers, amplifiers, terminals etc. However, it might be easiest to mark their positions now.

A few assembly tips:

- Align the left side, top

and right side on the panel such that the grain runs continuously up and over the speaker box. This is a little touch, but a nice one
- Mark the panels on the inside using a pencil or marker. This will let you keep track of things
- Choose sheets that allow you to cut with little waste
- You should be able to get your local Bunnings to cut this for you. There are only a few cuts for the whole speaker
- Keep the off-cuts; they make good bracing.
- Check that the longer wood screws that you have are the right length to go through the bracing material and into the speaker panels without going all the way through. We found that 28mm screws were just right for our material. Note also that for any screws going into the speaker from outside, you will want to drill pilot holes and countersink those holes, so the screws will end up flush.
- You need to glue and screw. We used standard PVA glue. As you build, have some acrylic filler to hand, filling any gaps as you go.
- We used 15 x 15mm timber off-cuts for bracing. This is large enough to let you screw things together without taking away too much from the internal volume. If your bracing is slightly different to this, don't worry about the effect on the volume.

Once you have cut the pieces, assemble them as follows:

The sides

Start by attaching the braces to the inside of the side panels. Make sure to leave gaps at the front and back of each side panel, slightly wider than

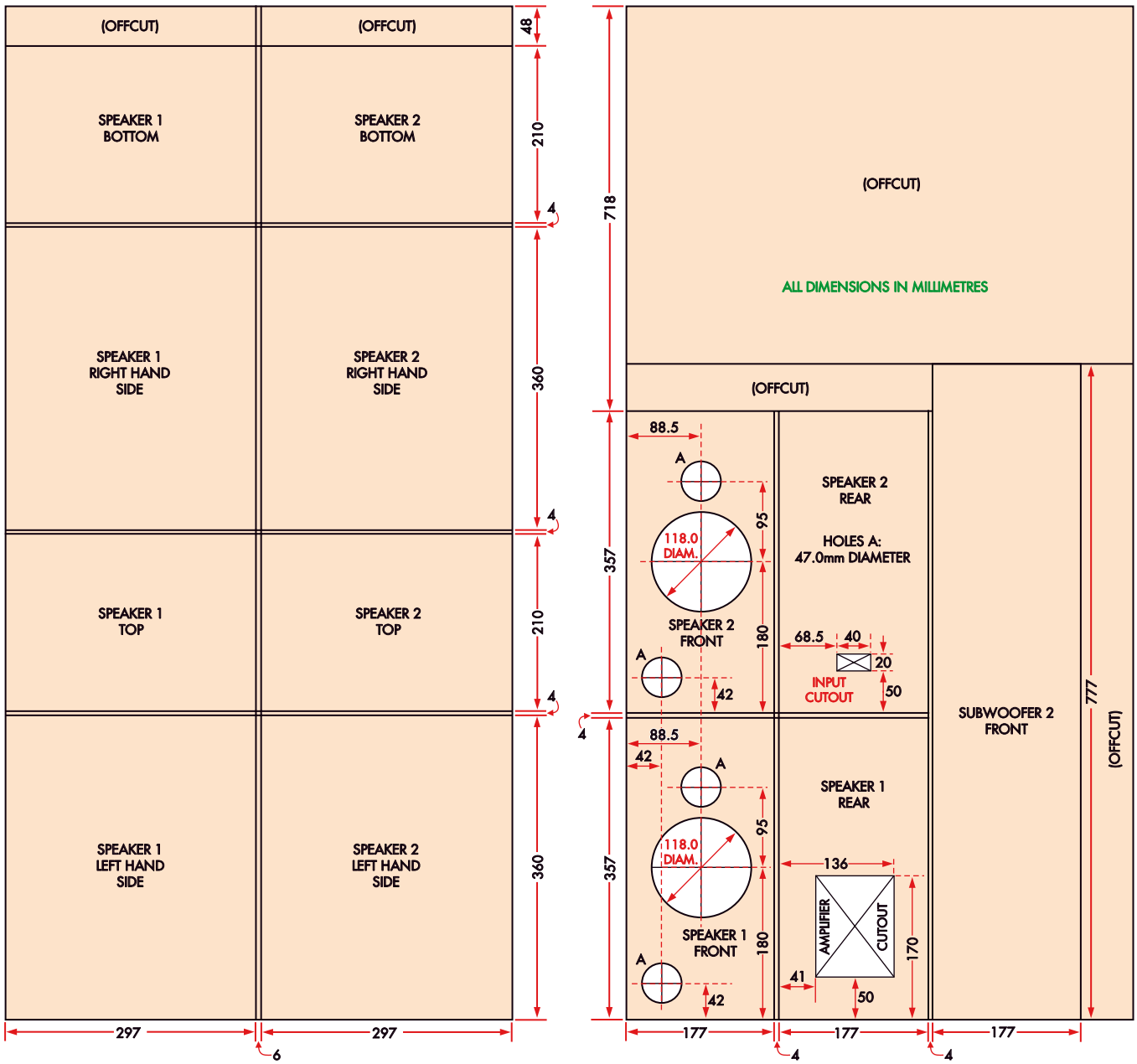


Fig.13: here's how to cut two 600 x 1200mm sheets of 15mm ply into the pieces you'll need to build two monitor speakers, plus one piece for the optional subwoofers. The dimensions have been chosen to minimise waste; depending on the width of your saw, you may be able to simply cut the left-hand sheet in half down the middle. The holes for the driver, port and terminals are best made once the boxes have been assembled.

Cut bracing as shown and use glue and 3-4 screws to attach these braces to the side panels. (Subwoofer panel shown here.)

the front panel is thick.

This is best achieved by holding a piece of off-cut material next to the bracing while you attach it.

At the top and bottom edges, screw the bracing very slightly inside from the top and bottom edges, so that when the top and bottom panels are screwed on, the bracing pulls the top/bottom panel in tight to the side panel. This will minimise gaps on the side.

Bottom panels

Drill and screw the bottom panel to the sides, with screws going in through the bottom from the outside. If you plan to mount the speakers such that the bottom panel is visible, you will probably want to screw the bottom panel from the inside instead.

