



Building the: Studio 350 Power Amplifier Module

Last month, we introduced our rugged new 350W power amplifier module and gave the circuit details. This month, we show you how to build it and describe a matching power supply.

TO HELP ENSURE that everything goes together without a hitch, it's a good idea to read the following information in its entirety before reaching for your soldering iron!

Referring to the overlay diagram in Fig.1, begin by installing all the wire links. There are 15 links in total, 11 of which must be formed from 1mm tinned copper wire. Use 0.7mm wire for the remaining four links. The over-

lay diagram shows the larger (1mm) links in red.

Set aside all of the heatsink-mounted transistors (Q4-Q17), the two 470 μ F electrolytic capacitors, choke (L1) and 6.3mm spade lugs for the moment. We'll deal with these in more detail shortly. All other components can now be installed, progressing from smallest to largest.

The 1W and 5W resistors should be mounted about 1mm proud of the PC board to aid heat dissipation. Also, be sure to orient the cathode (banded) ends of diodes D1-D5 as shown.

When installing the fuse clips, note that the small retaining lug on each clip must be positioned to the outer (fuse end) side, otherwise fuse installation will be impossible.

If you intend mounting the output transistors horizontally, then it's also necessary to install 3-pin header strips in the mounting positions for Q8 & Q9. As we'll see shortly, these are required because the transistor leads are too short to extend all the way through the PC board holes.

TO-220 heatsinks

Transistors Q4, Q5 & Q6 must be attached to TO-220 heatsinks before fitting them to the PC board. First, smear a thin film of heatsink compound to both the rear (metal) area of each transistor as well as the mating areas of the heatsinks. That done, fasten them to the heatsinks using M3 screws, nuts and washers (see Fig.2) but don't fully tighten the screws just yet. Note that insulating pads are not required here.

Now slip each assembly into place in its PC board holes, taking care not to mix up the BF469 and BF470 types. The tabs of the heatsinks should fully engage the holes in the PC board, such that all of the heatsink edge contacts the PC board surface.

Finally, push the transistors all the way down the slots in the heatsinks and then tighten up the screws. The transistor leads can now be soldered, taking care that the assemblies remain in place when the board is turned over.

Winding the choke

If you've building your amplifier module from a kit, the 6.8µH choke may have been supplied pre-wound. If so, all you'll need to do is scrape the enamel insulation off the wire ends, tin them and solder the part in place.

Alternatively, it's a relatively simple matter to wind the choke yourself. You'll need a 13mm I.D. plastic former (bobbin) and about three metres of 1mm enamelled copper wire.

Begin by bending the wire at right angles, about 10mm from one end. This will be the starting end. Slip it into the bobbin and position the end in one of the slots.

Now wind on 23.5 turns as evenly and tightly as possible, then pass the remaining wire length out through the opposite slot and cut off any excess,

Parts List

- 1 PC board coded 01102041, 136mm x 241mm
- 1 6.8µH air-wound choke (L1) (see text)
- 1 2-way 2.54mm terminal block (CON1)
- 2 3-way 2.54mm pitch SIL headers (for Q8 & Q9)
- 3 TO-220 heatsinks, 25mm x 12.5mm with PC board tabs
- 1 diecast heatsink, 300 x 75mm, 35mm shelf (0.4°C/W or better)
- 8 TO-3P or TO-264 silicone-based insulating pads
- 2 TO-220 silicone-based insulating pads & washers
- 1 TO-126 silicone-based insulating pad
- 350mm (approx.) 1.0mm tinned copper wire for links
- 70mm (approx.) 0.7mm tinned copper wire for links
- 4 M205 PC-mount fuse clips (F1, F2)
- 2 M205 5A slow-blow fuses
- 5 6.3mm chassis-mount spade lugs
- 10 220nF 100V MKT polyester
- 1 150nF 250V MKT polyester
- 1 100nF 63V MKT polyester
- 1 12nF 100V MKT polyester
- 1 330pF ceramic disc
- 1 68pF 250V ceramic disc (or mica) (Farnell 867-871)
- 1 10pF ceramic disc

Resistors (0.25W 1%)

- 2 22kΩ 1 1kΩ
- 1 18kΩ 1 680Ω
- 1 15kΩ 1W 1 470Ω
- 1 6.8kΩ 1W 10 100Ω
- 2 4.7kΩ 1 10Ω
- 1 2.2kΩ

