HIGH-END

PART 1: BY PHIL PROSSER

ACTIVE MONITOR SPEAKERS

WITH SUBWOOFER

This hifi system takes a 'no compromise' approach to build a truly superlative sound system that will be at home in a modern living room. We are utilising high-end components that are readily available while avoiding falling into the abyss of overly expensive, gold-plated parts. The parts used are not cheap but this system will still be within reach for many people.

This new high-end hifi system will be presented in three parts. This first part details the design and construction of the relatively compact main (left & right) speakers that provide excellent sound quality without being overly obtrusive.

Because these are active speakers, they need an amplification solution that integrates an electronic crossover, which will be the focus of the second article. The electronics are housed in an attractive two rack unit (2RU) black rack-mount case, including all the amplification, signal conditioning and power supply circuitry.

The third article will present a very high-quality Active Subwoofer to round out the system. It is ideal to combine with the speakers presented here, giving a full-range sound system. However, nothing locks the subwoofer into use with these particular speakers; it would be a fine addition to almost any sound system.

While you could build these speakers without the sub, I reckon almost anyone going to the trouble of building these will want to extend the bass all the way down to 20Hz.

So basically, all three parts are intended to be combined into one excellent sound system. Still, I have taken a modular approach, allowing you to choose which parts to build.

I was a bit cheeky in the intro when I said there were no compromises. There are always compromises – in this case, one of them is that the system is a little on the expensive side.

While most of our recent loudspeaker systems have aimed to be 'good value' systems with excellent sound quality, this one erred more on the side of ultimate fidelity without worrying too much about the bottom line.

Still, we aren't talking sheep stations. The four drivers for the Active Monitor speakers total just under $1000, while the subwoofer driver is another $339. Add in all the other bits and pieces and you can probably build the speakers for a little over $1500.

Factor in the electronics, and you're looking at perhaps a little over $2000; that's far from outrageous for a high-end speaker and amplifier system.

Another compromise we often make in our loudspeaker systems is to prefer larger enclosures. That helps us achieve excellent sound quality at a reasonable price. But for this system, I decided that many people these days do not want huge loudspeakers in their living spaces.

So I have tried to keep with the modern principle of keeping the speakers as small as possible without ruining the sound quality. That is part of the reason they are a bit more expensive. It does have the significant advantage that they are far less likely to be vetoed by any people who might have the power to say "no"!

Photos 1 & 2: the SB Acoustics tweeter (left) and mid-bass woofer (right) used in the Active Monitor speakers. They are quality units with a broad range of frequencies at which they can both operate, giving us many choices for the crossover frequency and slope.
Note that these photos are not to scale.

Features & Specifications

- Modestly-sized bi-amplified monitor speakers plus a subwoofer
- Frequency response: 25Hz-20kHz, ±3dB (20Hz-20kHz, +3,-12dB; see Fig.8 and the following article on the Active Subwoofer)
- Distortion: <1%, 20Hz-10kHz (typically <0.3% for normal levels; see Fig.9)
- Over 400W total power (2×50W tweeters + 2×50W woofers + 1×200W subwoofer)
- Active crossover @ 2.7kHz (woofer/tweeter) & 90Hz (subwoofer/woofer)
- High-end Satori drivers used throughout
- Good time alignment between woofers and tweeters
- Excellent off-axis response

Driver lineup

For this system, I have chosen drivers from the SB Acoustics Satori series, their premium product line. The 'Active Monitor' speakers utilise:

Satori MW16P-8 bass mid-range: a 165mm (6.5in) driver utilising papyrus fibres in the cone with a rubber surround and a copper sleeve on the pole piece. That sleeve helps to reduce inductance change with cone position and reduces flux modulation and distortion. In this design, it operates down to 90Hz in the active implementation and ~40Hz without the subwoofer.

Satori TW29R-B tweeter: a 29mm ring radiator with a frequency response within ±2dB over 1-20kHz. It has a low resonant frequency of 600Hz and a very well-behaved impedance. Distortion over the frequency range of interest is very low indeed.

Does that sound good? Wait a moment; a whole octave is missing from this equation, but it is delivered by the active subwoofer using the SB34SWNRX-S75-6. It is a 12-inch driver, although it is actually 346mm in diameter, with a 3in (75mm) voice coil, one of the real measures of continuous power handling of a driver.

It has a resonant frequency of 19Hz and a 22mm peak-to-peak linear cone excursion. In an 80-litre enclosure tuned to 25Hz, this driver will deliver solid bass to 25Hz (-3dB) and operate in its linear region right down to 20Hz at up to 200W.

The parts combine to form a stereo system of the highest quality. Both my measurements and listening tests reflect that.

The electronic configuration of this system is shown in Fig.1. Once built, you just need to plug it into your preamp and away you go.

Let's now turn our attention to the Active Monitor speakers that are the subject of this article. They are a 'pigeon pair' with the Active Crossover Amplifier that will be presented next month. Being active speakers, we dispense with the cost and complexity of passive crossover components. We also benefit from an amplifier directly driving each driver and the control that provides.

If you use the Active Monitor speakers without the intended subwoofer, you can achieve a low-frequency cutoff

The finished speakers shown with subwoofer and Philips CD player. The speakers can be mounted on top of 800mm tall stands, as shown here, bringing them to about ear height when seated (see the parts list).

Projects used in a stereo Active Monitor Speaker system

4 x Hummingbird Amplifier – *December 2021; siliconchip.au/Article/15126*
3-Way Active Crossover – *October-November 2021; siliconchip.au/Series/371*
Multi-Channel Speaker Protector (4-CH) – *January 2022; siliconchip.au/Article/15171*
Power Supply – *to be described next month*

Projects used in the Optional Subwoofer

Ultra-LD Amplifier Mk3 Amplifier – *March-May 2012; siliconchip.au/Series/27*
OR **Ultra-LD Amplifier Mk4** – *August-October 2015; siliconchip.au/Series/289*
Multi-Channel Speaker Protector (4-CH) – *January 2022*
Power Supply – *to be described in two months*

of about 45Hz, but note that you will have to adjust the active crossover for that. 45Hz is OK, but by adding the active subwoofer, you will experience the entire audible spectrum from about 20Hz to 20kHz. Few speakers can deliver that, especially with low distortion.

The drivers are very high-quality units and, as you will see, their performance is outstanding. While their price is not stratospheric, the quality of these components does mean the cost of building this system is relatively high.

The drivers used have excellent frequency responses and are well regarded for their subjective performance. See the panel titled "Subjective vs objective performance" for some insight into how I approached this design.

Working on a speaker system that costs thousands of dollars to build, I feel that I am obliged to bring both a scientific and analytic approach. But I also need to use a somewhat subjective and emotional assessment to tune the final result. Both approaches have a place in this exercise.

Photos 1 & 2 show the two drivers used in the Active Monitor speakers, while Figs.2 & 3 are plots of their individual frequency responses in a sealed box at 1m.

Those figures show that, in terms of simple frequency response, there is a very wide crossover region throughout which both the woofer and tweeter have a flat response and do not exhibit unwanted behaviour such as breaking up, unmanageable resonances, glitches and the likes. From this measure, these drivers are a good match.

The 30° off-axis measurement provided by the factory shows that for a 2-3kHz crossover point, both drivers remain well-matched and provide good off-axis coverage.

Editor's note: a good off-axis response is an essential feature of a hifi loudspeaker unless you only ever listen from a single point in a room!

The 'woofer' actually performs extremely well out to 10kHz looking at amplitude alone, but does show signs of breaking up in the 4.5-5kHz region.

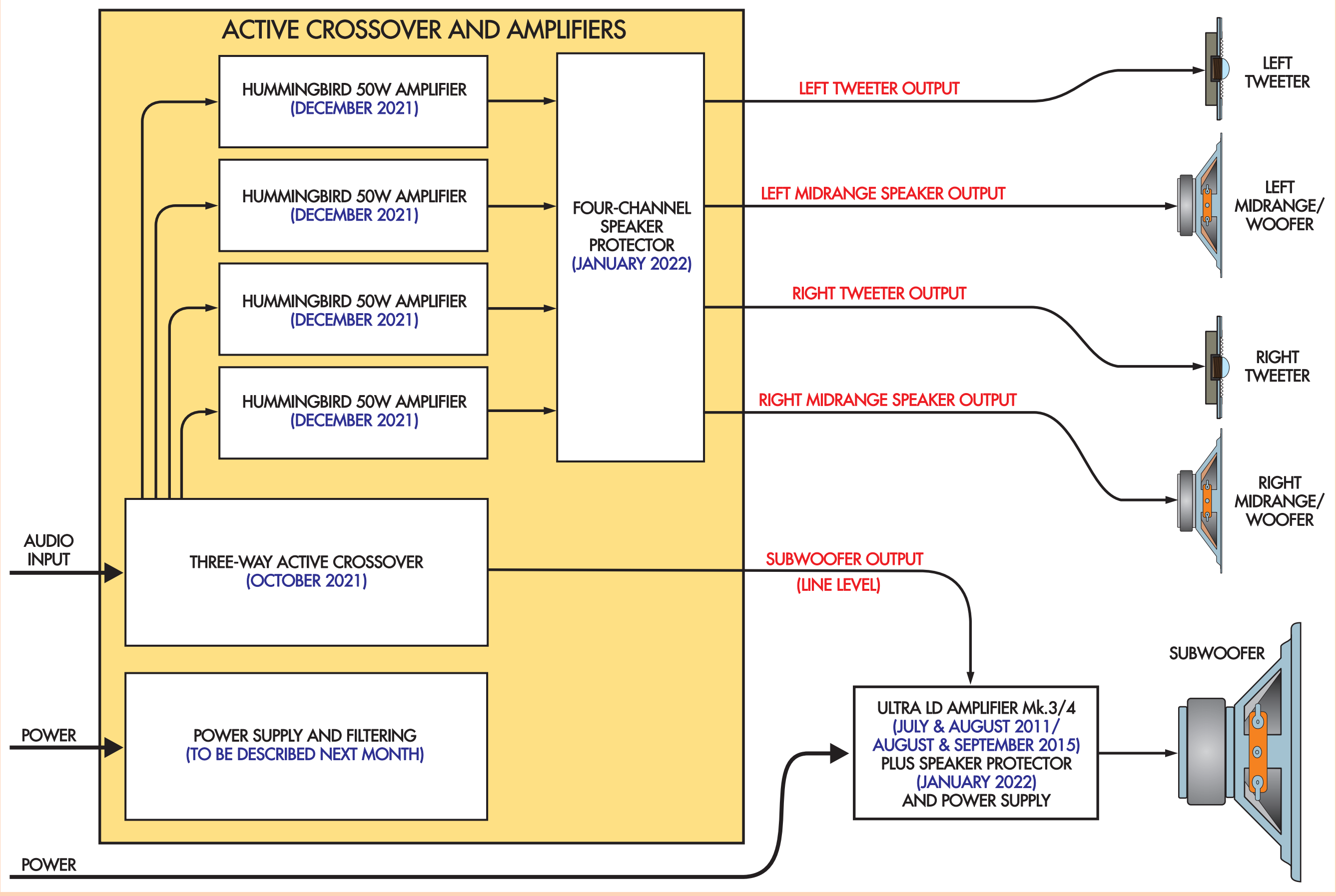


Fig.1: this block diagram shows the configuration of the speaker system. A single rack-mount case houses the power supply, four amplifiers for the Active Monitors, the speaker protector and the active crossover. The line-level subwoofer output drives the active subwoofer, which has an internal power supply and amplifier.

The tweeter response extends well beyond 20kHz. Cone breakup is not evident until above 20kHz, and is well-controlled. So crossing from the woofer to the tweeter in the 2-3kHz region will:

1 - Provide a fairly continuous horizontal coverage from the speaker

2 - Have the potential to have a very flat frequency response

3 - Not excite breakup modes in the woofer

4 - Operate the tweeter several octaves above its resonance (600Hz)

The MW16P-8 woofer

These drivers are a paper cone type with Neodymium magnets and the build quality is excellent. That is evident in the comparison of two drivers shown opposite in Fig.4. Modelling this driver indicates that a 21L enclosure tuned between 29Hz and 35Hz covers Butterworth-Chebyshev alignments. (Butterworth is a response with a ripple-free passband, while Chebyshev allows a little passband ripple for a faster roll-off).

Reducing this volume a touch to 18L and stuffing it well allows us to keep the size of the enclosure under control at the cost of the -3dB point moving up a few hertz, to 44Hz. Given that we are designing the system to have a subwoofer, this is a moot point. This slight reduction in volume means we can keep the depth of the enclosure within reasonable limits.

Driver alignment

The relative placement of the tweeter and woofer is critical to the operation of the speaker, especially through the crossover region. Aside from the obvious function of filtering signals for each driver, the crossover needs to do this in a manner that results in a flat frequency response through the crossover region.

There is a critical interplay between driver placement and the operation of the crossover, shown in Fig.5. The result of this misalignment of the acoustic centre of the tweeter and woofer is a skewing of the beam pattern of the speaker downwards (about 5° in our case) and a null at the crossover frequency about 5° above horizontal.

These effects occur for signal frequencies in the crossover region and result in a dip in the speaker's frequency response. If you are not aware of this, it can make designing a crossover very confusing!

There are a few ways designers tackle this problem. The most direct manner is to increase the output in this crossover region by playing with crossover frequencies and shifting the phase at crossover by pushing the tweeter crossover frequency down.

That approach can work but has the

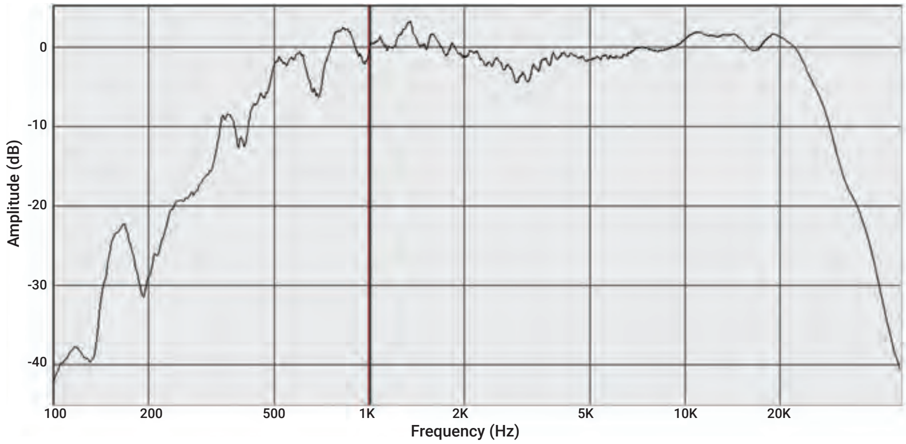


Fig.2: the SB Acoustics tweeter's frequency response, measured 1m away. The top-end roll-off is almost entirely due to filtering on the front end of the ADC used to make these measurements.

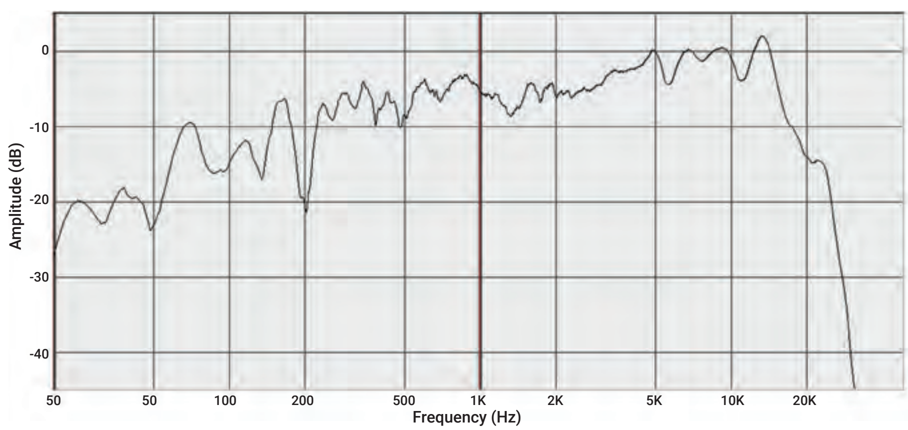


Fig.3: the SB Acoustics mid-bass woofer's frequency response in a sealed box, measured 1m away. The top end above about 5kHz looks good, but there is breakup occurring in this region. The roll-off below about 200Hz is due to the enclosure, while the ripple in the low end is due to room modes. No effort has been made to make the plot pretty or smooth. The response over the 200Hz-3kHz region is excellent.

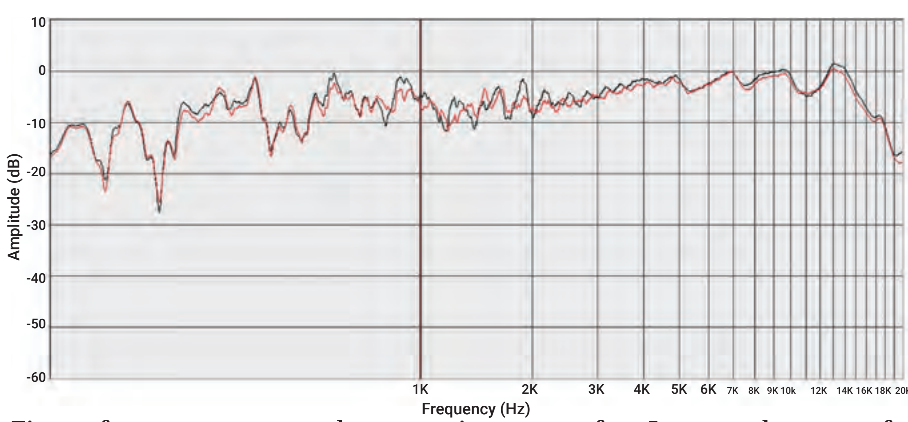


Fig.4: a frequency response plot comparing two woofers. I suspect that some of that difference is me standing a little too close to the measurement system! It is also very pleasing to note that the response is extremely smooth and flat. The ripple visible below about 1kHz is entirely room modes.

effect of putting more energy into the room at off-axis angles.

Editor's note: I reiterate my earlier point that little change in sound quality or frequency response off-axis is very desirable.

Another approach is to offset the drivers. There are several ways to approach this; a famous example is the Duntech speakers from the nineties, which used stepped baffles and acoustic treatment to reduce diffraction from the edges.

My solution is a bit of a mix of the two approaches. If this sounds like I am hedging my bets, I kind of am. I have opted for a gently-sloped baffle that somewhat offsets the tweeter back from the woofer (see Fig.6). I have also recessed the tweeter, which is good for avoiding diffraction around the transition of the tweeter face plate to the front panel.

The woofer is not recessed; I simply applied felt around it to help reduce the visual and acoustic impact of this choice.