If you are fixing from the inside of the box, drill holes in the bracing for the screws to pass through. Make sure to angle these holes so your screwdriver (drill) fits properly and the screwdriver bit engages the screw properly. If you pre-drill these perfectly vertically, it will be very difficult to screw the top/bottom on.

Top panels

Get the top accurately aligned with the sides, and fix the screw at the rear of the box.

Then check the alignment of the panels. If there has been movement during assembly, now is the time to fix it!

Do not be scared to drill a new hole in the bracing, allowing a new screw to be used, then remove the first screw and use the second hole to try again. Nobody will ever see a second fixing hole on the inside of the box, but they will see a crooked panel.

Once the rear of the top panel is properly aligned and tight, fix the front and middle of the panel.

Front panels

Before you fix the front panel, you really need to have a plan for how you will be finishing the boxes. I stained the boxes, so I was able to simply mount the front panel. This can be screwed and glued at this stage. Again, do this from the inside of the box. Acrylic filler is an excellent glue once it hardens. I used this to glue the front on.

Remember that the glue will form the primary bond, and the screws are there to hold things secure until the glue sets.

Before you do the screws up, get a T-square and check the box is square. Murphy's law says that it will be crooked. There are several ways to pull the box square before you screw it together. One option is to use ratchet straps, but I will describe a cunning alternative.

Put large screws in the gap between the side panels and front panel. Screw

Various stages in the construction process. The photo at left shows the internal sealing as the box is built to ensure it is airtight. It's also important to maintain panel alignment and "squareness" (as shown in the middle photo); the photo at right shows screws being used to ensure the gap remains constant all around.

Using a clamp while the glue sets will ensure that your square corners remain just that – square.

these in far enough to get even gaps on each side and top/bottom.

Provided your front panel is square – which we feel is a reasonable assumption – the overall box will necessarily be square now.

Once it is nice and square, fit the final screws and allow the glue to dry for a few hours.

Rear panels

I suggest painting the inside of the mounting lip with black paint. Do not screw this on until everything is done. If you think you might want to take it off again, put foam sealer strip on the inside lip. This will give you a good chance of getting back inside the box.

We got ahead of ourselves and glued the rear panel on too early. Working through a tiny woofer hole is tedious!

Adding a brace

Use an off-cut to make a brace that goes horizontally across the speaker. Place this in about the middle of the side panels, and use acrylic filler to glue it in place. Fear not, once the acrylic sets the brace will be more than strong enough to dampen resonance in these panels.