Wirewound resistors

- 2 470Ω 10W wirewound (for setup)
- 1 6.8Ω 5W wirewound
- 8 0.47Ω 5W wirewound

Trim pots

- 1 200Ω 25-turn miniature horizontal trimpot (VR2)
- 1 100Ω 25-turn miniature horizontal trimpot (VR1)

Screws & nuts

- 8 M3 x 20mm pan-head screws
- 3 M3 x 15mm pan-head screws
- 3 M3 x 10mm pan-head screws
- 14 M3 nuts
- 28 M3 flat washers
- 5 M4 or 3BA x 10mm pan-head brass screws
- 5 M4 or 3BA brass nuts
- 10 M4 or 3BA internal star washers (brass or stainless steel)

Power supply

- 1 50V+50V 500VA toroidal mains transformer (Altronics Cat. M-5750)
- 1 35A 400V chassis-mount bridge rectifier
- 6 8000µF 75V chassis-mount electrolytic capacitors (Altronics Cat. R-6722)
- 2 470nF 100V MKT polyester capacitors
- 4 15kΩ 1W resistors

Semiconductors

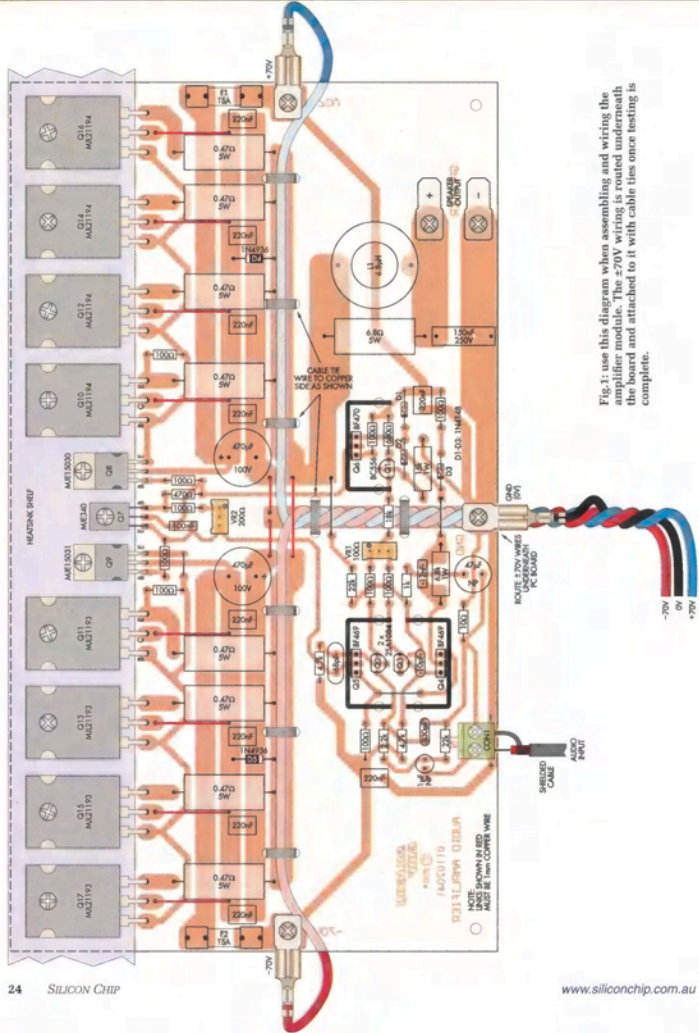
- 1 BC556 PNP transistor (Q1)
- 2 2SA1084 PNP low-noise transistors (Q2, Q3)
- 2 BF469 NPN transistors (Q4, Q5)
- 1 BF470 PNP transistor (Q6)
- 1 MJE340 NPN transistor (Q7)
- 1 MJE15030 NPN transistor (Q8)
- 1 MJE15031 PNP transistor (Q9)
- 4 MJL21194 NPN transistors (Q10, Q12, Q14, Q16)
- 4 MJL21193 PNP transistors (Q11, Q13, Q15, Q17)
- 3 1N4148 small-signal diodes (D1-D3)
- 2 1N4936 fast-recovery diodes (D4, D5)

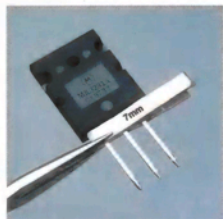
Capacitors

- 2 470µF 100V PC electrolytic (Farnell 319-9149)
- 1 47µF 16V non-polarised PC electrolytic
- 1 1µF 16V non-polarised PC electrolytic

leaving about 10mm protruding. Finally, wind on a couple of turns of insulation tape to hold everything in place.