It would have otherwise been necessary to slope the front panel back by 8° to get the offset between tweeter and woofer perfect.

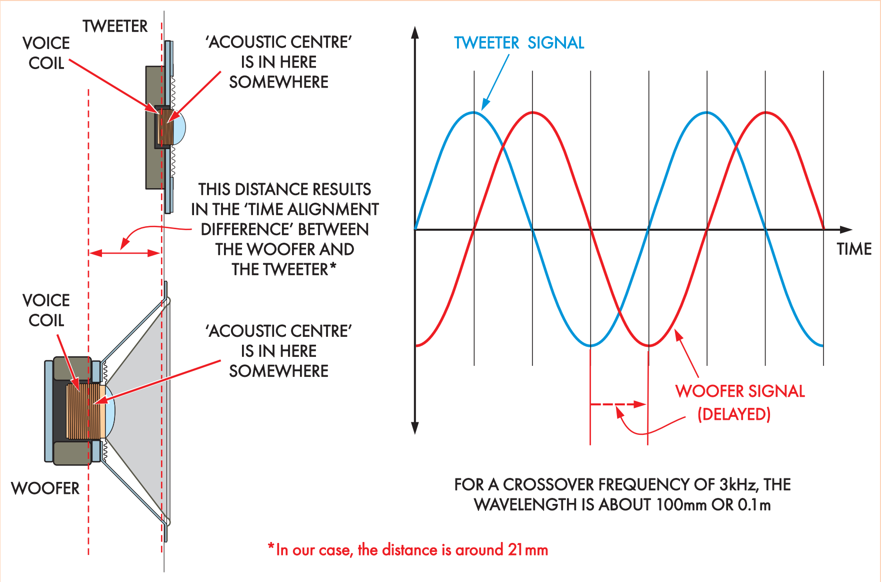


Fig.5: the drivers have different depths, so their 'acoustic centres' are not aligned when installed on a flat panel. Around the crossover frequency, both drivers are producing signals, and the phase shift due to this misalignment causes undesirable reinforcement and cancellation at different locations in the room.

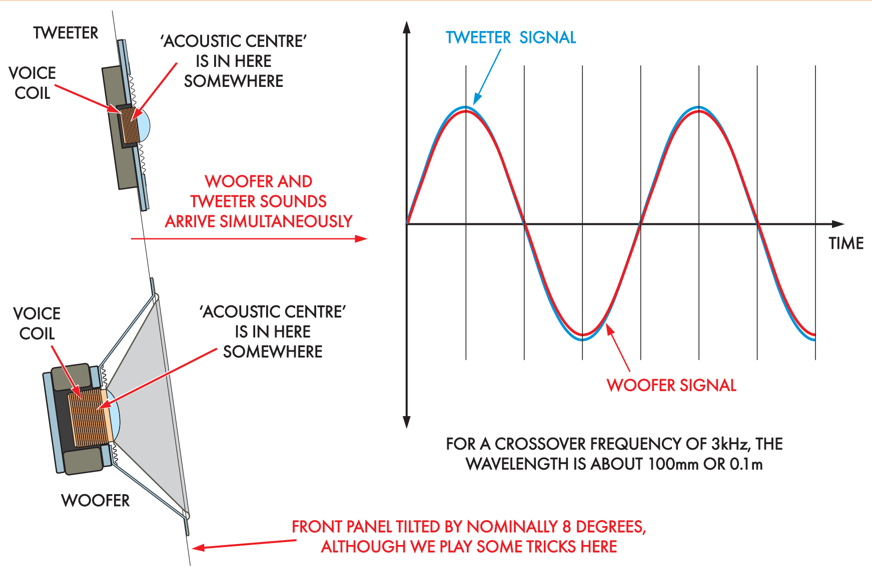


Fig.6: by tilting the front panel and using some other tricks, we bring the 'acoustic centres' into horizontal alignment, so the signals around the crossover frequency coincide, and we avoid constructive and destructive interference.

My tests show that the result is quite good. By recessing the tweeter, we get away with a modest 5° tilt on the front panel while keeping the drivers in time alignment. To my eye, the sloped front makes a pleasing change from a rectangular cube for a speaker. Still, the effect is subtle enough that you won't even spot the front panel tilt in many of the photos.

The crossover

I have set the crossover frequency to 2.7kHz, implemented by an active crossover in the amplifier. I have also implemented 'baffle step correction' in the amplifier. This accounts for the effect of acoustic radiation from the speaker transitioning from omnidirectional at low frequencies to directional at high frequencies.

The transition frequency is a function of the driver and its location on the front panel. The step can be as much as 6dB, but in our case, a boost of 3dB at frequencies below 250Hz works well.

As the speakers are bi-amplified, each driver is powered directly from its own amplifier. However, I have included a large 100μF DC blocking capacitor (Jaycar Cat RY6920) in series with the tweeters as the last line of defence against faults or crossed wiring.

This capacitor has no effect in regular operation but will save your bacon should LF or DC signals somehow make their way to the tweeters.

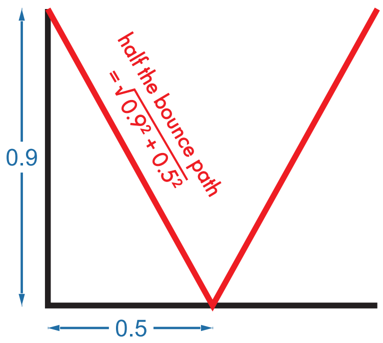
If substituting this part, make sure you use a high-voltage, high-current capacitor; many small 50V-rated bipolar capacitors do not have the ripple current rating for use in loudspeakers.

Performance

Measuring the system's overall frequency response was an exercise to minimise room reflections. The final plot (Fig.7) is a composite showing two measurements, one with the speaker on a stand and measured at 1m, the second plot with the speaker facing upwards. Both plots are smoothed one-third octave to eliminate the usual 'fuzz' you get on these plots.

It might look a bit lumpy, but loudspeaker systems are notoriously difficult to characterise in this way. As speakers go, this is actually remarkably flat when measured indoors, on average from around 25Hz up to 20kHz.

Fig.8 is a frequency plot measurement made outside over grass near the shed. For a stand 80cm tall and 1m from the microphone (with the speaker cone at about 0.9m), the "bounce path" is 2.06m ($2 \times \sqrt{0.9m^2 + 0.5m^2}$). The direct path is 1.0m, the difference being 1.05m. Because it's measured outdoors the -3dB point is shown at 35Hz rather than 25Hz quoted above.



For sound travelling at 343m/s or so, the half wavelength frequency is 163Hz, which is pretty close to the dip in that figure. That shows this is a test setup phenomenon, not the speakers.

Building the Active Monitor speakers

The cabinet material you choose comes down to the finish you want, your skill at woodworking and cost. I recommend you use MDF, plywood or chipboard. All these materials will work fine for the Active Monitor Speakers.

I prefer MDF over ply. MDF is denser and has a reputation as a "deader" material than chipboard. But be warned, it is also heavier and makes an extraordinary amount of dust when cut and routed. Wear a mask while working with it; breathing this dust can be harmful to your health.

My woodworking skill is modest, and in building the prototypes, I have intentionally stuck to tools that most people would have. The tools I recommend using are:

1 – Circular saw

with the cut angle adjustable to 5°

I used a cordless circular saw and it worked great. My old mains-powered unit would also have been fine for the job. A younger or skilled person could possibly make these cuts with a hand saw, but they would be nowhere near as clean or accurate.

2 – Jigsaw

Used for a couple of cuts, especially

Subjective vs objective performance

The engineer in me always thinks, "if you can't measure it, then you can't hear it". Ultimately, this is true. But the question is: what exactly do we need to measure to determine what makes one speaker sound better than another?

I have run tests to see what I can hear compared to what I can measure. I have been surprised at the results, concluding that the 'character' of a speaker comprises not only the gross frequency response but is also influenced by less overt parameters such as the stored energy in the driver, its breakup modes and distortion profile.

The lessons my experience brings to the Active Monitor speakers are:

- We should operate the drivers well within their linear regions
- I took note of trusted reviewers' opinions of the drivers
- I considered the stored energy (waterfall plots) of the drivers
- I sought to match the beam patterns of the drivers via the crossover
- I prefer higher crossover rates where practical
- I stuck to drivers with few breakup modes and definitely avoided exciting them
- After designing the system using proper engineering principles, I still needed to listen to the result and then tune or tweak it until I was happy with the sound
- I shouldn't be afraid to tune a speaker, but I should consider why I am making any given change

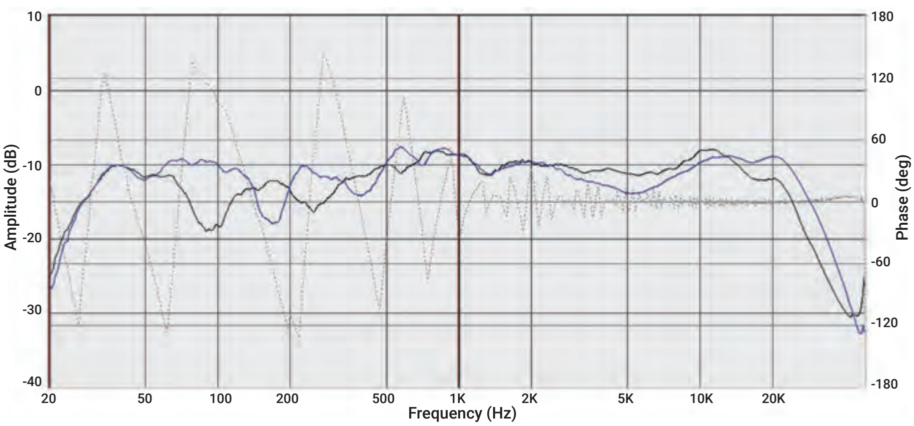


Fig.7: two frequency response plots of the overall system. Depending on where and how the speaker is located, we can move the low-frequency dip around and usually work out what is causing it. The only way to avoid it entirely would be to stick the speaker up a tall ladder, but that's a bit awkward! So it's best to ignore the very bottom of the frequency response as it was taken outdoors.

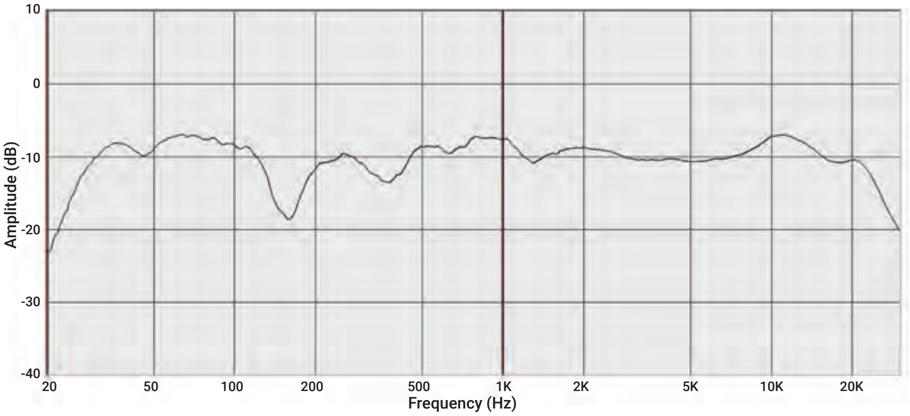


Fig.8: a frequency response measurement of the speaker system in a relatively open grassy area. That dip at 159Hz is because the measurements were taken outside with the sub arbitrarily placed.

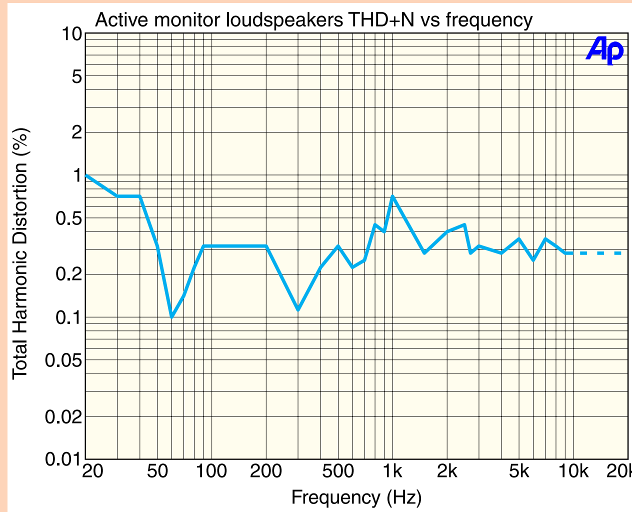


Fig.9: a distortion plot for the overall system. These levels are very low for a loudspeaker system, where 0.5% is considered good. It is excellent between 50Hz and 1kHz, with the distortion generally below 0.33%. The distortion is primarily second harmonic; the third harmonic is very low, which is why these speakers sound so good.

in the braces. You could use a small handsaw instead, but it would be a miserable task.

3 – Cordless drill/screwdriver

You will also need various drill bits and a Philips No.2 driver bit for the screws.

4 – Router and bits plus a circle jig

You will need a 10mm round over bit (or similar size), a 6mm round over bit (or similar size) and a 16mm straight cut bit.

5 – Sash clamps

You'll need at least two; many more if you choose to glue the enclosures only (not glue & screw).

6 – Sanding disc with 120 grit paper

This will be used to smooth the edges before routing. It is possible to do this by hand if your assembly is clean.

7 – 120-400 grit sandpaper and block

Buy lots of 120, 240 and 400 grit sandpaper (you can buy it as 5m rolls). Change paper frequently to reduce the amount of elbow grease required.

8 – Builders' bog

To smooth over gaps.

9 – 100mm roller, short nap

For applying the acrylic primer.

Assembly tips

If possible, attach your vacuum cleaner to your router. If you don't do this, don't say I didn't warn you! It's also important to work in a well-ventilated area to help prevent inhalation of sawdust.

Work out what final finish you are aiming for before you start. This will affect your construction method and planning. I chose to go for a smooth, painted finish. This choice was driven by cost, my existing décor, and to allow me to demonstrate that you can produce a good speaker finish at home with no special tools.

I have laid out the design with rebated joints, allowing you to glue and clamp or glue and screw the enclosure together. It requires some precision in routing, but once your jig has been set up, that is reasonably easy to achieve. If you do not have a router, fear not. Rejig the panel sizes to use butt joints and screw them on the end grain (with pre-drilled holes!).

Fig.10 shows the cuts for a 2400mm x 1200mm sheet of 16mm-thick MDF (or two or three smaller sheets). I could have brought the sheet home in a ute and made all the cuts myself, but instead, I asked the nice people at my local hardware store to cut two vertical strips 188mm wide, two 210mm wide and two 358mm wide. I took the extra as an off-cut.

That lot slid easily into a VW golf hatchback, and everything, including cutting, was $50 – the cuts came free. There aren't many free things in life, so you might as well take what you can get!

Figs.11, 12 & 13 show the details of the various panels that make up the enclosures for the Active Monitor speakers. Cutting the panels from the strips is relatively straightforward; just note that accuracy here will pay dividends in final assembly. Some things to keep in mind are:

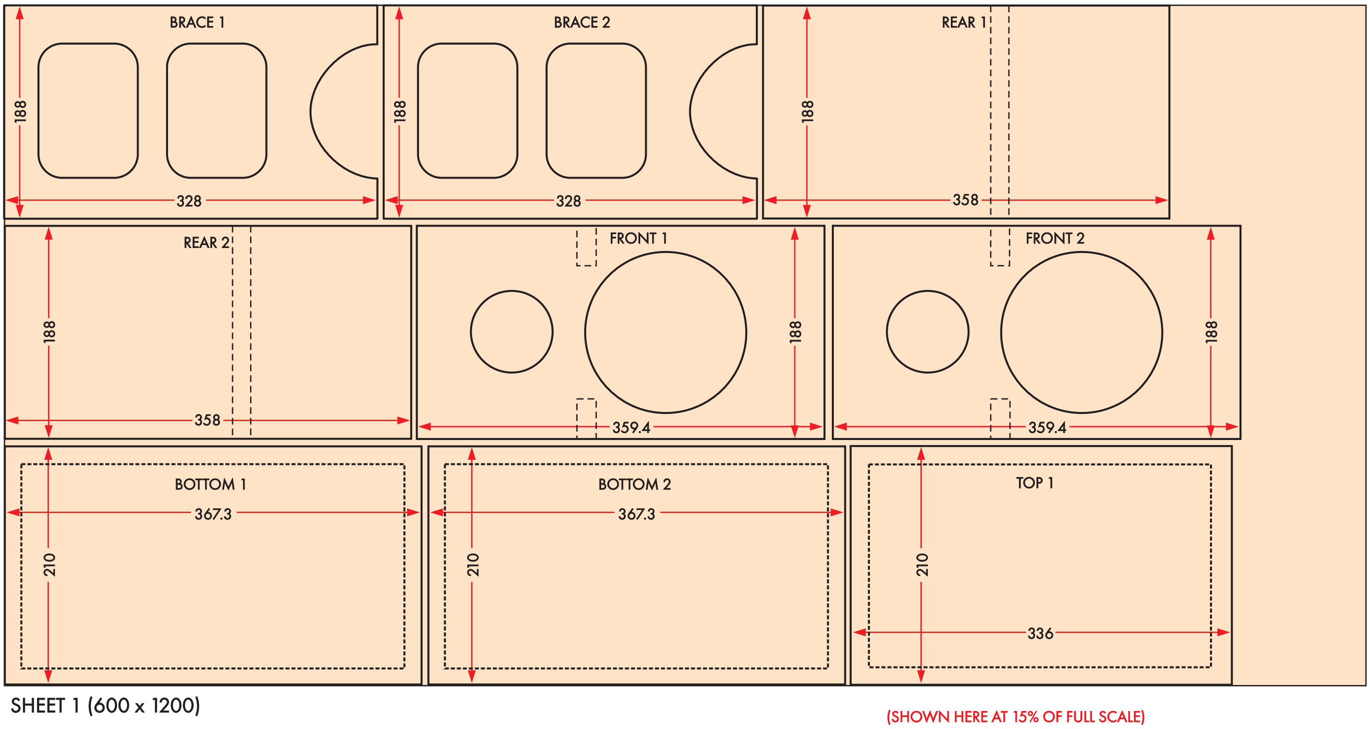
- The front panel and the internal brace are sloped back by 5°. I set my circular saw to an angle of 5° and admit to using some bog to smooth these joins in my assembly.
- All rebates are routed to a depth of 5mm. Do a test cut or two and get this right; do not cut too deep, or your panels will need trimming to fit.
- If you need to trim a panel, plane or use a disc sander – you do not want to lop off large chunks of timber.
- Keep track of your left and right panels as they have the routing on opposite sides!