Cutting the holes

Once the carcasses of the boxes are done, it is time to cut the holes. Refer to the photo opposite.

On the rear panel, you will have a large hole on one speaker for the plate amplifier, and a small one for the speaker terminals. Cut all holes before finishing the speakers. The cutout dimensions and locations are presented on the cut sheet drawings (Fig.13). Finishing the speakers is really a matter of taste and your selection of materials.

The port

The port is made from a 10.5cm length of 40mm PVC pipe. This has an internal diameter of about 38mm. Its length is moderately important, so get this within ±3mm.

While you can still get inside the box, use your finger to put a fillet of acrylic filler around the inside of the port once it is inserted through the front panel. If you cut the hole for the port a touch too large, use the filler to secure it, and allow the filler to set.

Finishing the boxes

You will note that we routed that end grain of the plywood at 45°. This makes a feature of the fact that there is an end-grain there. The first time I did this was during an experiment to see if it affected edge diffraction on the front panel. I was much less convinced about the effect on diffraction compared to the aesthetic impact of the routing.

This was done using a low-cost router and 45° bit with edge bearing. I did the route in two cuts, the first about half the final depth.

Staining/varnishing

To stain and varnish the enclosures, sand, sand and sand some more. Always sand along the grain. If you go across the grain, the sandpaper will tear the fibres in the wood, and varnishing/staining will highlight this is a way that I am sure you will hate. As strange as it sounds, this means that orbital sanders are really of limited use.

120 grit sandpaper is your friend. Use it liberally and discard it as soon as it gets clogged. After that, two coats of varnish are generally sufficient. Ideally, you should sand the box with 240 grit (or 400 grit) sandpaper after the first coat of varnish, then clean the dust off. Sand enough that you have a beautiful, smooth finish. The next coat then goes on smoothly, giving you a mirror-like finish.

Now wire the woofer and tweeter with hookup wire of at least 1mm copper diameter. You don't need to go crazy here; just don't use tiny wire.

When mounting the woofer and tweeter, put a run of foam tape around the edge of the mounting hole to form a nice seal between the driver and front panel. Don't use acrylic or silicone filler. I have seen this done and it makes the speakers impossible to repair!

Screw these on using 15mm wood screws. I find it much easier to drill pilot holes using a 1.5-2mm drill. This makes alignment a cinch, and reduces the chance of things slipping as you start screwing the drivers in.

To mount the crossover in each box, first cut a pair of red/black heavy duty wires (or a figure-8 cable) long enough so that it will reach from the crossover input terminals inside the enclosure, out through the hole at the rear, with around 10cm of spare length outside the box.

Strip the wires at both ends, and at-

The finished enclosure, sanded and ready to be lacquered or painted.

Cutting the holes with a jigsaw might not result in the most aesthetic of jobs but the edges are covered by the speaker surrounds, so it's not vital they are works of art!

tach each pair to the passive crossover input terminals.

It's also easiest to attach the wires which go to the woofer and tweeter at this point, making sure they're long enough to exit the front of the box so that you can attach them to the driver terminals before installation.

Now, stick foam to the underside of the crossover PCBs and screw them to the bottom panel of the enclosures, using 10-12mm screws. Wire up the woofer and tweeter as marked on the PCB.

The inside of the speaker needs to have a layer of poly wadding stapled to it as shown. Staple this in place. If you don't have a staple gun, just use 40mm nails and drive them in 10mm, then bend them over to hold the wadding in place. Wadding is available in craft shops such as Lincraft. Get the thick stuff and be reasonably liberal with it.

Now screw in the drivers, being careful not to slip and put the screwdriver through the cone. Philips head screws help keep things under control, but the main point is: don't slip!

Building the monitor 'plate' amplifier

Start by doing the metalwork. Cut and drill the 1.5mm aluminium sheet, as shown in Fig.14.

You can download this diagram as a PDF from the SILICON CHIP website, print it out, cut it to size and stick it to the sheet. Or you can stick pieces of masking tape on the aluminium, make the measurements shown and mark the hole locations on the tape before drilling them.

Centre-punch the holes before drilling. If you don't have a centre punch, use a large nail and a hammer. The centre punching will assist in getting the holes exactly where you want them. Then drill pilot holes of 1-2mm. These will guide the final drill holes. When finished, deburr all the holes with a countersinking tool or an oversized drill bit.