You can now test-fit the assembly in position, bending the leads as necessary to get the bobbin to sit down on the PC board surface. That done,





A strip of cardboard cut to the correct width (7mm) makes a handy bending guide for the leads of the heatsink-mounted transistors.

scrape the enamel insulation off the wire ends with a scalpel blade or similar and tin them before soldering the choke permanently in position.

Lug terminations

Except for the audio line input, all connections to the PC board are made via 6.3mm spade lugs. If the lugs are double-ended, then cut off one end using electrician's sidecutters. Position each lug as shown on the overlay diagram and fasten it securely to the PC board using the method depicted in Fig.3.

We recommended raw brass (rather than nickel-plated) screws and nuts for securing the lugs. As noted in several of our recent high-power amplifier designs, these return a slightly lower distortion figure at the high-power end of the spectrum.

Apart from the main heatsink-mounted transistors, the only parts yet to be installed are the two 470µF electrolytic capacitors. These can go in now, with an eye to correct orientation. Take particular care here, as they're oriented differently to one another. If you get one the wrong way around, it will be damaged at power up and may even explode!

Horizontal heatsink mounting

The amplifier module was designed for mounting to the horizontal shelf of a diecast heatsink. However, a vertical-mounting configuration is also possible – see the panel entitled "Using Different Heatsinks" for a discussion of this alternative method.

We recommend an Altronics 300mm diecast heatsink with 35mm shelf (Cat. H-0452), as used on the prototype. So let's look at how the PC board and transistors are attached to this heatsink.

The only guaranteed way of getting it all the heatsink holes in the right places is to use the PC board as a drilling template. First, find the smoothest side of the heatsink shelf and place it upwards. That done, position the PC board on the top of the shelf and butt it right up against the main body of the heatsink, centred left to right within the available space.

Next, making sure that nothing moves (clamp the board to the shelf if necessary), use a sharp pencil to mark through all 11 transistor mounting holes. Be sure to mark a clean circle around the circumference of each hole, so that you'll easily be able to find the centre. Remove the PC board

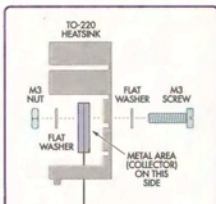


Fig.2: transistors Q4-Q6 must be attached to TO-220 heatsinks as shown here. Insulating pads are not necessary, but you should apply heatsink compound to the mating surfaces.

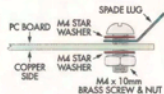


Fig.3: here's how to bolt up the spade lugs. If you have double-sided lugs, cut off one side with heavy-duty sidecutters first. Tighten them up enough so that they don't move around when the receptacles are pushed on.

and gently centre-punch your marks before drilling.

Initially, drill a pilot hole at each mark, using a 1mm bit. Finish with a 3.3mm bit, then deburr the holes by hand using a much larger drill

Table 1: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
□	2	22kΩ	red red orange brown	red red black red brown
□	1	18kΩ	brown grey orange brown	brown grey black red brown
□	1	15kΩ	brown green orange brown	brown green black red brown
□	1	6.8kΩ	blue grey red brown	blue grey black brown brown
□	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
□	1	2.2kΩ	red red red brown	red red black brown brown
□	1	1kΩ	brown black red brown	brown black black brown brown
□	1	680Ω	blue grey brown brown	blue grey black black brown
□	1	470Ω	yellow violet brown brown	yellow violet black black brown
□	10	100Ω	brown black brown brown	brown black black black brown
□	1	10Ω	brown black black brown	brown black black gold brown
□	2	470Ω 10W	not applicable	not applicable
□	1	6.8Ω 5W	not applicable	not applicable
□	8	0.47Ω 5W	not applicable	not applicable

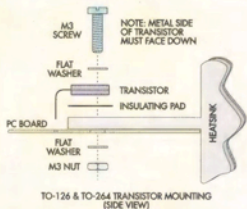


Fig.4: the mounting details for the TO-126 (Q7) and TO-264 (Q10-Q17) transistors. Don't solder the leads until the screws have been tightened to their final torque.