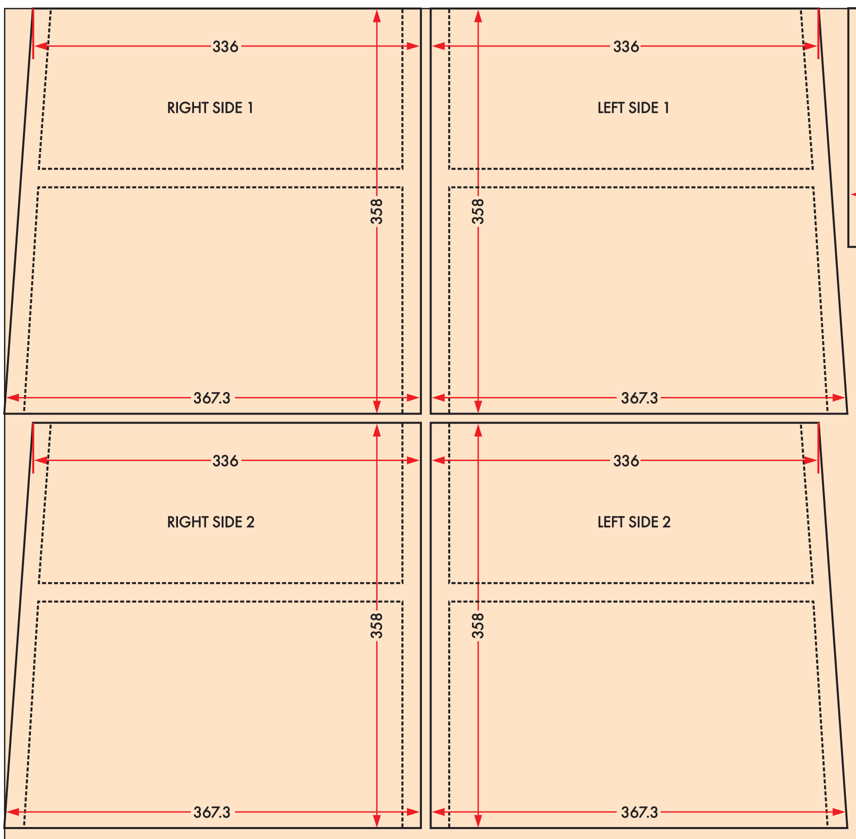
I used an extremely simple jig to allow simple right-angle and 5° cuts and routed lines to be made, as shown in Photo 3.

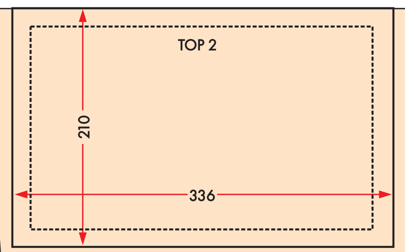
Once you have cut the panels to size, mark and route the rebate for the tweeter, which is 104mm in diameter and 5mm deep. Check that the tweeter fits your circle by routing an off-cut.

Next, cut the tweeter and woofer holes, noting that there are two notches

Photo 3: my simple jig allows quick and repeatable 90° (and angled) cuts and routed lines to be made. This saved hours of fiddling with clamps at the cost of a few timber off-cuts. You can use this with a saw or router but be prepared to throw away your 'alignment edge' every time you change the angle.







Making circular rebates for the tweeters

You need a router circle jig to make neat rebates for the tweeters, as they will be visible. You can buy a circle jig for most brands of routers, but you can also make one.

Get a flat sheet of aluminium about 100mm wide and 250mm long and drill a hole near one end that's larger than your biggest router bit. Measure and drill mounting holes for the router relative to that and countersink them so the screws will not scratch the timber.

Next, drill a series of 3mm holes to provide various radii from the router bit and countersink them from the top.

Attach the jig to a centre hole on your workpiece using a countersunk M3 machine screw with an extra nut between the jig and the workpiece to keep it stable, and voila, you have a circle jig. Just make sure to test it on offcuts to select the ideal hole in the jig before doing the final rebate.

359.4mm = 14 $\frac{5}{32}$ inch   367.3mm = 14 $\frac{29}{64}$ inch

SHEET 2 (800 x 1200)

ALL DIMENSIONS IN MILLIMETRES

Fig.10: here's how to cut the full set of Active Monitor panels from one or two MDF sheets. Smaller sheets could be used, or as described in the text, take advantage of the free cutting service offered by many hardware stores. Cut these as accurately as possible, then route and cut the indicated holes in the panels for the drivers, ports and holes in the brace.

in the tweeter cutout to accommodate the connection terminals. Once the front panel is finished, you can cut the holes in the brace. I marked these and then used a jigsaw. There is nothing terribly special about the dimensions on these cutouts, but you want to leave sufficient material to strengthen the enclosure.

Finally, cut out the speaker terminal hole. Again, a jigsaw is handy but not essential. Also make the cutouts for the input terminals and speaker port on the rear panel.

Now route all the rebates. I recommend setting up a jig as this will save you a lot of time and give you consistent route line locations.

Cabinet assembly

Whether you plan to simply glue and clamp or glue and screw the enclosures, do a dry assembly to check that all the joints are neat and fit correctly. Make any adjustments now, so that everything sits flush.

If you are planning to screw the panels together, be prepared to drill 2.5mm pilot holes for your screws and countersink the heads. If your timberwork is neat and achieves a clean and tight fit together on dry assembly, simply gluing the enclosures together is something you could consider.

Apply a generous layer of glue to both surfaces and use masking tape to hold panels in place if you find yourself looking for an extra hand. Wipe away excess glue as you assemble them, keeping everything relatively clean.

With the rebates and internal brace, which sit horizontally between the front and rear panels, the boxes should fit nicely together. Jiggle the panels into their final places and add sash clamps to hold the lot together while the glue sets. To 'clamp' the top and

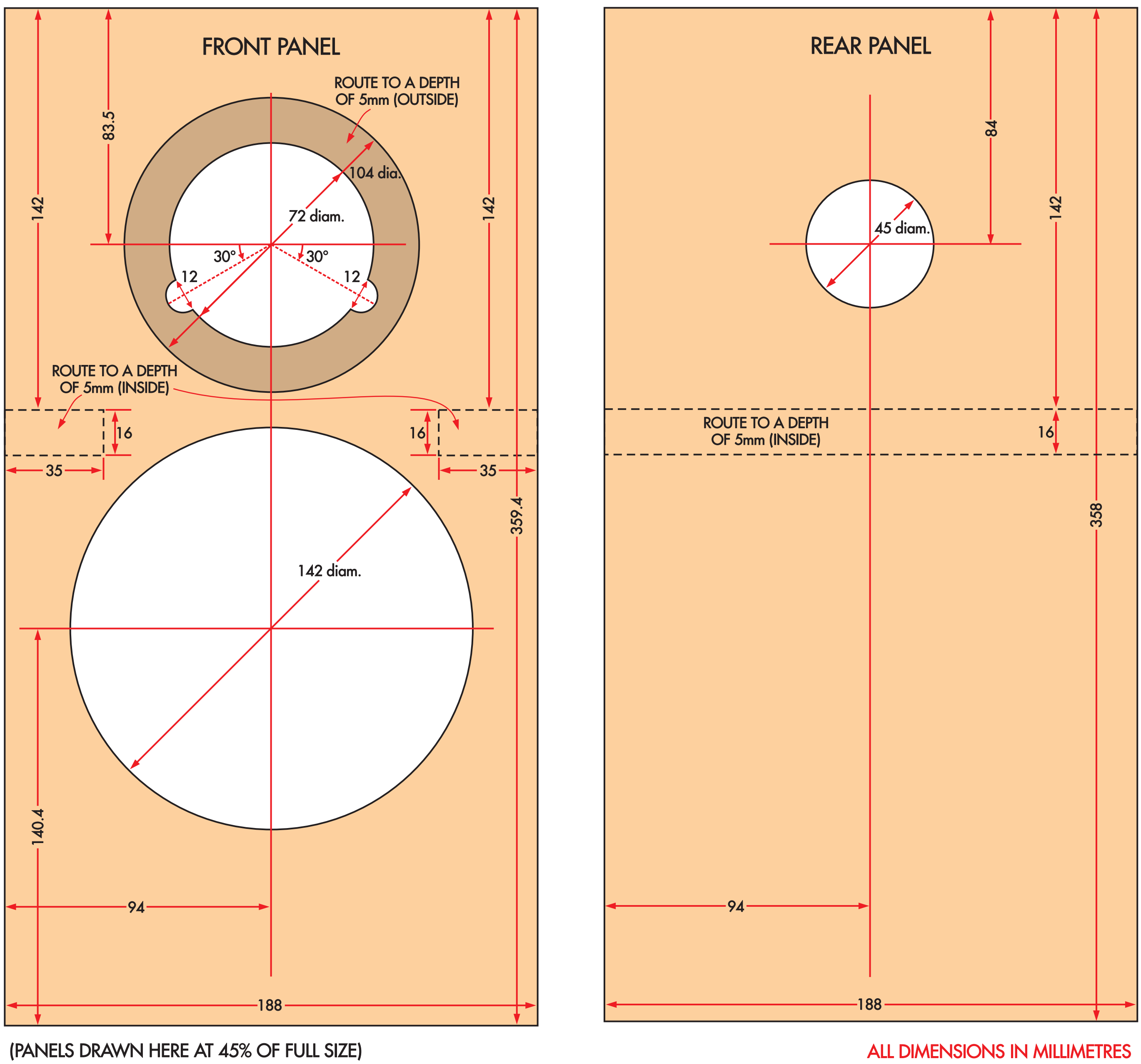


Fig.11: details of the Active Monitor front and rear panels. Note the notches for the tweeter terminals, the rebate to recess the tweeter and the rectangular areas routed out of the inside for the internal brace.

bottom panels down, I sat the assembled speaker on the floor and put some bricks and a hefty box of transformers on top of it, as shown in Photo 4.

Once clamped, take a damp cloth and wipe all excess glue from the joints. This is an essential step as sanding PVA glue is extremely difficult.

Applying the finish

No matter how you choose to finish your speakers, the most important thing is preparation. Once the glue had set, I used a sanding disc to sand back all external joints to flush. I then used 'bog' to fill any gaps between joints, being extremely careful not to overfill. The sand-and-fill process was

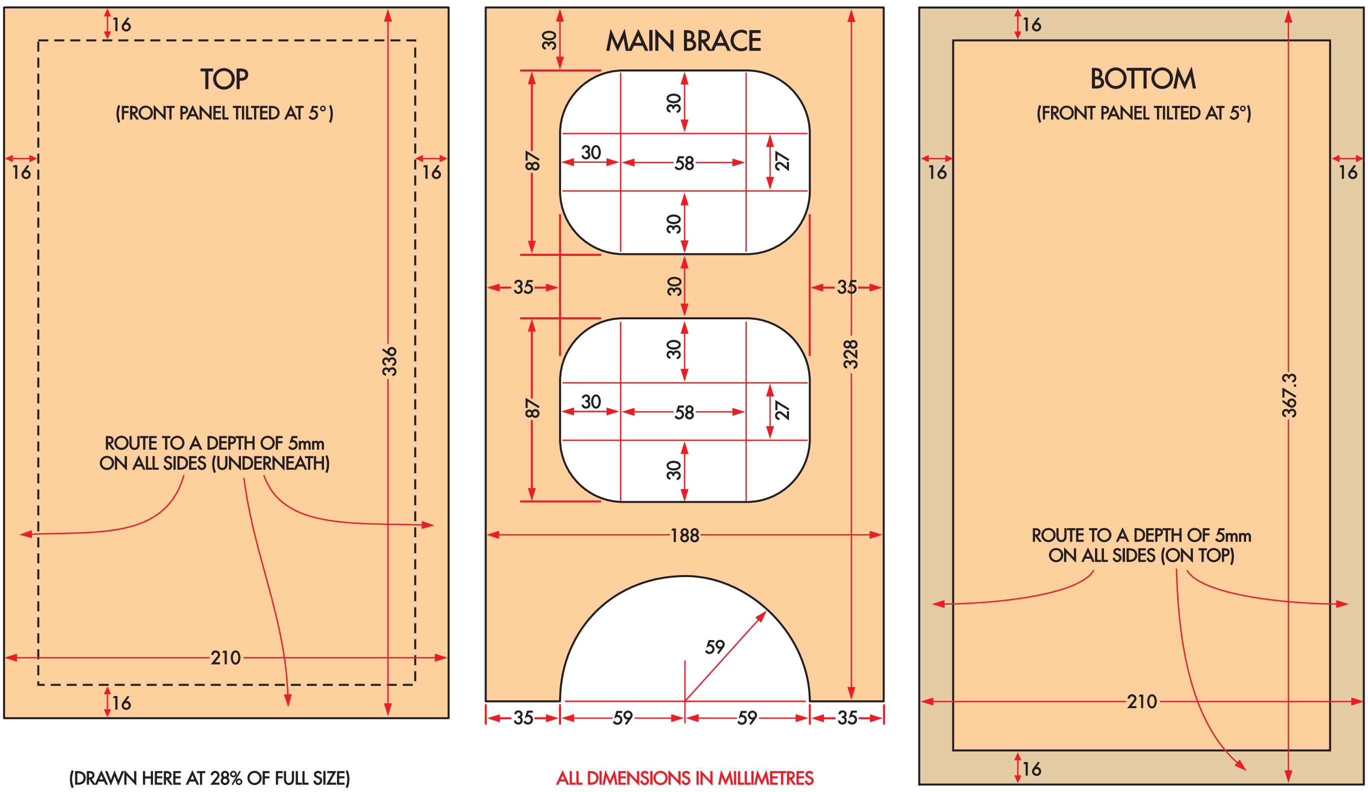


Fig.12: details of the top and bottom panels, and the internal brace. The brace fits horizontally between the drivers and ensures good rigidity. The bottom panel is larger than the top due to the angled front.

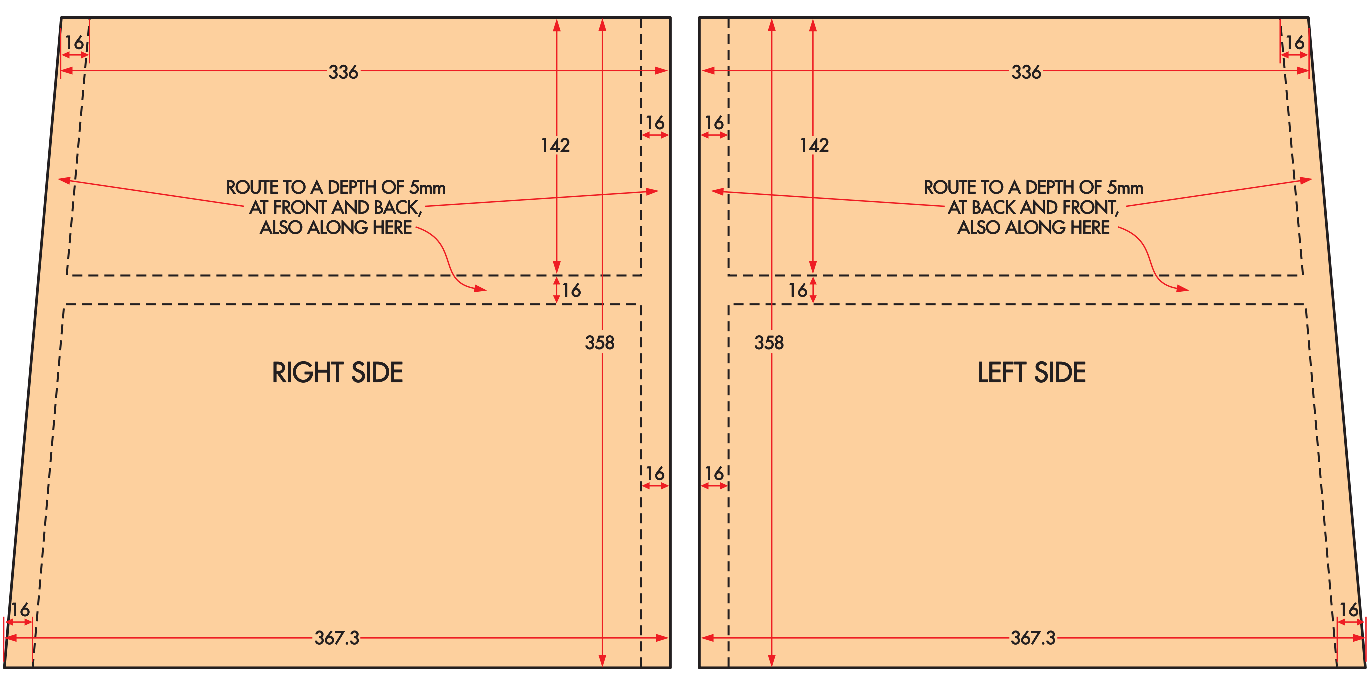


Fig.13: details of the side panels, which are trapezoidal to fit the tilted front panel. The routed areas are where the front and rear panels attach as well as the horizontal internal brace.

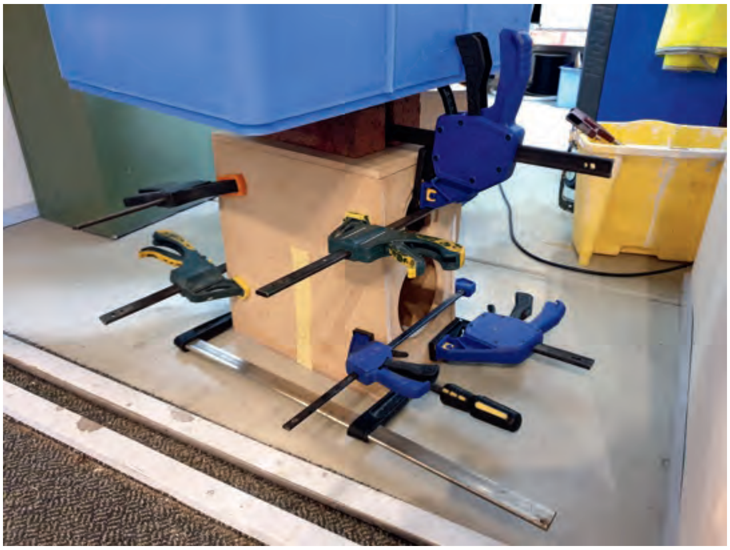


Photo 4: one Active Monitor speaker box, glued and clamped, waiting to dry. This sat for 24 hours before further work was undertaken.

repeated, moving through 120 grit to 240 grit sandpaper until the boxes were totally smooth.

You will see in the photos that I rounded the speakers' edges. The front edges have a 10mm radius curve to the edge, while the sides have a 6mm radius. The front edges are rounded to reduce diffraction, although if your finish demands a square edge, that will be OK. My earlier prototypes had square edges and did not show significant refraction-related problems.