The mounting holes need to be drilled large enough to accept the screws you will use to fix the amplifier to the speakers. We suggest that 4mm is a good start.

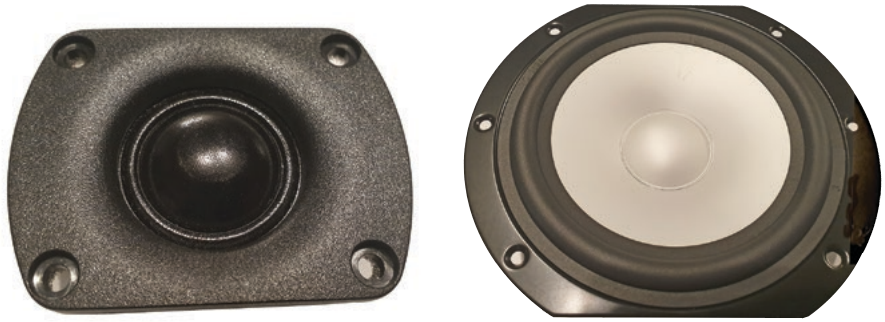
The four holes to mount the amplifier module (marked A) may need to be enlarged to 3.5 or 4mm to accept 3mm machine screws. The fifth hole marked "A" is for the locking pin on the volume potentiometer.

If you don't have a 10mm drill, drill holes "D" to the largest size you have and then use a tapered reamer or file to enlarge the holes. Or even better, purchase a stepped drill bit, which makes drilling larger holes in aluminium a breeze.

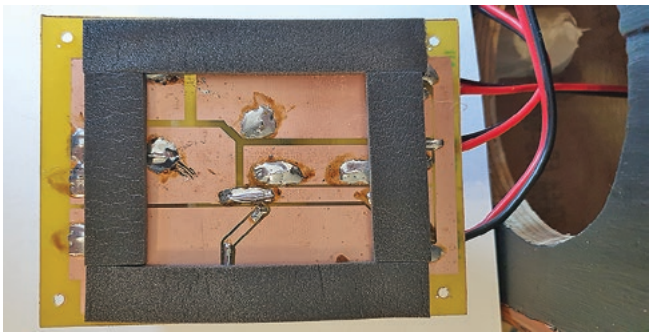
Remember that this plate mounts on the outside of the speaker box, so be careful to finish it well, and preferably paint the aluminium to protect it.

While you're at it, now is also a good time to cut and drill the small aluminium plate which will be attached to the rear of the second (pas-

The woodwork side – including a clear coat of woodstain – is now complete. All that remains is to build the amplifiers and crossovers, fit the speaker drivers and . . . relax!



The two Altronics speakers selected for this project: at left is the C-3019 tweeter while at right (obviously not to scale!) is the C-3038 midrange.



The foam glued to the back of the crossover PCBs prevents them rattling when they are secured to the enclosures.

sive) monitor speaker. The details are shown in Fig.15.

If you're going to paint the metal plates (black is a good choice), now is the time to do it.

This is not absolutely necessary if you're planning on attaching a full-panel label, an option which is described below, although it may still be a good idea, to prevent corrosion.

Preparing the TDA7398 amplifier module

Before mounting the amplifier, check the mounting of the heatsink to the amplifier IC.

This shows how the acoustic wadding is installed in the speaker enclosures. These are actually the subwoofer boxes, which we will look at next month, but the principle is the same.

During the survey of amplifiers we undertook (we bought many samples before settling on this unit), we noticed that the heatsink mounting was a bit of a weak point. In fact, some of the heatsinks were mounted with no thermal paste at all, and some were quite loose!

To check this, remove the two screws that hold the heatsink to the PCB. These are on the back. Take the heatsink off and if it has heatsink paste on it, wipe it clean with a tissue. If not, thank goodness we checked!

Now put on some fresh heatsink paste, then add a 3mm shake-proof washer to each of the mounting screws if they were not fitted.

Our boards came without these, and we are pretty sure that after a few years inside a speaker box, the heatsink would come loose otherwise.

When you replace the screws, do not over-tighten them. These put pressure on the amplifier IC is by pulling the heatsink down onto it and flexing the PCB a little.