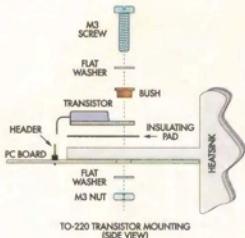


Fig.5: the leads of the TO-220 (Q8 & Q9) packages are too short to reach all the way through the PC board. Simply bend the leads so that they touch the header pins instead. Again, don't solder the leads until the mounting screws have been tightened.

Insulated TO126 Packages

Transistor Q7 (an MJE340) is supplied in a "plastic" TO-126 package. These packages usually include a small rectangular metal area on the rear. This area is electrically connected to the collector and therefore must be isolated from the heatsink with an insulating washer (see Fig.4).

However, some TO-126 packages do not have this metal area – they're "plastic" on both sides. This isolated type package should be mounted without an insulating washer. Simply smear its mating surface with a small amount of heatsink compound and bolt it directly to the heatsink.

size. Both sides of the shelf must be completely free of swarf and sharp edges.

By the way, a drill press is mandatory for this job, as drilling accurate holes in thick aluminium with a hand drill is extremely difficult.

Attaching the transistors

Now position the PC board beneath the heatsink shelf and insert two M3 x 20mm screws in the extreme left and righthand holes. Fit M3 washers and nuts (on the PC board side) and wind them up barely finger tight. The idea here is not to clamp the board against the heatsink shelf too tightly; it must be allowed to move at this stage. These screws are temporary placeholders and can be removed when necessary.

All transistors must be insulated from the heatsink with silicone-based pads. The TO-220 devices (Q8 & Q9) also require insulating bushes for the screws. Figs.4 & 5 shows how to mount each transistor type.

As you can see, the leads of each transistor must be bent at right angles before installation. The position of the bend should be placed so that the leads slip easily into the PC board holes while the mounting holes line up with the holes in the heatsink and the PC board underneath.

A strip of cardboard cut to the appropriate width makes a handy bending guide (see photo). Mount the TO-126 package (Q7) first, then progress outwards in left and right pairs (Q8 & Q9, Q10 & Q11, etc).

The two TO-220 transistors (Q8 & Q9) present a special case. Their leads are not long enough to reach all the way through the PC board holes, so instead must be soldered to the 3-pin headers installed earlier. However, do not solder to the header pins just yet. Simply bend the device leads so that they just make contact with the rear of the header pins.

You'll probably find that you need to trim a little off the leads so that they don't interfere with the plastic base of the header strips.

Wind up the nuts only finger tight during installation. Once they're all in place, go back and tighten each one to

the final torque, starting in the middle and working towards the sides. Don't overtighten – about one click of the elbow is more than enough!

That done, set your meter to read Ohms and measure between the heatsink and the centre lead (collector) of each device. You should get an open circuit reading in all cases.



Although featuring a different amplifier module, this picture shows the vertical mounting method for the output and driver transistors.

If everything checks out, then solder all transistor leads to complete the assembly.

Note that the mounting screws must be tightened up before soldering the leads. If this is done in reverse order, then stress will eventually crack the solder joints and perhaps even delaminate the PC board copper.

Vertical heatsink mounting

Details for vertical mounting will vary according to the style of heatsink. However, we've included a rough guide to get you started. Of course, you must have already modified the PC board as described in the "Using Different Heatsinks" panel!

To begin, use what ever you have on hand to raise the PC board to the required mounting height. A pair of 3mm holes is provided at the rear of the board for tapped spacers but you'll also need to place something under the front of the board to bring it back to the horizontal position.

Next, fit the 11 transistors (Q7-Q17) into their respective mounting holes but don't solder or cut any of their leads just yet! That done, butt the assembly up against your chosen heatsink and centre it roughly within the available space. Note that the transistors should be mounted as close to the centre of the heatsink as practical although this will be affected by the available transistor lead length.

If possible, line up the transistors so

that the mounting holes will fall between the heatsink's cooling fins. This way, you can avoid the additional task of thread tapping.