Next, I used a roller and acrylic primer to seal the timber, paying particular attention to the end grain. We need this sealed; otherwise, it will absorb paint and be visible through the top coat. The primer had an orange-peel effect which required yet more sanding with 240 grit paper to make the finish smooth, as can be seen in Photo 5.

After the acrylic primer had been sanded totally smooth, I applied a spray primer. This sealed any patches of MDF showing through. I sanded that again using 400 grit paper and then applied two top coats with a light sanding using 400 grit paper in between. I used "satin black", which is more matte than gloss. Gloss is the worst case for showing any flaws.

Luckily, the results were excellent. Photo 6 shows the least flattering aspect of the speaker, with a slight imperfection along the top rebate joint at the rear. I almost filled and re-coated this to make them perfect, but the reality is this is only visible from this angle, so I considered the extra effort unwarranted.

Installing the drivers

Set the speaker port to 100-110mm in length. This does not need to be super exact; a 90 to 115mm range is acceptable. The specified Altronics port is 110mm long with the adjustable extension removed. Install and screw the port in, as shown in Photo 7.

The connector is the ideal place to mount the protection capacitor for the tweeter. The 100µF capacitor will protect against the application of DC and provide a small measure of protection against modest levels of full-range signal. However, it will not protect against prolonged high-level low-frequency material.

To prepare the connector, you must take the bridging straps off before soldering anything to the tabs.

I hot-melt glued the capacitor to the input connector and wired it directly in series with the tweeter wire. I used 1mm^2 (17AWG) heavy-duty speaker cable for the tweeter and woofer connection. Make sure you cut these long enough that you can solder them to the drivers when you install them.

I started with 600mm lengths, soldered them to the input terminals and trimmed them to length when I connected the drivers – see Photo 8. Mark the woofer and tweeter connections so

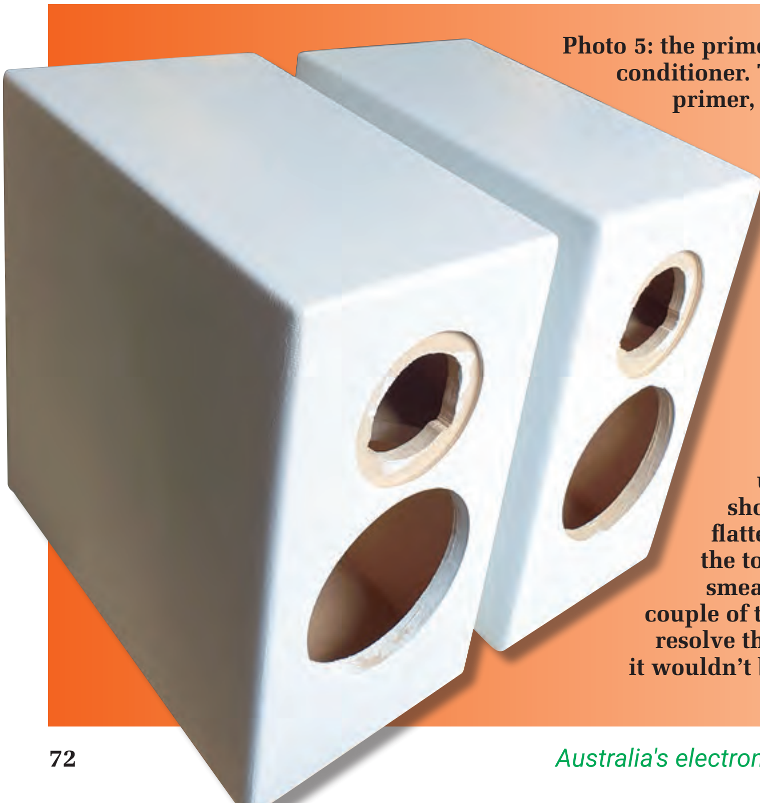


Photo 5: the primed Active Monitor speakers drying in front of the air conditioner. These were later sanded smooth before applying spray primer, then sanded again before the top coat.

Photo 6: the ultimate finish, shown at the least flattering angle (see the top rear). A final smear of filler and a couple of top coats would resolve this, but I figured it wouldn't be visible in the listening room.

you do not get them confused. I also suggest labelling the connectors on the exterior of the box so that in the future, when you have forgotten how you built these, the connections are clear.

Poke the speaker wires into the enclosure, put foam tape around the terminal cutout, then screw it down with four wood screws.

Next, cut two strips of thick wadding about 1m long, fold one and stuff it above the brace, then the second one below it. The aim is to loosely fill the enclosure with wadding to damp rear radiation into the enclosure.

The drivers have pre-installed foam gaskets. Solder the tweeter wires to the tweeter, being careful to get the phasing correct. Now screw the tweeter in and follow by installing the woofer. Secure the drivers with 16mm screws.

Finally, I installed the felt. It is best to cut the circles after it has been stuck to the front panel but cut the straight lines using a ruler and sharp knife before installing. The pattern I used is shown in Fig.14.

This is required as we are mounting the woofer flush to the front panel; the felt neatens the appearance and allows the woofer to be moved forward, improving time alignment and reducing diffraction.

Depending on the felt you can source, you might need two layers. Ultimately, you want the felt flush with the woofer frame.

Photo 7: the rear of the speaker, showing the texture you get if you don't sand the undercoat. This also gives you a good view of the vent and the terminals.

Parts List – Active Monitor Speakers *(per pair)*

1 Amplifier/Crossover (to be described next month)
1 active subwoofer (**optional**; but recommended; described next month)
2 SB Acoustics Satori MW16P-8 165mm mid-woofers
[Wagner Electronics – siliconchip.au/link/abfi]
2 SB Acoustics Satori TW29R-B 29mm ring tweeters ❶
[Wagner Electronics – siliconchip.au/link/abfj]
2 100µF 100V bipolar crossover capacitors **[Jaycar RY6920]** ❷
2 35mm adjustable speaker ports **[Altronics C3638]**
2 bi-wire speaker terminals with two independent inputs **[Altronics P2019]**
1 2400 × 1200 × 16mm sheet of MDF or similar, cut as per Fig.10
30 16mm-long 8G wood screws
1 2m length of 1mm^2 (17AWG) figure-8 speaker **[Altronics W1936]**
2 5mm-thick sheets of dark felt, 300 × 200mm
1 5m length of 5-10mm wide soft foam sealing tape (for sealing driver and terminal holes)
1 2m × 1m acoustic wadding blanket **[Lincraft "king size thick wadding"]**
1 300mL tube of PVA glue
1 500mL tin of acrylic primer paint
2 350g cans of spray primer paint
2 350g cans of spray paint (for two or more top coats)
❶ If you're ordering the drivers from Wagner and want to build the subwoofer, you can get the SB34SWNRX-S75-6 subwoofer driver at the same time (siliconchip.au/link/abfk).
❷ Increasing the value up to 220µF is beneficial but not required. Make sure the capacitors can handle the currents involved.

Parts for optional stands (per pair, 800mm tall)
2 2m lengths of 120 × 19mm DAR pine
2 300 × 300 × 16mm sheets of MDF or similar
2 200 × 140 × 16mm sheets of MDF or similar
8 75mm-long 10G wood screws
8 50mm-long 10G wood screws
1 250mL tin of acrylic primer paint
1 350g can of spray primer paint
1 350g can of spray paint (for two or more top coats)

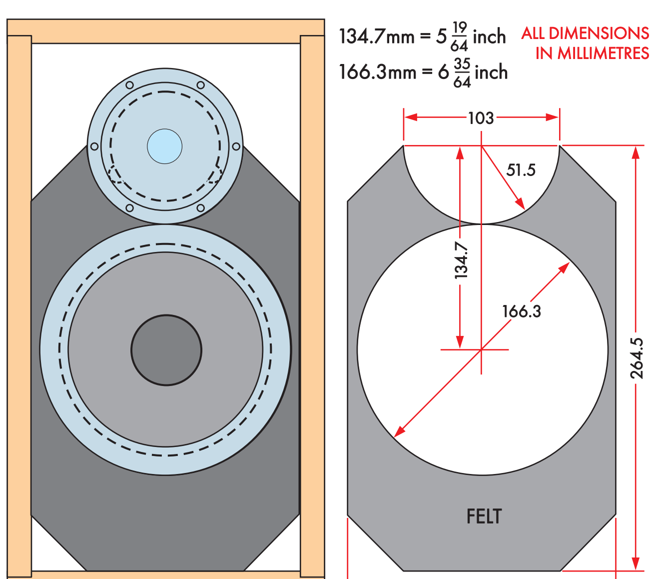


Fig.14: cut the felt to this shape and glue it to the front of the speaker. It serves two purposes: to prevent sound from refracting from the edges of the drivers and to hide the difference in the mounting styles of the two drivers.

Speaker stands

Where and how you use your Active Monitor speakers is a personal choice. That said, positioning is important; having them at ear level is a good idea.

My speakers are in a listening room and I wanted some stands to set them at the right height. I made suitable speaker stands from off-cuts of MDF and 120 × 19mm DAR pine timber. I used angled braces to make them both stronger and more visually interesting.

Fig.15 shows how you can make some of these simply and cheaply. I cut the timber as shown, primed, sanded and applied a top coat in a similar manner to the Active Monitor speakers. The overall height of the stands as specified is 800mm; you can tweak the height to suit your needs.

Testing

We're getting a bit ahead of ourselves

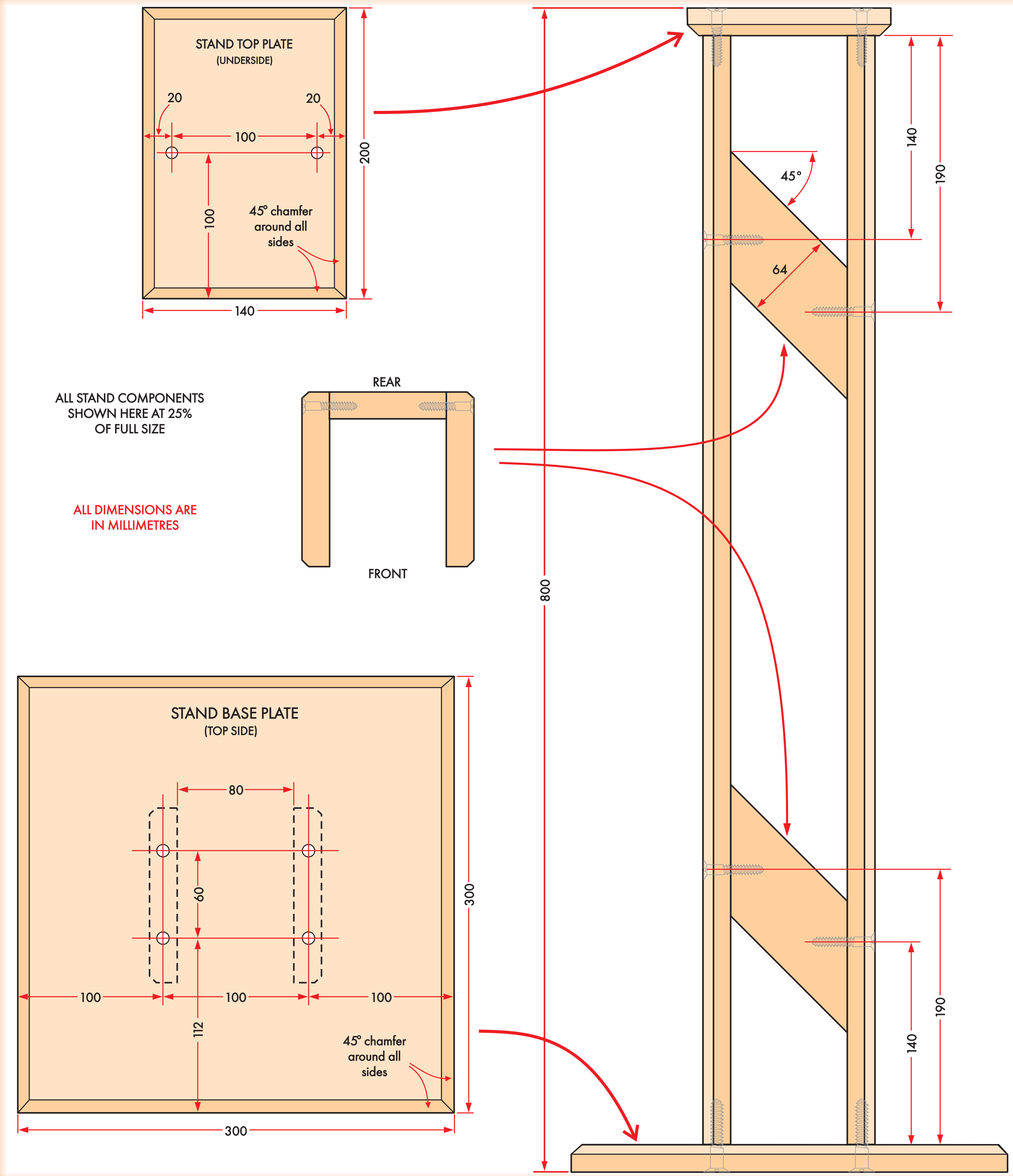


Fig.15: the details of the low-cost but sturdy and attractive stands I designed for the Active Monitor speakers. You can probably cut the base and top plates from off-cuts of the material used to make the speakers.

here because you'll need to build the amplifier/crossover system described in the article next month to test your new speakers properly. Still, this is an appropriate place to discuss how to check that everything has gone together properly, so let's proceed on the assumption that you have already built the electronics.

A good test for a crossover and speaker alignment is to invert the tweeter phase and see if there is a dip at the crossover frequency. Fig.16 shows a 10dB dip in the response at the crossover frequency when I invert the phase of the tweeter. This indicates that the time alignment is correct and that everything in the system is working as planned.

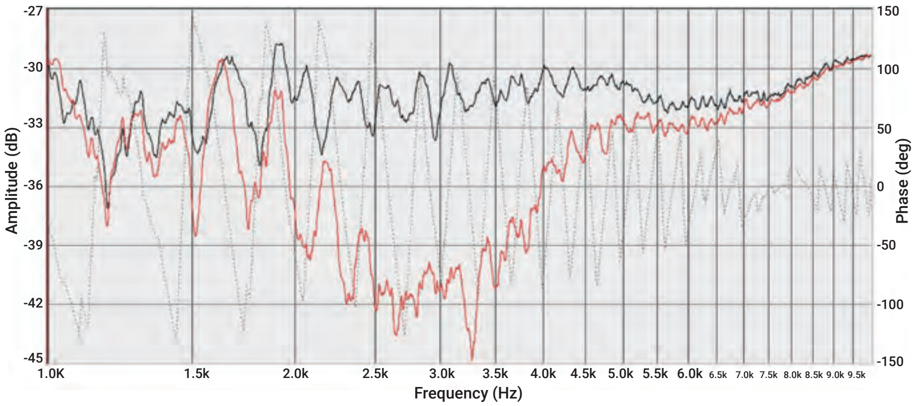


Fig.16: a major dip is seen in the frequency response when the tweeter phase is inverted. This sound cancellation shows that everything is well aligned and working as expected.

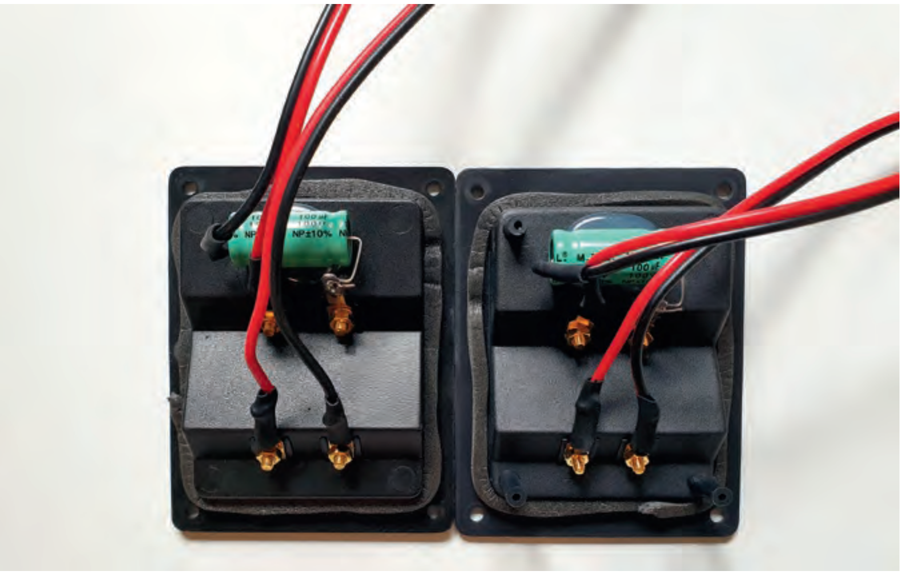


Photo 8: I used hot melt glue to attach the DC block capacitor for the tweeter to the back of the speaker terminal. I then soldered 600mm of heavy-duty speaker wire to the terminals, ready for attachment to the drivers.

Calibration and use

Assuming you are setting the output level controls on the 3-Way Active Crossover, I recommend you use an oscillator and AC voltmeter. The oscillator could be your PC audio output. Be a little cautious using DVMs as an AC voltmeter as some do not respond to signals above 400Hz, so check you get sensible readings. The steps are:

1 - Unplug your Active Monitor speakers from the Active Crossover Amplifier.

2 - Set the woofer level to maximum.

3 - Set your oscillator to generate 400Hz at 1V RMS.

4 - Measure the woofer output of the active crossover or amplifier. These should be 0.65V/12.6V RMS respectively; ±1dB precision on these is 0.58-0.73V & 11.2-14.1V.

5 - Now set your oscillator to 5kHz. Check that your meter still reads 1V RMS at the input to the Active Crossover Amplifier.

6 - Adjust the tweeter volume control to get 0.24V/4.7V RMS on the active crossover or amplifier's tweeter output; ±1dB precision on these is 0.21-0.27V/4.17-5.25V.

7 - Set your oscillator to 40Hz and check that your meter still reads 1V RMS at the input to the Active Crossover Amplifier.

8 - Adjust the subwoofer volume control to get 0.59V RMS on the subwoofer output; ±1dB precision on this is 0.48-0.61V.

It is probably best to set the subwoofer output by ear as there can be huge differences between listening rooms. Adjust the level up until it sounds 'bassy', then back it off until the sound is dry. The right level is in between those settings. If you have an SPL meter, use it, just be aware that your room will create all sorts of interesting peaks and dips.

Some say that two subs can help fill these, but it is an expensive proposition. Still, there's absolutely nothing stopping you using both subwoofer outputs from the Active Crossover Amplifier to drive one sub each. In that case, you'll initially want to set the subwoofer output closer to 0.4V RMS.