This works, as is evidenced by the

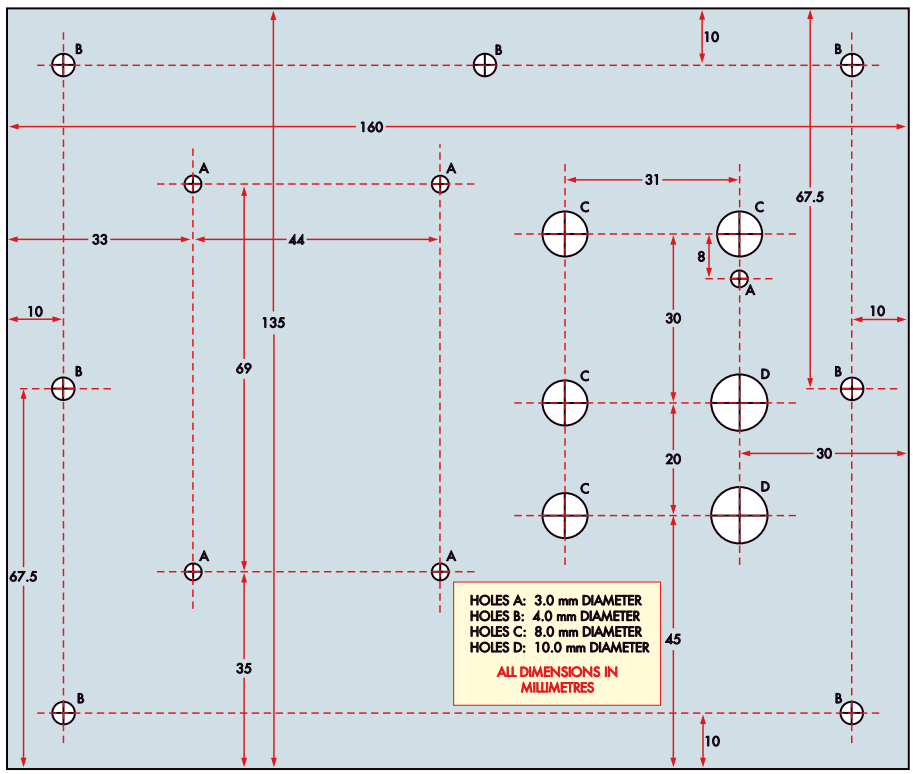


Fig.14: the monitor amplifier, terminals and volume control mount on this 1.5mm-thick aluminium plate. Once you've cut it to size, mark out and centre-punch the hole positions and drill pilot holes, then enlarge them to the sizes shown and deburr.

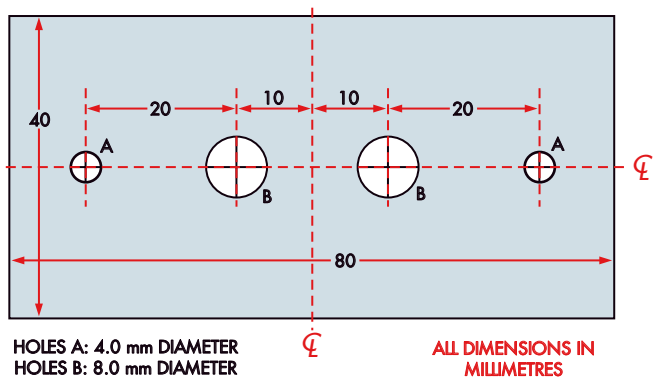
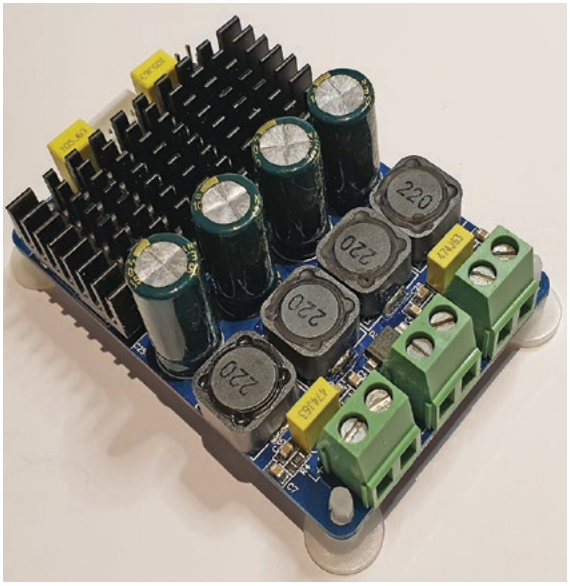


Fig.15: this small plate, also made from 1.5mm-thick aluminium, holds the pair of binding posts used to connect the passive monitor (or subwoofer) speaker back to the active one, which contains a stereo amplifier.