Once you're happy with the positioning, mark through each transistor mounting hole with a sharp pencil. Now centre-punch each mark and drill 1mm pilot holes. Redrill to 3.3mm if you'll be using screws with nuts, or use a smaller, 2.5mm bit size in preparation for M3 thread tapping.

After drilling, deburr the holes by hand using a much larger drill size so that the mating surface is entirely smooth.

Attaching the transistors

Loosely attach the transistors to the heatsink using insulating pads and bushes where necessary. The requirements here are similar to those shown for horizontal mounting as shown in Figs. 4 & 5. Be sure to check that the PC board is sitting horizontal and at right angles to the heatsink before tightening up the screws. It's then just a matter of

turning the assembly over and soldering all transistors in place.

Finally, it's a good idea to make sure that all transistor collectors are indeed isolated from the heatsink. To do this, set your meter to read Ohms and measure between the heatsink and the centre lead (collector) of each device. You should get an open circuit reading in all cases.

Power supply assembly

Due to the weight of the mains transformer, the power supply components

DANGER: HIGH VOLTAGE! ⚡

The 140V DC supply across the filter capacitor bank and the amplifier supply rails is potentially lethal! After the power supply wiring is complete and before you apply power, mount a clear Perspex sheet over the capacitor bank to protect against inadvertent contact - now or in the future! Note that the capacitors take some time to discharge after the power is switched off.

Table 2: Capacitor Codes

Value	μF Code	EIA Code	IEC Code
220nF	0.22 μF	224	220n
150nF	0.15 μF	154	150n
100nF	0.1 μF	104	100n
12nF	0.012 μF	123	12n
330pF	-	331	330p
68pF	-	68	68p
10pF	-	10	10p

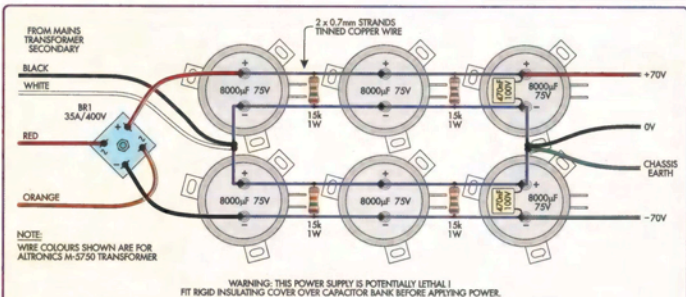


Fig.6: the power supply wiring is quite straightforward. Take particular care that you have the positive (+) and negative (-) terminals of the capacitors connected as shown. The same goes for the bridge rectifier, also noting that it must be bolted firmly to a metal surface for heatsinking.

Using Different Heatsinks

As shown in the various photos, the transistors on our prototype are mounted horizontally, on the shelf of a large diecast heatsink. This method of mounting is mechanically robust and relatively easy to assemble but obviously unsuitable for heatsinks without a shelf.

Suppose, for example, that you've decided to build a stereo unit, utilising a pair of Jaycar's fan-cooled tunnel heatsinks (Cat HH-8532). In this case, the transistors must be mounted vertically along the edge of the PC board, allowing them to be bolted directly to the heatsink faces. With just one modification, the PC board can accommodate this alternative, vertical mounting style.

This modification involves cutting off a portion of the PC board so that the transistors are just a few millimetres from the PC board edge. This must be done before any components are mounted on the PC board!

A thin broken track has been included on the PC board as a cutting guide. Note that there should be about 0.5mm of space between the pads/tracks and the board edge. This ensures that once the unit is assembled, the bare copper tracks can not short out on the face of the heatsinks. For this reason, we suggest cutting along the

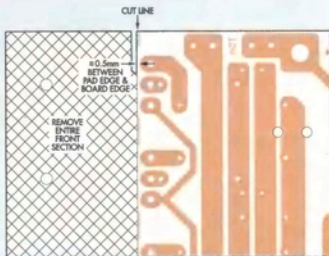


Fig.8: to enable vertical transistor mounting, cut off the entire front section of the PC board as shown here. You do not need to do this for the horizontal mounting style shown in the various photographs!

outside of the line, to allow for the width of the cut and any subsequent filing (see Fig.8).

must be mounted on a substantial metal baseplate. Typically, this will be the base of a rack-mount case or similar. If deemed necessary, the base can be strengthened with an additional plate to achieve sufficient rigidity.