I adjusted the baffle step correction to achieve optimal subjective sound quality in my listening room. You might wish to tweak this to suit your room.

This is because the baffle step corrects how much sound is heard at the listening spot – but remember that diffraction merely redirects the sound off to the side, and the sound is still in the listening room. So each room may demand a different correction.

Increasing the 2.2kΩ resistor will reduce the amount of baffle step correction (and reduce the frequency at which the correction kicks in). The recommended value should be correct in many situations, but you may like to experiment with it.

I trust that you will enjoy building and tweaking, then listening to these very high-quality speakers and possibly making your own version inspired by some of these ideas.

Next month

The second article next month will describe the Active Crossover Amplifier system for driving the Active Monitor speakers. After that, we'll have an article on building the matching High Performance Subwoofer. SC

HIGH-END

ACTIVE MONITOR SPEAKERS WITH SUBWOOFER

PART 2: BY PHIL PROSSER

The Active Crossover Amplifier fits in a clean-looking black metal case and contains everything you need to drive the Active Monitor Speakers presented last month. It could also be used to power a different two-way bi-amplified speaker system with or without a subwoofer.

You will have heard us discuss active speakers and their benefits before. One of the problems with them is that if you use standalone parts, you end up with a stack of boxes containing preamplifiers, crossovers, power amplifiers and speaker protectors. The result can deliver excellent performance but can also be an unruly mess.

This article will describe how you can fit all the required electronics into a svelte two-rack-unit (2RU) high case, offering 50W per channel for each midrange/woofer and tweeter, with line level outputs for an active subwoofer or two. A high-quality matching subwoofer will be described next month that can deliver substantial, clean bass down to almost 20Hz.

An output power of 50W for the midrange/woofers and treble drivers might seem modest, but there is also a 180W amplifier in the subwoofer, giving a total system power of 380W. 50W is actually an enormous amount of power for the other drivers as these amplifiers do not need to handle the large voltage swings required to deliver the bass (any signals below ~85Hz).

This article brings together several previous projects; in terms of electronics, we are only adding a very simple power supply board. I have worked to keep metalwork to a modest level of complexity, though some drilling and filing will be necessary.

I built it in a high-quality Altronics H5038 case as this avoids the hassle of fabricating the enclosure and provides enough space to fit all the parts. To start building it, gather or make all the required sub-assemblies, as shown in the panel at lower left.

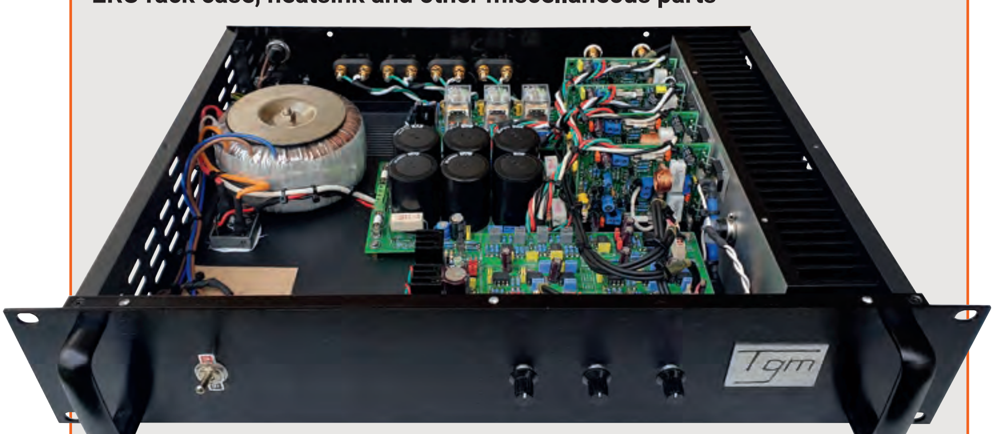
The input to the Active Crossover Amplifier is the stereo output from your preamplifier, with line level outputs to your active subwoofer and speaker level to the midrange/woofers and tweeters. The Active Crossover Amplifier is the heart of the High-End Speaker System, as shown in Fig.1 from last month.

A full description of each subsystem is provided in the referenced articles. I suggest you read them as they provide good background information that I won't repeat here. The metalwork and subsystem integration forms the majority of this project.

Let's start with building the case, as once that is done, the modules drop in, ready for wiring. You can see the overall arrangement in the adjacent panel and Photo 9 overleaf.

What is needed to build a stereo Active Monitor Amplifier system

4 x Hummingbird Amplifier Modules – *December 2021; siliconchip.au/Article/15126*
3-Way Active Crossover – *October-November 2021; siliconchip.au/Series/371*
Multi-Channel Speaker Protector (4-CH) – *January 2022; siliconchip.au/Article/15171*
Active Monitor Speakers Power Supply – *described in this article*
2RU rack case, heatsink and other miscellaneous parts



Chassis and metalwork

Start by marking and drilling the base of the chassis as shown in Fig.17. Also drill and file the front and rear panels as shown in Figs.18 & 19. Test-fit the connectors and other items to ensure you won't need to rework anything. On the front panel, be careful to check the height of your PCB standoffs, as these determine the location of the holes for the crossover controls.

For the front panel, you will be best off installing the 35mm standoffs at both the front and rear locations of the

Features & Specifications

- Stereo three-way active crossover with 24dB/octave Linkwitz-Riley roll-off
- Four 50W high-fidelity amplifier channels
- Line-level subwoofer outputs (left and right or dual mono)
- Speaker protection and de-thumping on all outputs
- Baffle step correction implemented at line level
- Fits in a high-quality, two-rack-unit (88mm high) case
- Silent operation with passive cooling

crossover board and sliding it forward to verify the drill holes match up with the height of the potentiometer shafts on the crossover.

There are small locating pins at the bottom of the potentiometer mounting threads. The best thing to do is use a 3mm drill and drill a 'blind hole' into the rear of the front panel deep enough to accommodate the pin without going right through the panel. This is not as hard as it sounds, but if you are concerned, filing, cutting or snapping these off is a cheeky alternative.

Slide the crossover in and check the alignment with the holes in the base. Mine were very close. If there is a minor misalignment, it is fine to drill the mounting holes in the base out to 4 or 4.5mm, which will give you wiggle room with the standoffs. I did not install the front standoffs on the Active Crossover board as they interfere with the lip on the front panel.

Now is a great time to drill and tap the heatsink, as shown in Fig.20. There are not that many holes, and the holes line up with the gaps in the fins. If you cannot tap these holes, it is possible to run long M3 machine screws or bolts through the heatsink, but I found that tapping the holes was easy enough and took less than half an hour. To tap the holes, drill to 2.5mm diameter and use an M3 × 0.5mm tap with plenty of lubricant (light oil).

Amplifier construction

If you haven't already, assemble four Hummingbird amplifier modules as described in the December 2021 issue (siliconchip.au/Article/15126). It is important that you attach the wiring before mounting them on the heatsink; once they have been installed on the heatsink, you will not be able to get a screwdriver in to tighten the terminals.

I used 300mm lengths of heavy-duty (7.5A rated) red, green and black wire and a 500mm length of white wire (for the positive, ground, negative and

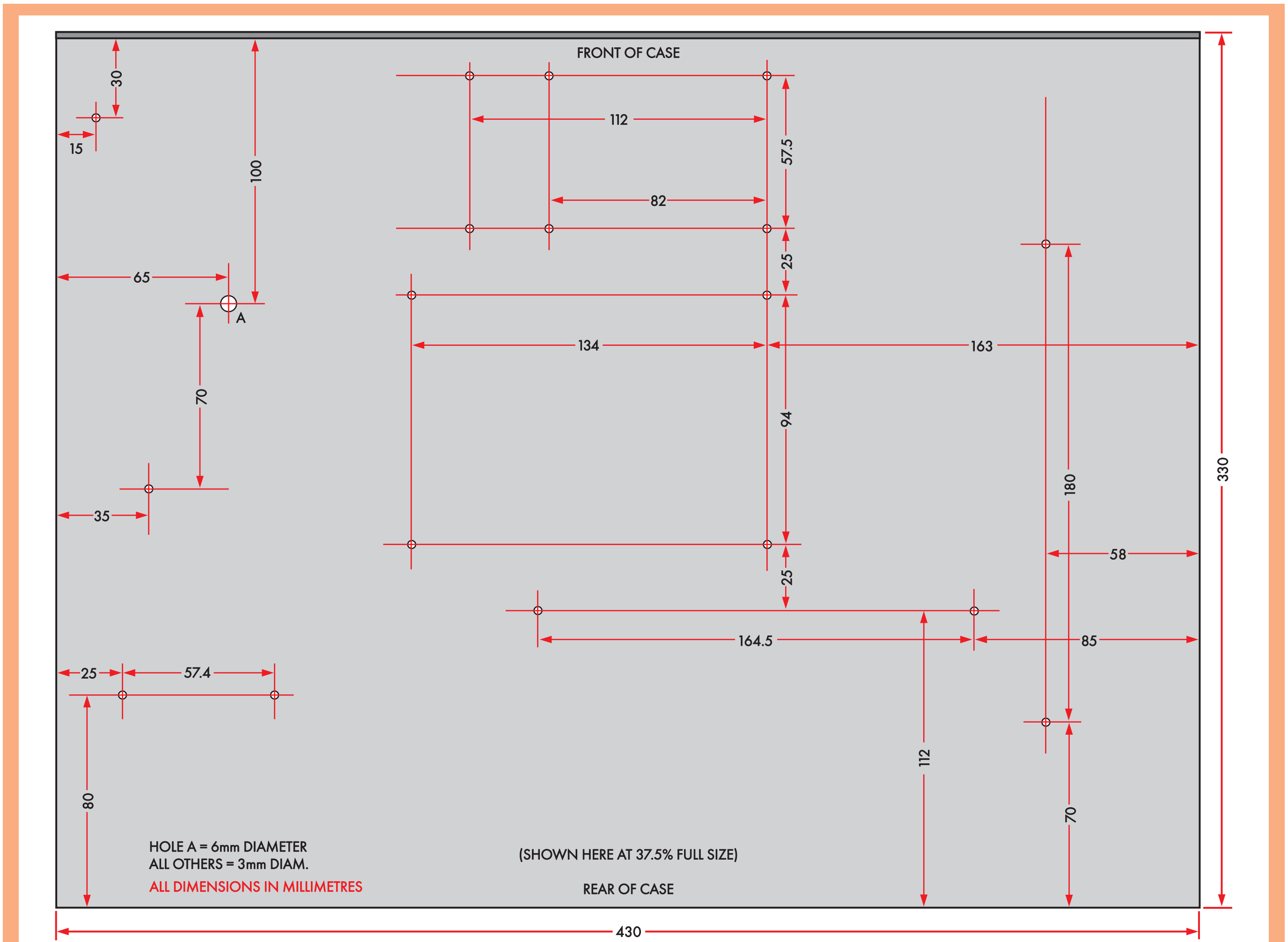


Fig.17: mark & drill the base of the Altronics 2RU case as shown. Drill the holes to 3.5mm for mounting locations; if you need extra wriggle room, you can drill or file them to 4mm. If using a different case, you will have to make adjustments.

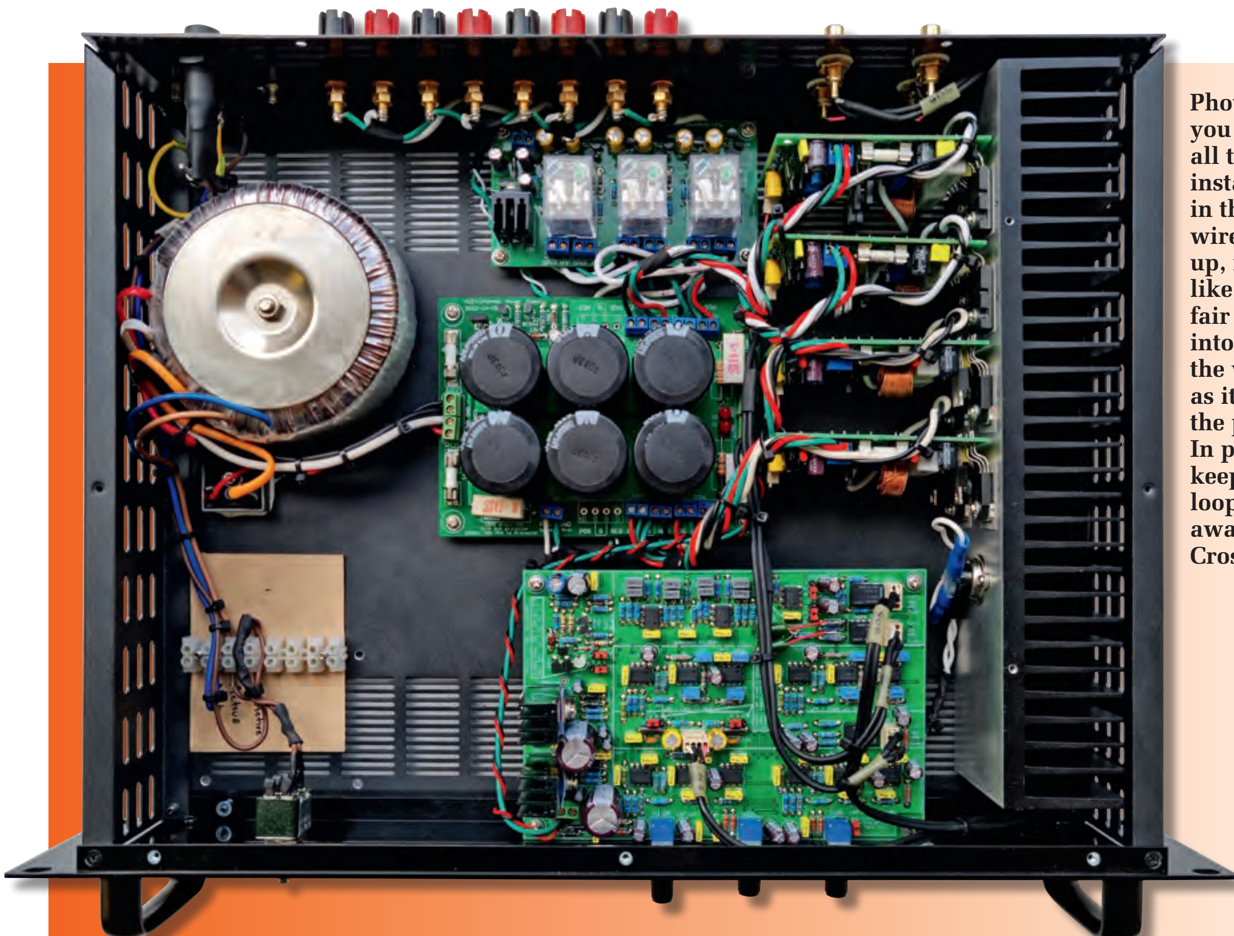


Photo 9: When you have built all the modules, installed them in the case and wired everything up, it should look like this. I put a fair bit of effort into keeping all the wiring neat as it helps with the performance. In particular, keep those AC loops tight and away from the Crossover.

output of the modules, respectively). These will be slightly too long, but we can trim them to be the perfect length when we connect them to the other modules (mainly the power supply).

If you did not fully test them when you built them, you need to do that now. Once installed, it would be a real bother to strip everything apart to fix a silly mistake. To do this, strip the ends of the pigtail leads on each module and power each amplifier up. You can run functionality tests without the heatsink if there is no bias.

If a module draws a lot of current, switch it off immediately and sort the problem out! The most likely cause is that the pot is adjusted the wrong way, and you have maximum bias.

The most basic functionality check is to power the amplifier up and check for DC on the output. If the output is within 50mV of 0V, it is very likely that the amplifier is working, as this shows the DC feedback loop is operating. If available, check the output with a scope to verify that it is not oscillating. For bonus points, run a sinewave through the amplifier module and check that the output waveform is clean.

You can run this last test using an AC voltmeter provided you use a test signal of 400Hz at 100mV RMS; you should get about 2.8V at the output.

Once the modules are all working, mount them and adjust their bias. First, mount the module at the back of the heatsink. Do not forget to use insulators and insulating bushes on the screws. Otherwise the power supply will be shorted out via the collector tabs and heatsink! Also use flat and shakeproof washers on each screw so that they don't back out.

Power up the first module using a bench supply and adjust the bias current until it is 50mA, either by measuring across a resistor in the fuse holder (in place of the fuse) or across the emitter resistors.

Anything that can supply at least ±15V DC at 1A or more is sufficient to power the module for this test. Let the module sit for a while; the current will eventually settle down (it will change as the transistors warm up).

During development, I tested the impact of changes in the bias current. I determined that minor misadjustments only marginally impact performance; the amplifier gives well under 0.01% distortion when it is close to correct bias.

As you finish one module, mount the next and make all adjustments. Rinse and repeat until you have all modules mounted. You will end up with an assembly like that shown in Photo 10.

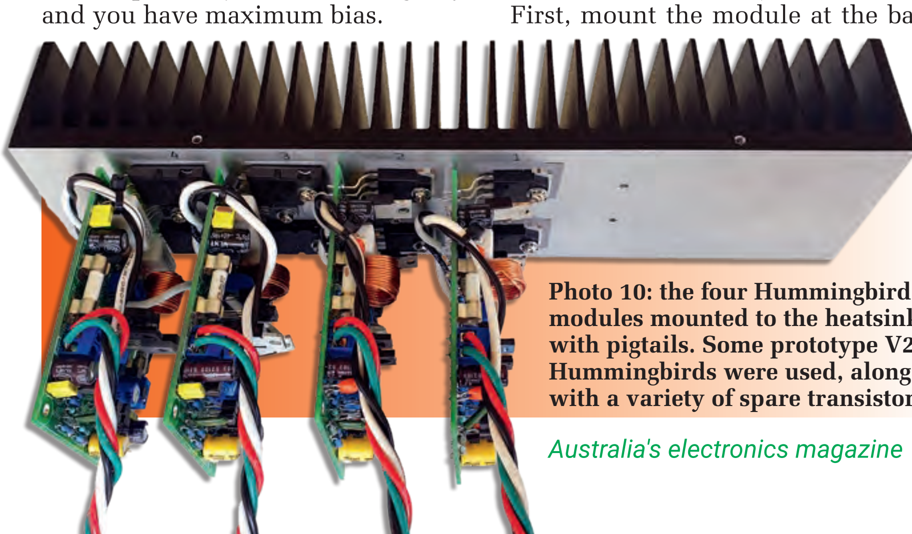


Photo 10: the four Hummingbird modules mounted to the heatsink with pigtails. Some prototype V2 Hummingbirds were used, along with a variety of spare transistors!