A close-up of the TDA7498 80W/Channel Class-D stereo amplifier which we purchased on ebay for less than $20 – including postage! You couldn't hope to build one for anything like the price. Add a 24V DC power supply and it's ready to rock'n'roll (or classics, or swing, or orchestral . . .)!

way many computer CPU heatsinks are mounted, but this is a small chip, so we have to be careful with it.

So once the first screw 'grabs', do it up an extra turn. Then do the same with the other. Repeat this until you feel the heatsink pressing against the amplifier IC.

Add half a turn or so until you feel it is nice and firm and you sense the PCB taking up the strain. Let the PCB flex a bit; this is forming a spring that will hold the heatsink tight to the amplifier.

After everything is together, it's a good idea to add some red paint or nail polish over the screw heads to lock them tight and prevent them from unravelling due to vibration.

Fitting the parts to the plate

Now the amplifier is ready to be mounted to the base plate. But first, you should think about how you are going to label the rear plate.

In our case, we dug through the bottom draw in the kitchen and found a labelling machine.

This did a fine job of making labels for the back panel of the amplifier. These labels come in really handy in a few months when you have forgotten which plug does what!

If you're going to stick on labels, you can do that later. But as another option, we've prepared label artwork which can be downloaded as a PDF from the SILICON CHIP website and printed onto overhead transparency film (mirrored, so the ink goes on the inside) or a sticky label, fixed to the outside of the rear panel, if you prefer that approach.

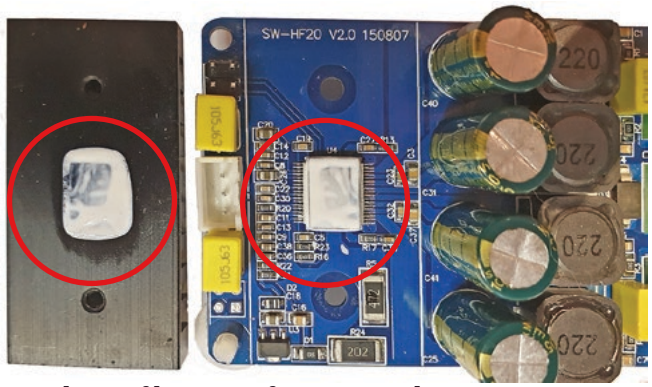
If you're going to attach a full-panel label, you will need to do that before you fit the other components. Once you've stuck it on, cut out the holes for the various components with a sharp knife, and you are ready to continue construction.

Now fit the amplifier, input terminals, output terminal for the second speaker and power connector to the plate.

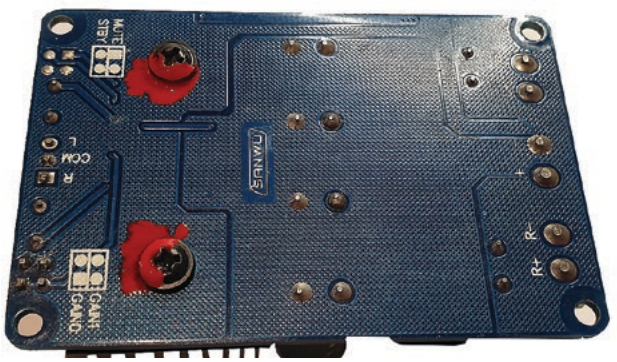
The component mounting positions and wiring information is shown in Fig.16 and the photo below it.

Start by attaching the input, output and power terminals, and the volume pot, then wire them up as shown. Make sure that the speaker terminal wire entries will be facing up once the plate amplifier is mounted. If you don't check this, you might kick yourself later!

Tighten the DC socket nut carefully, as the thread is aluminium. Make this tight, but be careful not to overdo it. When mounting the volume control pot, do its nut up tight.



Use plenty of heat transfer compound on both the rear of the heatsink and the amplifier IC . . .



. . . and some form of locking compound (nail polish works well) to ensure the screws do not loosen over time.