The suggested wiring for the bridge rectifier (BR1) and capacitor bank is shown in Fig.6. The bridge rectifier must be attached directly to a flat area of the metal chassis for heatsinking. Smear the face of the rectifier and the contact area with a thin film of heat-sink compound before assembly.

The 8000µF capacitors are attached to the baseplate using circular clamps. They should be positioned as close

together as practical, with their terminals in line to allow hookup with lengths of solid-core wire. Use two strands of 0.7mm tinned copper wire or similar for a total wire diameter of at least 1.4mm for each connection.

If you only ever intend driving 8Ω speakers, the filter capacitor count can be reduced by two for a worthwhile saving. For 4Ω speakers, the full complement of six capacitors is required to achieve the listed power and distortion figures.

Connections to and from the capacitor bank should be made with extra-heavy duty (10A) multi-strand cable. The +70V, -70V and 0V wires leading away from the bank should be twisted tightly together to minimise radiated noise and improve appearance.

Before applying mains power, the capacitor bank must be covered with a rigid, non-conductive shield. A section of clear perspex is ideal for the job. This step is very important, as simultaneous contact with the +70V & -70V rails could easily kill you (or someone else)!

As shown on the wiring diagram, four 15kΩ 1W resistors must be installed across the ±70V rails. These will gradually discharge the capacitors after power is switched off. However, before working on any part of the circuit, always measure the supply rails

Where To Get The Parts

Kits for this amplifier project will be available from Altronics and from Jaycar Electronics. Check out their websites at www.altronics.com.au and www.jaycar.com.au for further details.

Individual items can be obtained from the usual kit suppliers, including DSE, Altronics and Jaycar. The 2SA1084 low-noise transistors are available from WES Components, on the Internet at www.wescomponents.com or phone (02) 9797 9866.

Parts shown with a Farnell catalog number can be ordered on-line at www.farnell.com or phone 1300 361 005.

with a multimeter first to make sure that it is safe to do so.

Wiring

Housing and wiring of the amplifier modules is totally up to you. However, we've outlined a few points below that will help you to get the most from your amplifier.

First, never take shortcuts with mains wiring. Always use mains-rated

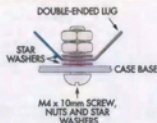


Fig.7: the mains earth should be securely attached to the base of the metal chassis as shown here. Tighten the first nut very firmly before winding on the second "locknut". The earth wire from the capacitor bank also connects to this point.

cable and be sure to insulate all exposed connections. This includes the use of rubber boots (or equivalent) on the rear of IEC sockets, switches and fuseholders.

The mains earth must be connected to the metal chassis using the arrangement shown in Fig.7. Return all earth wires to this point to eliminate potential earth loops.

Use extra heavy-duty (10A) multi-strand cable (or larger) for all power and speaker connections. The wire ends need to be terminated with 6.3mm push-on receptacles to suit the board-mounted lugs. These are available in insulated and non-insulated varieties.

For the insulated type receptacles, you'll need a ratchet-driven crimping tool, such as the Altronics T-1552, Jaycar TH-1829 or DSE T-3535. Don't be tempted to use a cheaper (non-ratchet style) crimper, as they're just not up to the job.

If you don't want to cop the expense of a new crimper, then you can use the non-insulated style receptacles and solder them on instead. These are available from DSE (Cat. H-5012) and most electrical wholesalers. While you're at it, get some terminal covers to suit (Cat. H-5022).