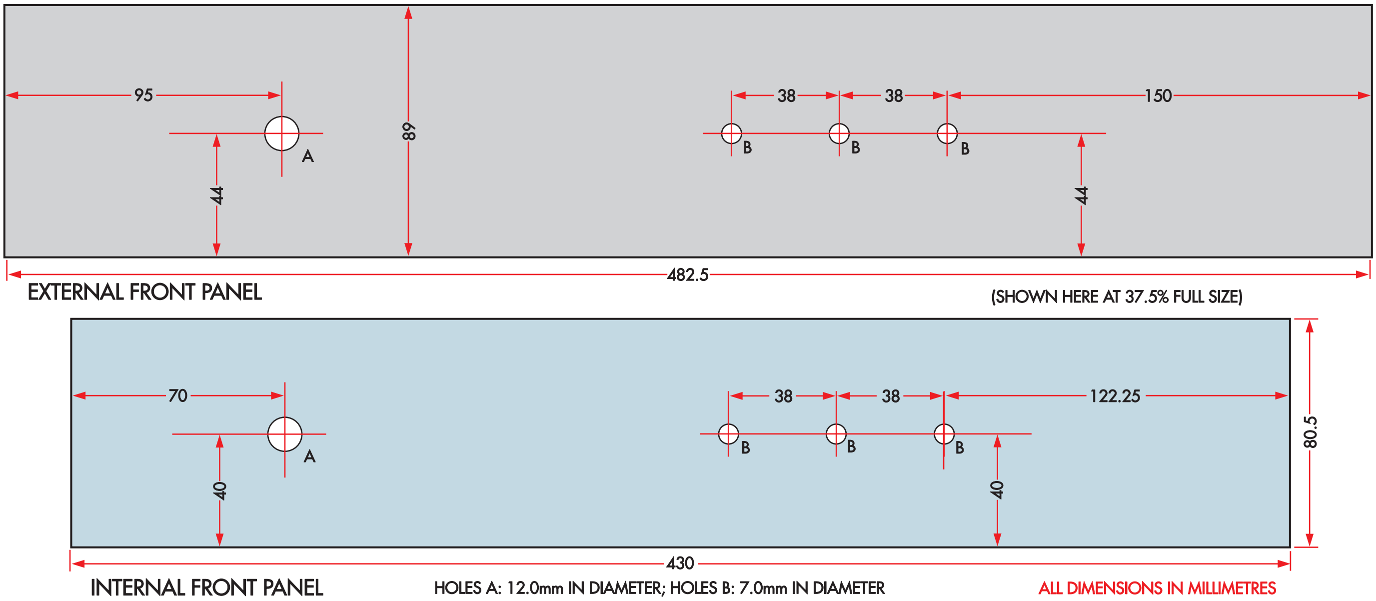


Fig.18: drilling details for the front panels. These are outside views. If drilling a different case, you can use the same general pattern, but you might need to adjust the overall position of the template.

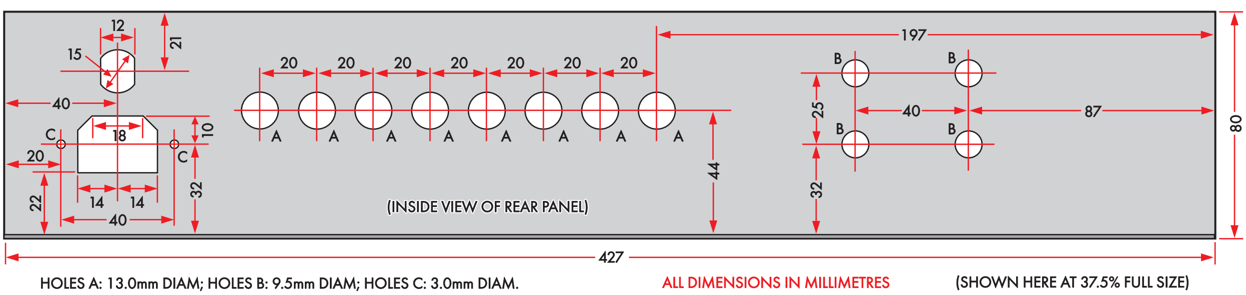


Fig.19: the amplifier rear panel drilling details – note that this is an inside view.

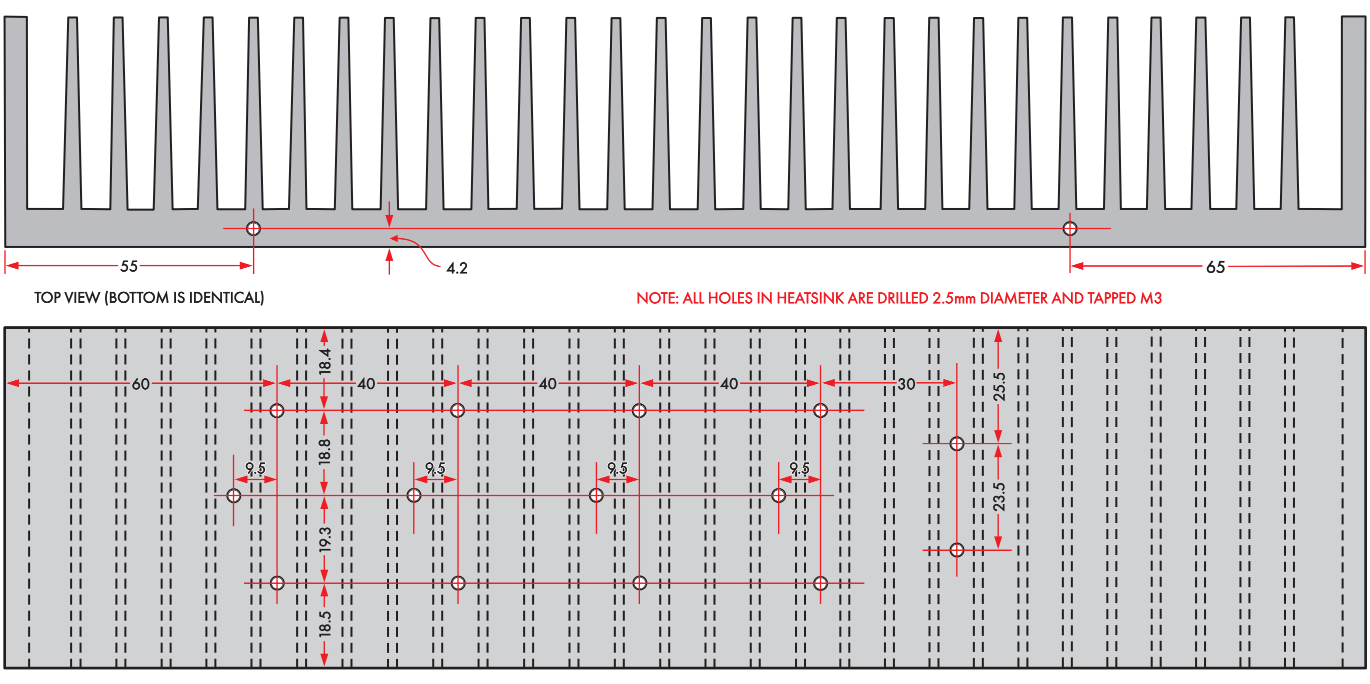


Fig.20: each set of three holes on the heatsink is for mounting one Hummingbird amplifier, with two more holes for the thermal cut-out. Drill and tap at least two holes in the bottom of the main section to mount it to the base of the case.

Twist the wires together to ensure you know which ones go where and also to make tidy bundles. This has the added benefit of keeping magnetic field radiation from the power wiring to a minimum. Tie wrap the power leads as shown in the photos. You will achieve pretty good mechanical rigidity by tying the bundles between adjacent modules.

If you plan to use this as a portable amplifier or for road use, you will need to install bracing between the Hummingbird amplifiers and the chassis base. For example, angle brackets secured to the mounting holes in the Hummingbird amplifier boards.

Next, mount a 70°C normally-closed thermal switch via the two remaining holes on the heatsink, with flat and shakeproof washers on each screw. I have included this as a safety measure – if the heatsink gets too hot, it will switch off. I have never managed to get to that point with mine, but I am happier with that protection in place.

Power supply assembly

The power supply is very simple, comprising a 300VA transformer, bridge rectifier and filter PCB. Its circuit is shown in Fig.21.

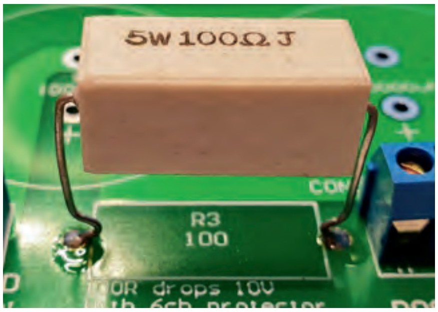


Photo 11: space the wirewound resistors off the PCB to help with heat.

As this is supposed to be a 'high-end' design, I decided to provide maximum scope for constructors to 'go the extra yard' *[extra metre? - Editor]*. My original power supply accepted 10,000µF capacitors. I tweaked this to fit 35mm diameter capacitors, and as seen in the final pictures, that allows me to fit three 15,000µF capacitors in parallel for each rail.

I doubt that will make a big difference, but it makes me feel happy. I recommend a minimum of three 6,800µF capacitors, with 10,000µF being the 'sweet spot'. The limiting factor on capacitor size is the 10A fuses at the input to the power supply. If your capacitors are too large, these fuses will become unreliable on power-up due to the massive inrush current.

I have included a one-second delay on the Speaker Protector power supply. This is arguably unnecessary given that there is also a switch-on delay built into the Speaker Protector. There is also a 100Ω resistor in series with the power supply to the Speaker Protector. This drops about 10V, thus reducing dissipation in the Speaker Protector regulator.

PCB assembly is straightforward – use the overlay diagram, Fig.22, as a guide. The power supply is built on a double-sided PCB coded 01112221 that measures 147 × 60mm.

Start by fitting the screw terminals, then the fuse clips and fuses. I put a fuse in the clips and soldered the assembly in from the top, ensuring everything aligned and fitted. Load in the components in the delay section next, making sure not to swap the PNP and NPN transistors. The BD139 must go in with the metal surface facing the edge of the PCB.

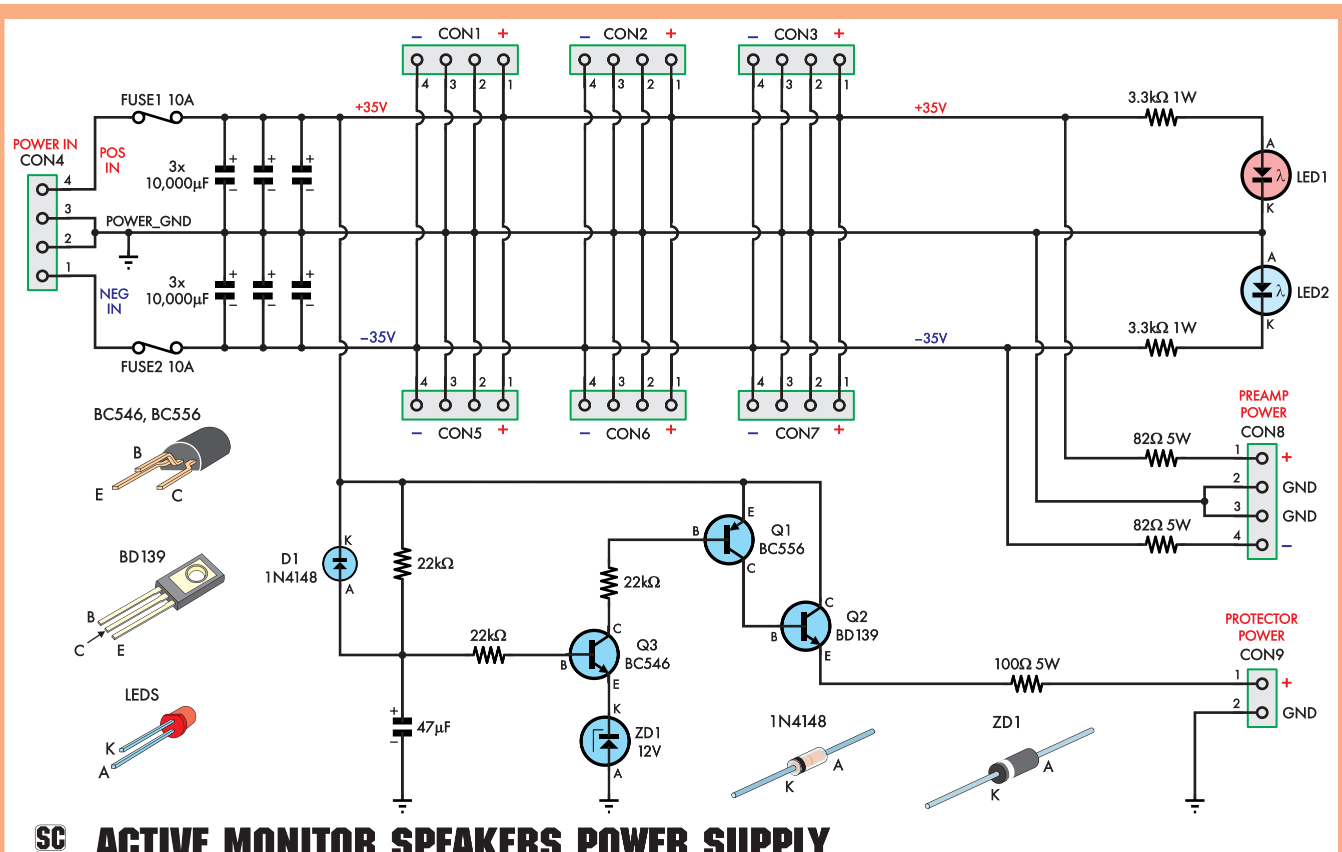


Fig.21: the upper part of the power supply circuit is a capacitor bank with multiple terminals to connect the amplifier modules, fuses for protection and LEDs to indicate when power is present and act as bleeders. The lower part is a delay circuit that applies power to the Speaker Protector after roughly one second.

The 3.3kΩ resistors have a maximum dissipation of 380mW with the nominally ±35V supply rails, so 1W resistors are OK, provided you space them at least 5mm off the PCB.

The 100Ω 5W resistor for the speaker protector runs quite warm to the touch, dissipating about 1W. The 82Ω 5W resistors for powering the Active Crossover drop about 10V and dissipate 1.5W. This might be much less than their 5W rating, but they still get very warm. Stand all these resistors off the PCB by 10mm, as shown in Photo 11.

Mount the power supply board in the case using tapped spacers and machine screws with flat and shakeproof washers. When doing the wiring, do not place plastic insulation wiring against these resistors. The final power supply board, as presented here, moves these resistors away from the power amplifier boards to make that easier.

Powering the Active Crossover

At this point, it will save you a lot of fiddling to connect 500mm of twisted red, green and black light-duty hookup

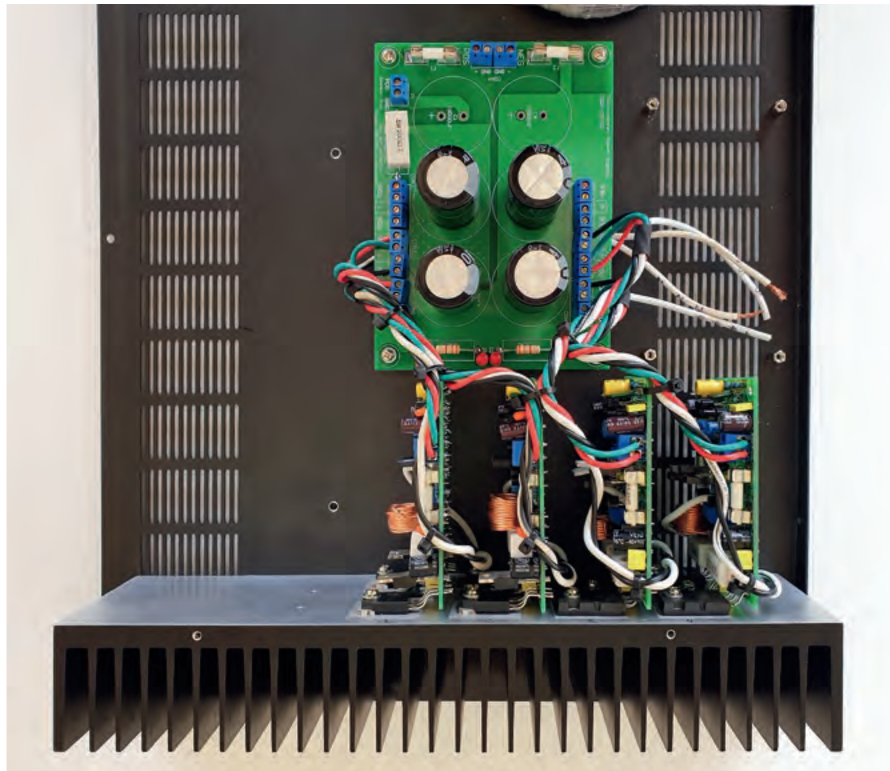


Photo 12: the four Hummingbird amps are now wired up to the power supply, and the output wires running under it are ready to attach to the Speaker Protector. Note that this is not the final power supply board design.