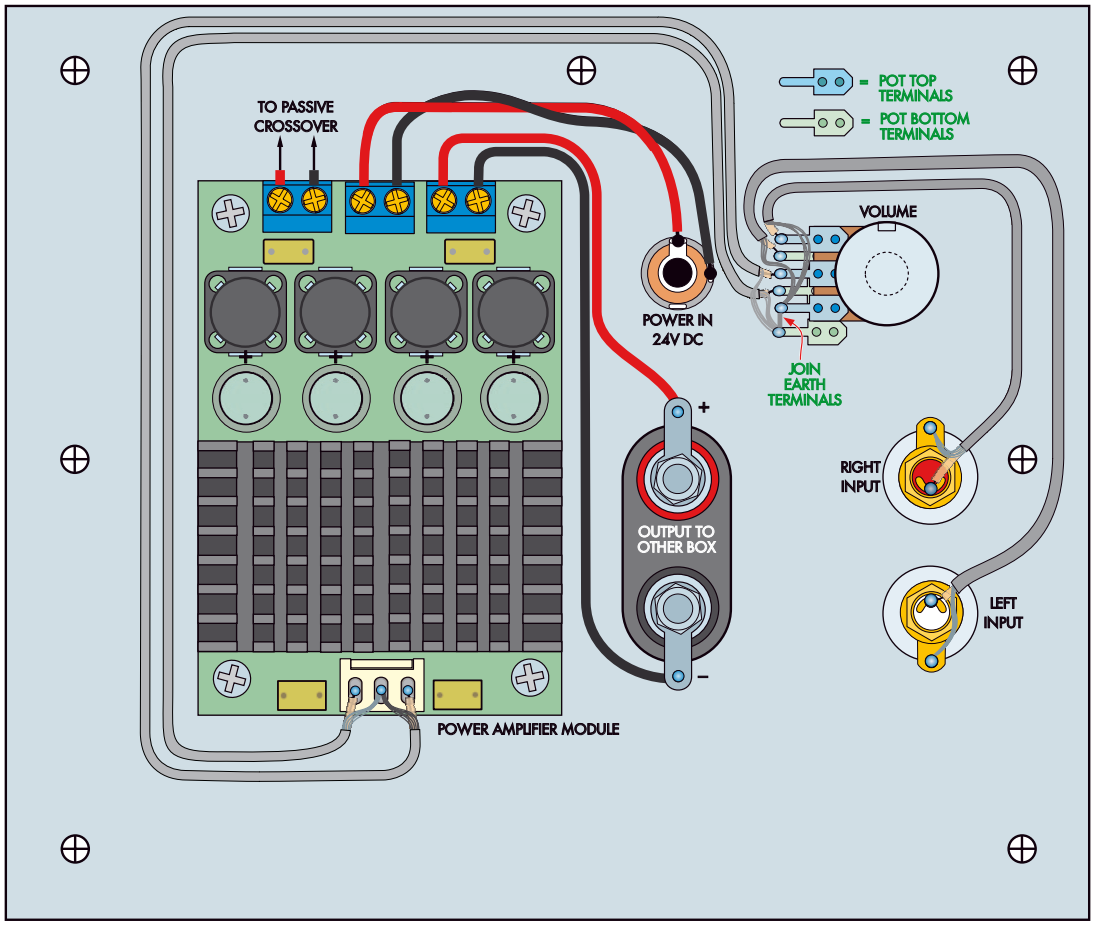


Fig.16: once the amplifier plate is ready, attach and wire up the components as shown here. The RCA input grounds and amplifier module input ground are all wired to the anti-clockwise end of the dual-gang potentiometer. The RCA input socket centre pins go to the separate clockwise end track terminals of the pot, while the amplifier inputs come from the corresponding pot wipers.

If you drilled through the panel for the locking pin, seal the hole using a dab of neutral cure silicone on the inside. If you don't have any, use some of the acrylic filler you used when building the boxes.

The input RCA connectors specified are through-panel units with integral insulation bushings. When appropriately mounted, the bushing sits inside the 8mm hole, insulating the RCA socket from the panel.

The amplifier module is mounted on the inside of the rear panel on 10-25mm long threaded standoffs with machine screws and shakeproof washers.

Use shielded wire for the input and volume wires and reasonably heavy-duty hookup or figure-8 wire for the power and output wiring.

The amplifier inputs are via a 3-way, 3.96mm pitch polarised header. You will need to strip one end of the stereo shielded wire back and crimp and/or solder the two inner conductors and the outer shield into the pins for this plug, as shown in Fig.16.