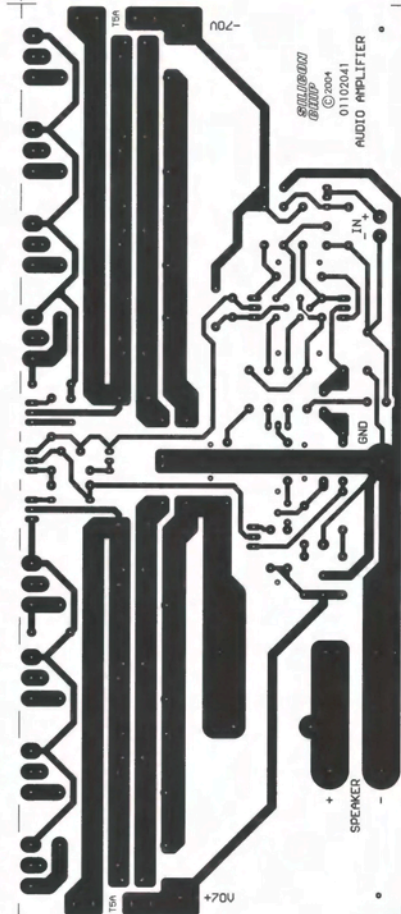
Supply wiring

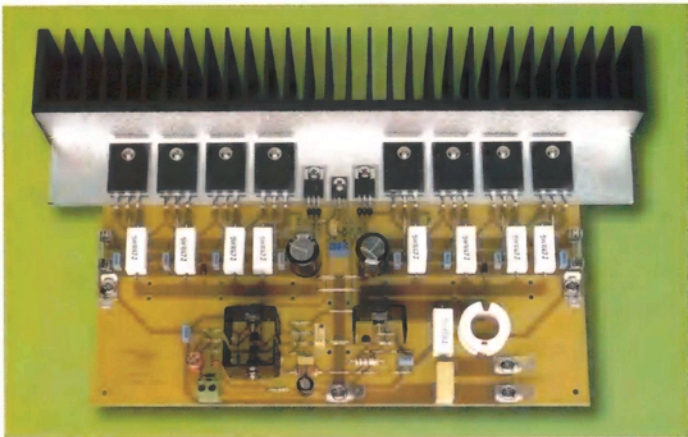
The +70V, -70V and 0V connections to the amplifier module should be twisted tightly together and positioned as shown on the overlay diagram. Note how the 0V wire connects to the centre lug, whereas the $\pm 70V$ wires continue beneath the PC board. Small cable ties are then used to secure the wires in place underneath the PC board.

Positioning the wires as shown helps to cancel the fields resulting from currents flowing in the PC board tracks. This produces the lowest possible signal distortion.

Setup & testing

With nothing connected to the power supply output, apply mains power and measure the positive and negative rails. Both readings should be close to the 70V mark, depending on mains fluctuations.





This is what the completed amplifier module looks like. Be sure to mount the 5W wirewound resistors about 1mm proud of the PC board, to allow the air to circulate beneath them for cooling. The spare holes in the PC board allow the supply power wiring to be secured in position using cable ties.

The next task is to zero the amplifier's input offset voltage and set the quiescent current in the output transistors. To protect the amplifier in case of faults and to simplify adjustment, remove both fuses from the board and solder a 470 Ω 10W resistor across each fuseclip pair. You may find it easier to tack solder the resistors on the rear (copper) side of the PC board.

Note that nothing should be connected to the input or output terminals until these checks are complete.

Set VR2 fully anticlockwise and

then apply power. With your multimeter set to read millivolts, measure the voltage across the output (speaker) terminals. Adjust VR1 for a reading of 0V \pm 2mV.

That done, set your meter to read 70V or more and measure the voltage across one of the 470 Ω 10W resistors. It's not important which one you choose. Rotate VR2 clockwise until you get a reading of 47V. This gives a total quiescent current of 100mA.

Now give the amplifier about 10 minutes to warm up, then readjust

VR2 if necessary. It's normal for this reading to vary by a few volts as circuit temperature varies.

To check that each output transistor is doing its job, you can measure the voltages across the 0.47 Ω emitter resistors. With about 25mA flowing in the emitter legs, you should get a reading near 11mV across each of these resistors. Note that the innermost pair of resistors also carry the driver transistor (Q8 & Q9) emitter current, so these two will read a few millivolts higher.

Problems?

If you're unable to adjust VR1 or VR2 for the specified readings, then there is a fault somewhere on the board. We've provided voltage readings for various points on the circuit that may help you to track down the problem (see Fig.7, Pt.1). Your readings should fall within \pm 10% of our listed values.

If everything checks out OK, switch off the power, remove the 470 Ω resistors and install the fuses. Your amplifier is now ready for use!

Errata: the 470 μ F 100V electrolytic capacitor connected to the -70V rail (adjacent to fuse F2) is shown reversed on the circuit diagram (Fig.7) on page 16 of last month's issue. **SC**

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