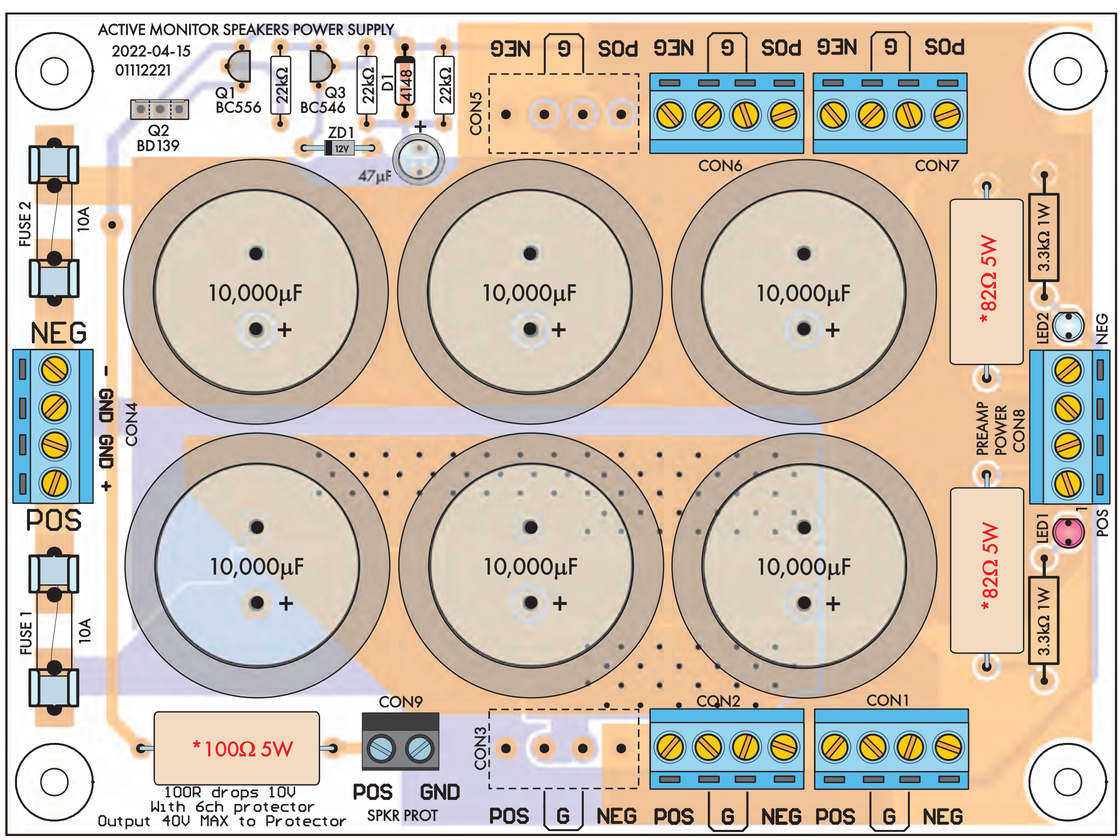


Fig.22: use this PCB overlay diagram as a guide to fit the components on the power supply board. Be very sure to get the electrolytic capacitor polarities right, or it could fail spectacularly!

wire to the Active Crossover header on the power supply board and leave this for later. If you forget this now, it can be installed later, but you will need needle-nosed pliers to get the wires into the terminals.

Now mount the power supply PCB in the case. It should be about 5mm clear of the Hummingbird modules horizontally, with DC input close to the transformer and rectifier.

Next, we need to connect the amplifier wiring to the power supply. The DC supply and mains wiring details are shown in Fig.23. I chose to run one pair of amplifiers from each side of the power supply PCB.

Note that there are output headers for up to six modules, but we only need four in this application. It does not matter which terminals you use as they all connect to large low-impedance copper fills on the PCB.

I kept track of the amplifier modules, numbering them 1 through 4 from front to rear of the heatsink. I used tape on the twisted bundles and for the outputs, ran amplifiers 1 through 4 left to right, looking from the rear of the amplifier case – see Fig.26.

For the wiring, cut the positive, negative and ground wires so that they are a neat fit to the connectors on the Power Supply board, ensuring there is sufficient slack that you can remove PCBs later if necessary.

Do not cut the speaker output wire; this goes right through to the Speaker Protector, twisted with the extra ground wire we are about to add from the power supply. Route it with the power loom to minimise the output current loop area. That also minimises distortion by reducing the coupling of these fields into the amplifier front end and input circuitry.

Connect 450mm lengths of heavy-duty green wire from the second ground screw terminal on each output from the power supply. These go to the speaker terminals, following the speaker output wiring through the Speaker Protector. These will finally be trimmed to length when you connect these to your speaker terminals.

The Speaker Protector

We are using the four-channel version of the Multi-Channel Speaker Protector (January 2022; **siliconchip.au/Article/15171**). However, I had some spare six-channel versions left over from the development of that project, and it seemed a terrible waste not to use them. There is no need for more than four channels, though.

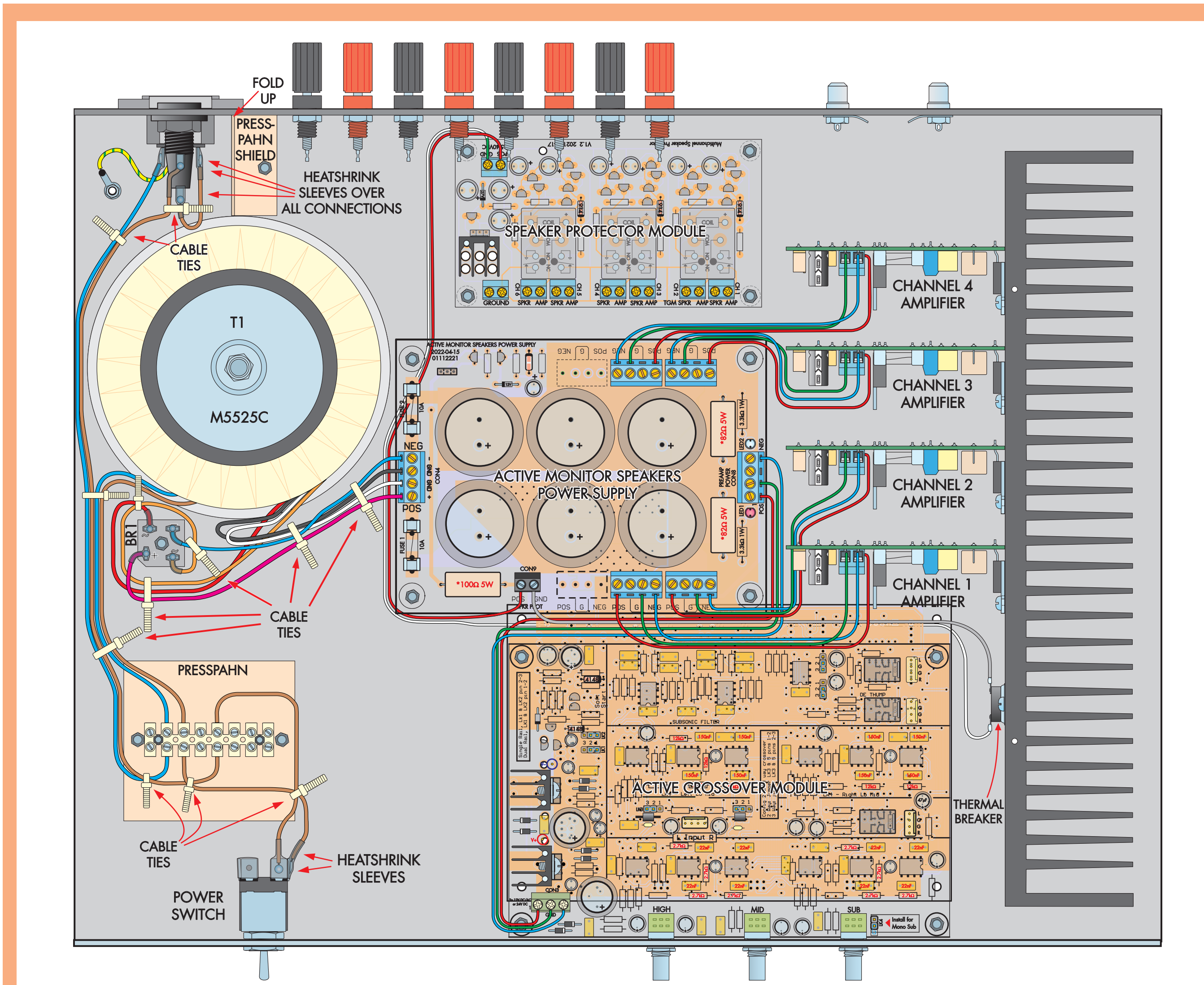


Fig.23: the mains and DC supply wiring. The signal and amplifier output wiring is shown separately, in Fig.26. Read the text for important information on safely running and insulating the mains wiring.

To test these, power them from a bench supply. As described in the original article, apply positive and negative DC voltages to the AMP inputs one by one, and check the relevant relay 'clicks' out. With this working, your speaker protection is good to go.

Mount the module to the chassis using tapped spacers and machine screws with flat and shakeproof washers. Wiring the protectors into the system is easiest with the rear panel removed. Wire up the inputs as shown in Photo 13. Note the following:

1 - The ground wire from the power supply to the speaker terminals runs straight underneath the Speaker Protector PCB.

2 - I twisted the output wires with the ground, as shown in the photo. This keeps things neat and again minimises current loops.

3 - I marked the wires to be soldered to the output terminals with a small piece of heatshrink tubing to ensure I did not confuse them with the amplifier outputs, then connected these to the "SPKR" terminals. I ran channels 1-4 left-to-right across the protector – although the critical thing to get right is the pairing of the amplifier and speaker terminals.

4 - These connections are definitely the fiddliest bit of this project. Use needle-nosed pliers, and don't cut the leads too short.

Now cut a 600mm of white light-duty hookup wire plus two 300mm lengths (white & red) for the speaker protector power and ground connections. Twist them together and secure with heatshrink tubing, referring to Fig.23 for the required layout. Run the wires between the Speaker Protector power terminal, under the Power Supply PCB to the power output for the Speaker Protector, with the GND side going via the thermal switch.

The connections to the thermal switch are made using 6.3mm spade lugs.

The recommended 100Ω 5W resistor on the Power Supply PCB is the correct value for a 25V AC transformer. If your transformer voltage is below 20V AC or above 30V AC, check this resistor once it is operational and adjust as needed. Top tip: connect this wire before you screw the rear panel on unless you have three arms!

Transformer and rectifier

Now is the time to install the transformer. The recommended transformer is a 25+25V AC 300VA toroidal type. A lower power unit would work but should only be used if you will either reduce the supply voltage or don't plan on ever driving the amplifier hard.

Suppose you really want more than 50W output per driver and will only ever connect this to 8Ω speakers or our Active Monitor Speakers.

In that case, you could use a 30V AC transformer instead, provided you check the voltage ratings of all the power supply capacitors. That will give you close to 70W per output.

I have specified a 35A bridge rectifier; this is especially necessary if you use high-value capacitors on the Power Supply board. The 35A bridge rectifier should be mounted to the base of the chassis with a 25mm-long M3 panhead machine screw with a flat washer and shakeproof washer. Put a dab of thermal paste under the bridge rectifier to ensure it stays cool even if the amp is driven hard for extended periods.

Secure the power transformer with the flying leads toward the bridge rectifier. We are trying to minimise high current paths near the crossover here. Transformers are typically supplied with two rubber washers for the top and bottom, plus an M6 bolt and dished plate. Do the bolt up moderately tight, but not so tight that you crush the windings.

Using the colour codes for the Altronics transformer:

1 - Connect the white and black secondary wires directly to the middle two GND terminals on the power supply PCB. If necessary, scrape the enamel insulation off to expose bare copper. Also check that the tinning on these wires does not extend back under the PVC sleeve, as that can be a shorting hazard.

2 - Next, connect the orange and red wires to the AC terminals on the bridge rectifier. Usually, the positive terminal and one AC terminal are marked on rectifiers. The other AC terminal will be diagonally opposite the marked one, and the negative terminal will be diagonally opposite the positive terminal.

3 - You will need to cut these leads to a sensible length, but too long is better than too short. These wires have very high current pulses, and we don't want big loops to generate magnetic fields. Depending on the type of wire used, you might need to scrape off the enamel coating after cutting them.

4 - Tie wrap the leads from the Power Supply as shown in the photos.

It's now time to install an eight terminal length of the terminal strip. These come in various sizes; 57mm spacing is good for the recommended part. If you are using an alternative, check the mounting hole placement. Cut a 70 × 80mm piece of insulating card such as Presspahn and fit it under the terminal strip. Our terminal strip is laid out as shown in Fig.23.

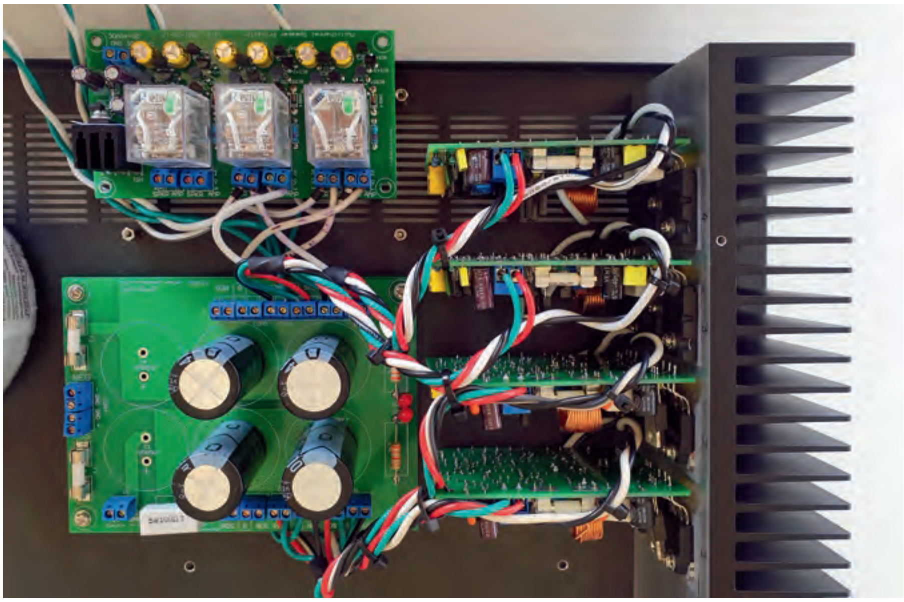


Photo 13: the wiring to the Speaker Protector is easier to do before you have fully mounted it in the chassis. Note the removal of the rear panel to gain some extra space while doing this.

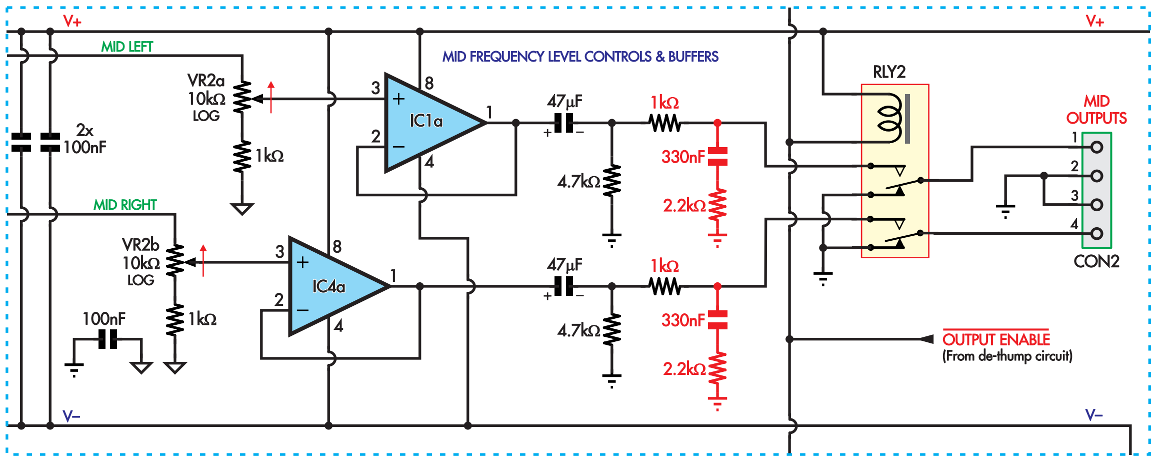


Fig.24: these minor modifications to the Active Crossover midrange/woofer output implement 'baffle step correction' below 250Hz. The 2.2kΩ resistors and 330nF capacitors are added to the existing PCB, while the existing 100Ω resistors change to 1kΩ.

Now do the mains wiring as follows, using Fig.23 as a guide:

1 - Attach the IEC socket to the case using 10mm M3 panhead screws, nuts and shakeproof washers. The nuts need to make connection to the chassis by scraping away any paint or anodising. Connect the IEC Active pin through the fuse to the terminal strip using brown mains-rated wire.

2 - Connect the active from the terminal strip through the power switch and back to the terminal strip (making the front panel easy to remove). Ensure that the active input wire goes to the power switch's switched (NO) pin, with the output from the common terminal (so the spare pin is not connected to Active when power is off). Insulate the pins on the switch, including any unused ones.

3 - Connect the Active wire from the front panel switch to one side of the transformer primary.

4 - Connect a wire to the IEC Neutral pin running alongside the Active run to the front panel, then to the terminal strip using blue mains-rated wire.

5 - From here, connect to the other side of the transformer primary.

6 - Connect the Earth pin of the IEC connector to the chassis Earth lug using a 3.2-4mm solder lug or (even better) crimp eye terminal screwed down securely to an M3 machine screw to the chassis. Make sure that the paint on the chassis is scraped back to bare metal and that you have a star washer to cut through to the chassis under the bolt. Use green/yellow striped wire for this.

7 - Score and fold the 120 x 40mm sheet of Presspahn to form an L-shape 90mm tall, 30mm wide and 40mm deep. Mount it between the mains input and speaker terminals using a 10mm machine screw, flat washer, shakeproof washer and nut as shown in Figs.23 & 26, just touching the bottom of the lid.

Active Crossover

When building the Active Crossover, install Altronics H0655 heatsinks (or equivalent) in place of the suggested Altronics H0650. These are twice the size and will keep the regulators cool during operation.

Compensation for baffle diffraction requires a slight boost to the bass/mid output below about 250Hz. This compensates for diffraction from the edges of the loudspeaker for the particular enclosure. The following changes suit the Active Monitor Speakers; for others, you will need to change the values:

1 - Instead of 100Ω at the output of the midrange/bass section, use 1kΩ (these are next to RLY2).

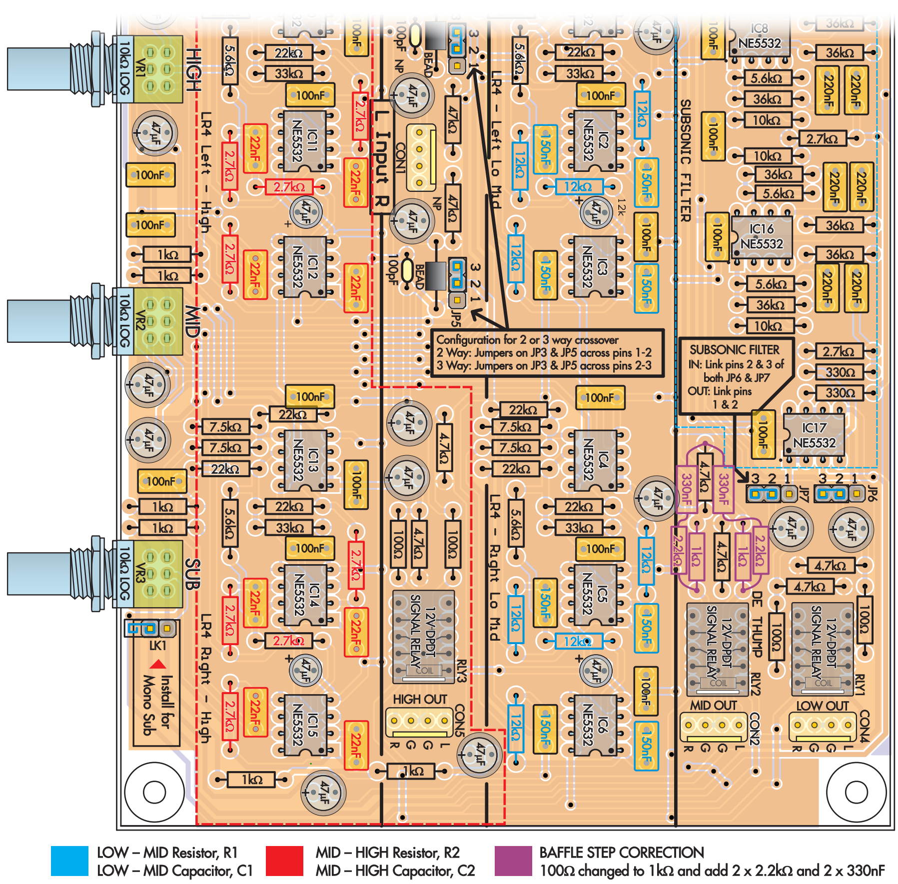


Fig.25: the annotations show the components whose values determine the crossover frequencies, plus the changed parts for the 'baffle step correction'. The full overlay for the Active Crossover PCB is shown in the October 2021 issue.