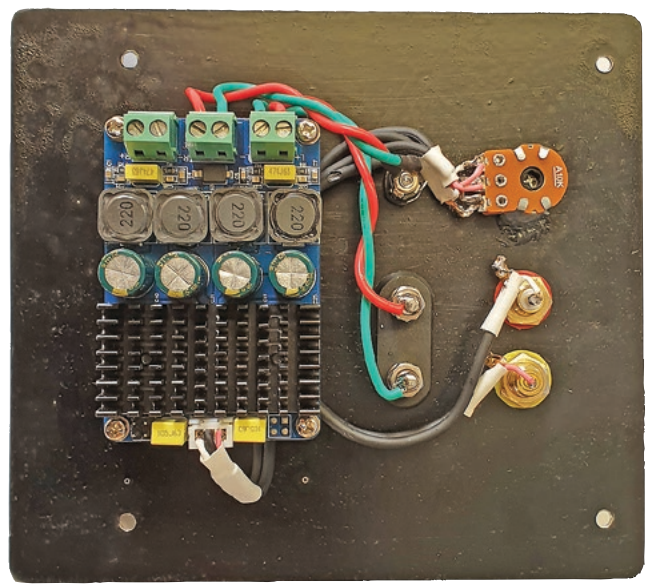
You can use two separate, single-core shielded wires, or a single twin-core shielded wire. The latter makes construction a bit easier.

Note that the pins for this plug have two crimp sections, one to contact the bare copper wire and one to hold the plastic insulation. Make sure both are crimped securely. You should ideally use a tool designed specifically to do this, but in a pinch (no pun intended), you can use a pair of needle-nosed pliers.

We find it best to add a little bit of solder to the end of the copper wires once each pin has been crimped, to hold it all secure.

Once all three pins are ready, push them into the socket, making sure the ground pin is in the middle. If the pins won't click into place, you may not have crimped the wire insulation hard enough.

When soldering the wires to the speaker terminals and DC socket, you will find it a lot easier if you add a bit



Here is the final amplifier plate, ready to install in one of the enclosures (it is a stereo amp so only one is required). Cables connect from the output terminals to the other enclosure. This photo compares with the diagram above (Fig.16).

The opposite (external) view of the amplifier plate seen on P91. This is screwed into the cutout on the appropriate enclosure (see below). While the volume control can be adjusted at will, it's probably not going to be real convenient. We would imagine this control being "set and forget" to an acceptable level and the volume adjusted from the source.

of flux to the terminals first. Once finished, use heatshrink tubing to make sure nothing can short together later.

The vast majority of 'brick' type power supplies use a 2.5mm ID barrel plug, with negative on the outside and positive on the inner — Fig.16 shows the wiring for this case.

Check your supply; in the unlikely case it is a 'tip-negative' type, swap the locations of the wires for the DC socket.

You should have a complete monitor amplifier, ready to install in your desktop monitor, or any other speaker that you want to make "active".

Finishing the speaker assembly

There isn't much left to do here. If you've attached wires to the input terminals of the passive crossovers as recommended earlier, you just need to connect these to the free terminal block on the amplifier board in the active speaker, or attach them to the tabs on the inside of the binding posts in the passive speaker.

Now would be a good time to wind the volume all the way down, plug in the power supply, connect a signal source and check that it all works.

Assuming it does, screw the rear panels onto both enclosures, and you are ready to rock and roll! It's a good idea to apply the same foam tape around the edges as you did with the drivers so that it forms a good seal.

By the way, while we feel that the bass/mid/treble balance of these speakers is spot-on, should you feel that they are a bit 'dull', it is possible to slightly change the passive crossovers to increase the treble by about 2dB.

To do this, remove the 12Ω resistors and change the 5.6Ω resistors to 4.7Ω. However, this may also lead to increased distortion as the tweeters will then be much less damped.

We suggest you give the speakers a good listen first and make sure that you really want to make this change before going ahead. However, you can easily change it back if you try this change and are not happy with the result. SC

Front and rear of the finished speakers. The rear shot is of the speaker which contains the inbuilt audio amplifier.

NEXT MONTH:
We'll finish off this project with the description of the optional subwoofers. Of course, being optional, you can use the speakers as described so far. It's up to you . . . but the subwoofers really bring out their best!