2 - Connect a 2.2kΩ resistor in series with a 330nF MKT capacitor and connect this network from the junction of the 1kΩ resistor & relay to ground.

The modified Active Crossover circuit is shown in Fig.24, while PCB changes are shown in Fig.25.

Also, when building the Active Crossover, set it up for dual rail operation and set the jumpers as described in the original article. It's a good idea to do a quick bench test to check its operation after construction. Feeding it with ±15V DC will allow you to check that the regulators are generating the correct output voltages, and that the de-thump relays click out after a couple of seconds.

The jumpers on the Active Crossover need to be set as follows:

- Three-way operation is achieved with JP3 and JP5 set to pins 2-3.
- JP1 and JP2 set to pins 1-2 for dual-rail operation.
- I left the 20Hz subsonic filter in, but note that the active subwoofer will generate useful output below that! To do this, set JP6 and JP7 set to pins 2-3.

Other choices you need to make when building the Active Crossover are whether it should be a two-way or three-way crossover and what the crossover frequencies should be.

We will configure it as a three-way crossover (with the lowest output for the subwoofer) and crossover frequencies of 88Hz for Low-Mid and 2.7kHz for Mid-High. However, if you are not planning on using the system with a subwoofer, you will need to change it to a two-way crossover at 2.7kHz.

The required component values were given in Table 1 on page 48 of the October 2021 issue. They are 12kΩ/150nF for 88Hz (Low-Mid) and 2.7kΩ/22nF for 2.7kHz (Mid-High). MKT capacitors are readily available in both values in either 5% tolerance (preferable) or 10%. Use 1% metal film resistors for the best precision. The locations for all these components are also shown in Fig.25.

Now install the Active Crossover in the case. The front panel should have been drilled to suit it already. Power wiring for the Crossover should have been connected to the power supply already; route and trim this to connect to the power connector at the right front corner of the Active Crossover.

Doing the input and output wiring for the Active Crossover involves

Parts List – Active Monitor Amplifier / Crossover

1 430mm wide, 330mm deep 2RU black rack-mount case **[Altronics H5038]**
4 assembled Hummingbird amplifier modules (Silicon Chip, December 2021)
1 assembled 4-way Speaker Protector with larger heatsink (see text) (January 2022)
1 assembled Stereo Active Crossover with modifications as per text (October 2021)
1 300mm wide, 75mm tall diecast aluminium heatsink, 10mm fin spacing, 0.37°C/W **[Altronics H0545 or two Jaycar HH8555 joined with hole position adjustments]**
1 300VA 25-0-25 toroidal mains transformer **[Altronics M5525C]**
1 double-sided PCB coded 01112221, 146.5 × 108.5mm
1 250V 3A+ SPST power switch (toggle, rocker etc)
1 normally-closed thermal switch/breaker, 250V AC 10A, 70°C **[Jaycar ST3823]**
8 TO-3P insulating kits **[Altronics H7220]**
4 TO-126 insulating kits **[Altronics H7120]**
1 small tube of thermal paste
1 3.2-4mm solder lug or crimp eyelet connector

Connectors & fuses
1 chassis-mounting IEC mains input socket **[Altronics P8320B]**
4 chassis-mounting dual red/black binding posts **[Altronics P9257A]**
1 red chassis-mounting insulated gold RCA socket **[Altronics P0218]**
1 black chassis-mounting insulated gold RCA socket **[Altronics P0220]**
2 yellow chassis-mounting insulated gold RCA sockets **[Altronics P0219]**
1 8-way 17.5A terminal block strip **[Altronics P2135A]**
6 4-way 5mm terminal blocks (CON1-2, 4, 6-8) **[Altronics P2026A]**
1 2-way 5mm terminal block (CON9) **[Altronics P2034A]**
4 2-way polarised header plugs with pins **[Altronics P5472 × 4 + P5470A × 8]**
1 M205 10A chassis-mount safety fuse holder **[Altronics S5992 or Jaycar SZ2028]**
1 M205 5A fast-blow fuse
4 M205 PCB-mount fuse clips
2 M205 250V 10A ceramic fuses

Hardware
1 M3 × 25mm .... 9 M3 × 16mm .... 9 M3 × 10mm .... 19 M3 × 6mm panhead screws
35 M3 shakeproof washers
32 M3 flat washers
7 M3 hex nuts
8 M3 × 10mm tapped spacers
40 100mm cable ties
2 sheets of Presspahn or similar insulating material, 80mm × 70mm & 120 × 40mm sheets

Wire & cable
1 2m length of each colour **(red, black, green & white)** heavy-duty (10A+) hookup wire
1 2m length of 7.5A mains-rated brown wire
1 1m length of 7.5A mains-rated blue wire
1 10cm length of 7.5A mains-rated green/yellow striped wire
1 150cm length of each colour **(green & white)** light-duty hookup wire
1 50cm length of red light-duty hookup wire
1 3m length of figure-8 screened cable **[Altronics W2995 or W3022]**
1 10cm length of each diameter **(3mm, 5mm & 10mm)** heatshrink tubing

Semiconductors
1 BC556 80V 100mA PNP transistor (Q1)
1 BD139 80V 1A NPN transistor (Q2)
1 BC546 80V 100mA NPN transistor (Q3)
2 5mm LEDs, any colour (LED1, LED2)
1 12V 400mW zener diode (ZD1) **[eg, 1N963]**
1 400V+ 35A chassis-mount bridge rectifier with spade terminals (BR1)
1 1N4148 75V 200mA signal diode (D1)

Capacitors
6 10,000μF 50V electrolytic, 10mm lead spacing (6800μF-15,000μF acceptable)
1 47μF 50V low-ESR radial electrolytic
2 330nF 63V MKT 1 •

Resistors *(all 5% 5W wirewound unless otherwise stated)*

3 22kΩ 1% 0.6W metal film	2 3.3kΩ 1W	2 2.2kΩ 1% ¼W metal film •
2 1kΩ 1% ¼W metal film •	1 100Ω	2 82Ω

• *for the baffle step correction (see Fig.25)* making four flying leads of 800mm length using figure-8 shielded cable, plus two at 350mm long. To make the cables, you need the following parts (also in the parts lists):

- 4 × four-way 2.54mm polarised header plugs with matching pins
- 4 × two-way 2.54mm polarised header plug with matching pins
- 2 × 80cm lengths and 2 × 35cm lengths of figure-8 screened cable
- 3mm and 5mm heatshrink tubing

Photo 14 shows what the header ends of these cables should look like. To make them:

1 - Start by separating the two coax channels, then strip 25mm of the outer sheath from each, exposing the braid.

2 - Tease the inner conductor from the braid and strip the end by 5mm.

3 - Twist the braids together into a neat bundle.

4 - Cut two 20mm lengths of 3mm heatshrink, such that when put on the braid, it will leave enough exposed copper to crimp to.

5 - Slide a 10mm-long, 5mm diameter piece of heatshrink over both the braid and central conductor but do not shrink it yet.

6 - Slide the 3mm heatshrink over the braid; there should be 4-5mm of wire protruding. Shrink this down.

7 - Slide the 5mm heatshrink to cover about 3mm of the junction where the braid and inner core separate and shrink it down.

8 - Present the braid to the crimp connector. You need to trim off excess braid wire so that the strain relief crimp will go over it, and there is about 3mm of braid wire in the electrical crimp section.

9 - Take one of the pins and, using sharp-nosed pliers, crimp the end of the braid conductor. Carefully add a tiny amount of solder to the crimped part, careful not to let it wick down to the spring section.

10 - Strip back 3mm from each of the inner conductors and crimp and solder as above. I was dissatisfied with the strain relief crimp missing the plastic and added a small piece of heatshrink, but that is optional.

11 - Now push the pins into the header plug, with the braids in the middle and left and right conductors on the outside. You will feel and/or hear a click when they seat properly.

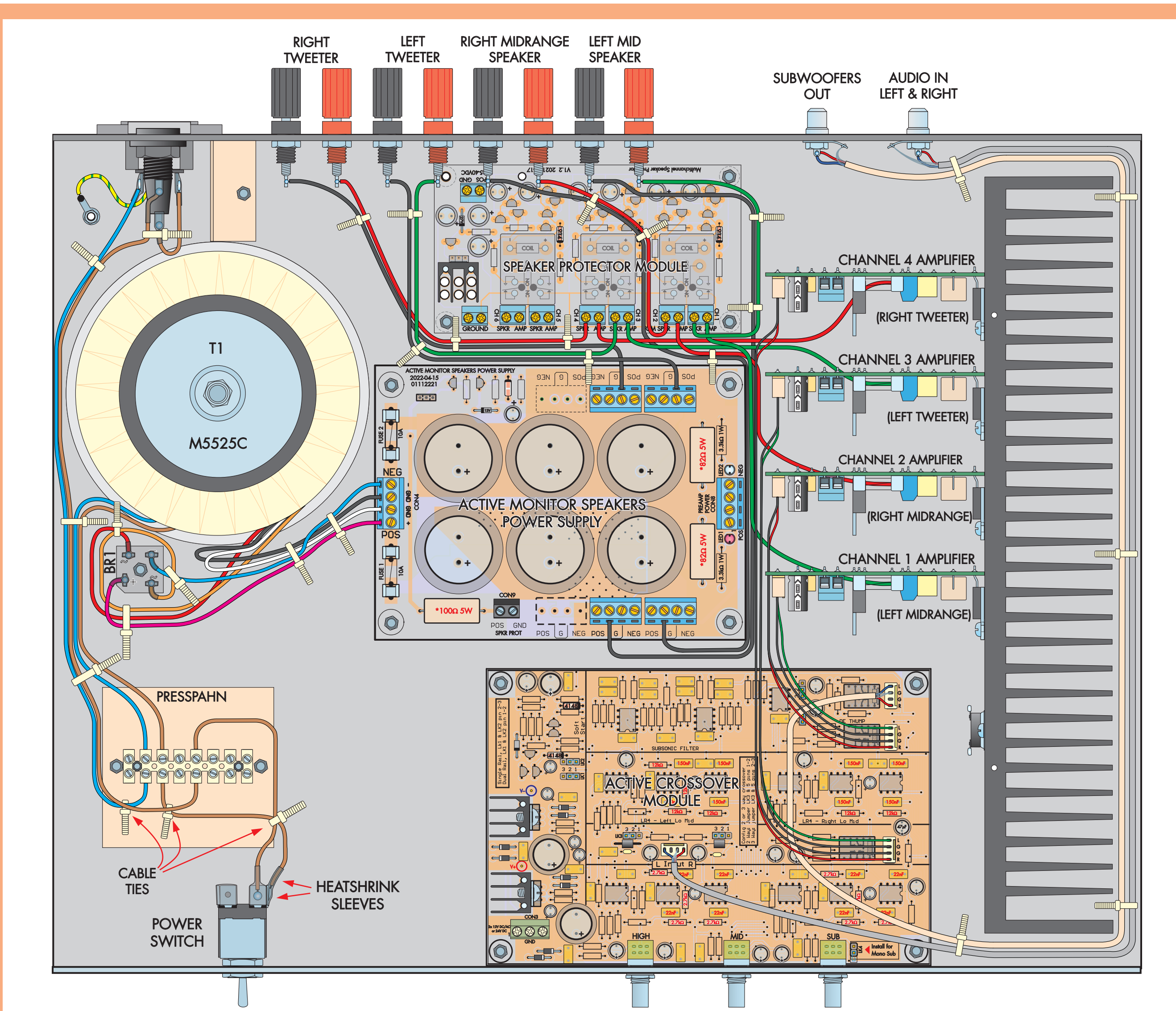


Fig.26: the signal wiring for the Active Monitor Speakers. While the wires from the Active Crossover board to the Hummingbird amplifier modules are shown separately for clarity, they should be run using figure-8 shielded cable to avoid hum and buzz pickup.

Now that you've made the cables, you can complete the signal wiring as in Fig.26. The input and subwoofer output connections go to the rear panel, while the midrange/woofer and tweeter outputs go to the amplifier modules. I opted to use modules 1 and 2 (the two most forward in our case) for the midrange/woofer and modules 3 and 4 (rearmost) for the tweeters. The final configuration is shown in Photo 15.

Testing

By this stage, you should have verified that the amplifier modules, Speaker Protector and Active Crossover function correctly. The next steps are a few safety checks:

1 - Using a DMM, check that there is no continuity between the chassis and the power supply ground (or, for that matter, the main positive and negative DC rails). The aim here is to check the integrity of the insulation bushes. If your meter registers a resistance on its 20MΩ range, you need to find and fix the conductive path.

2 - Using a DMM, check that there is a solid connection between the Earth pin of the mains socket and all chassis panels. You should get a reading under 1Ω in each case. If not, find the problem and, if necessary, add Earth jumpers from the affected panels to the base panel or main Earth lug.

3 - Using a DMM, check that there is no continuity from the Active/ Neutral wiring to the amplifier's chassis and the power supply 0V point. If your meter registers a resistance on the 20MΩ range, you need to find and fix the conductive path.

Assuming that all checks out, insert the 5A mains fuse in the chassis holder and, while monitoring the voltage across the main supply rails, briefly switch on mains power. As you need to do this with the lid open, ensure you stay clear of the mains wiring while it's switched on. Use two DMMs with alligator clip leads attached so you can do it hands-off.

If you don't have two DMMs or enough clip leads, connect a DVM between the main positive and negative rails.

The rails should very quickly rise to close to ±35V or 70V total. They could be a few volts higher or lower than that. If you don't get the correct reading(s), switch off quickly and check the following:

- Carefully check all of the mains wiring.
- If the voltage is zero: is the fuse blown? Is the switch on?
- Is there mains voltage across the transformer primary? You can check this by probing the terminal strip.
- Is there AC at the input to the bridge rectifier?
- Is there pulsating DC at the power supply input terminals?

The voltage across each pair of amplifier module outputs should be under ±50mV.

If that all checks out, apply an AC signal (or music) to the inputs and check that the sub, midrange/woofer and tweeter outputs behave as expected. If not:

- Check the wiring from the Active Crossover to the amplifier modules.
- Check that the amplifier modules have a reasonable output; this can be measured on the top of the emitter resistor using an oscilloscope probe or AC voltmeter.
- Check that the amplifier outputs go to the correct Speaker Protector terminals and, subsequently, the rear panel connector.
- Check that the Speaker Protector is working properly.

At this point, you should have a functioning Active Crossover Amplifier. The levels need to be set to match your speakers. The process for doing that was at the end of the article on the Active Monitor Speakers published last month, so refer back to that. If you're using the Active Crossover Amplifier with different speakers, you'll have to tweak the crossover frequencies and levels to suit.

Next month

The final article in this series will describe the High-Performance Subwoofer that can optionally be paired with the Active Crossover Speakers. It connects to the subwoofer output on the Active Crossover Amplifier and extends the bass of the system almost down to 20Hz.

We highly recommend that this Subwoofer be built as part of the system, although you can still enjoy the Active Monitor Speakers without it. SC

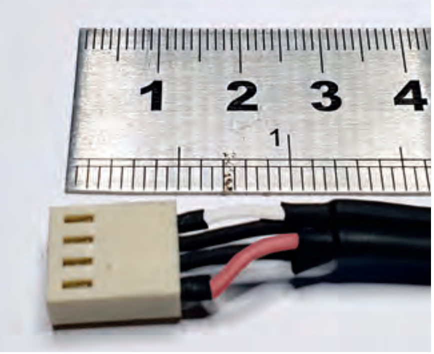


Photo 14: this is how each of the four stereo shielded cables should look once terminated to the polarised plugs, ready to connect to the Active Crossover board.

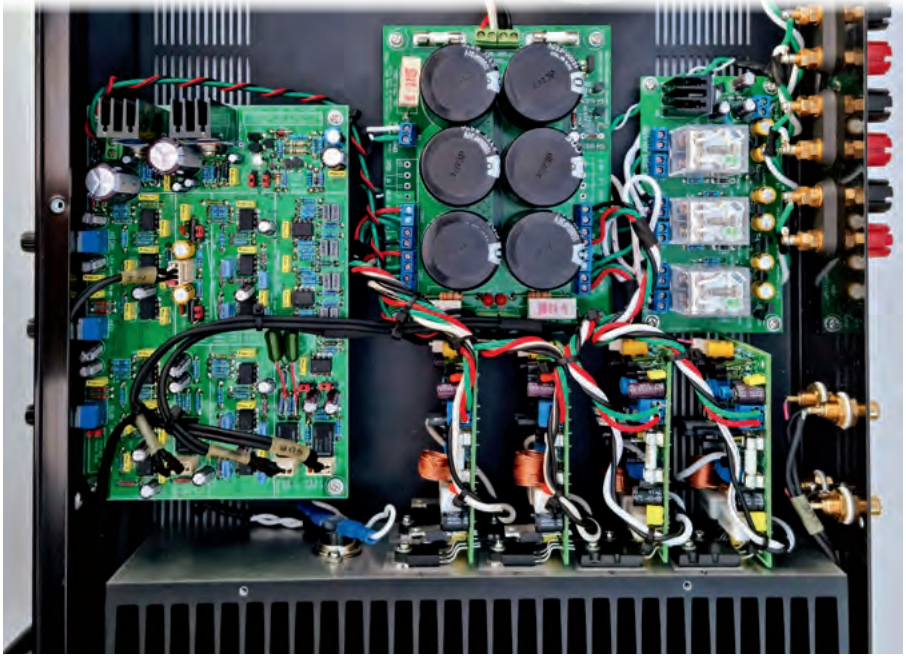


Photo 15: a close-up shot showing the details of the complete low-voltage DC and signal wiring.