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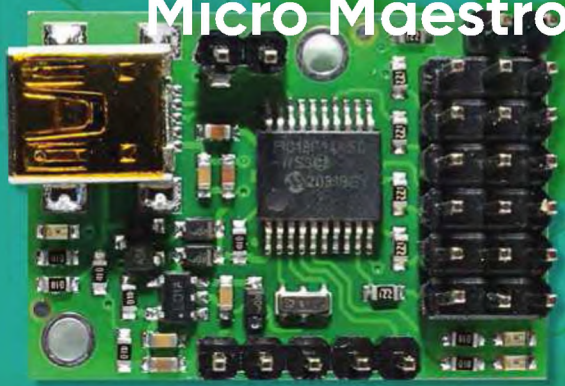

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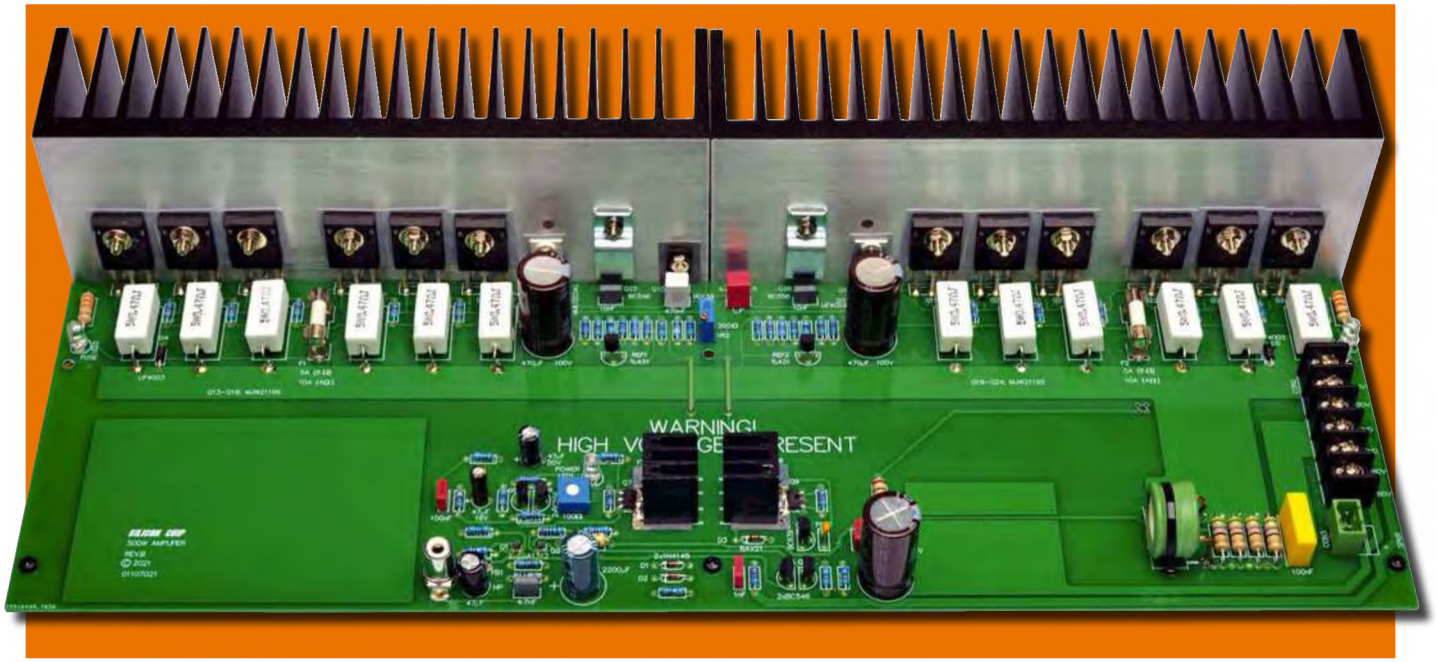
500 WATTS POWER AMPLIFIER

PART 2 BY JOHN CLARKE



Having described our new *500W Amplifier Module* last month, giving its performance details and describing the circuit, we follow on this month with the amplifier construction, beginning with the PCB (Amplifier Module) assembly. Next month, we'll build this into a complete amplifier, along with fan cooling, a speaker protector and a clipping detector.

The 500W Amplifier has four main components: the *Amplifier Module*, its power supply, the *Fan Cooling and Loudspeaker Protector* board and the *Clipping Indicator* board. The last two of those have already been described in the February and April 2023 issues respectively.

This article focuses on the assembly of the *Amplifier Module* – its circuit was described last month. Next month, the final article will detail the power supply, the chassis and the final assembly and wiring, bringing all those parts together.

Now let's move on to building the all-important *Amplifier Module*.

Construction

The *500W Amplifier Module* is built on a double-sided, plated-through PCB coded 01107021 that measures 402 x 124mm. Refer to Fig.6, the parts layout diagram during construction.

Before starting, it's a good idea to inspect the board carefully. This will familiarise you with its layout and reveal any defects (however unlikely that is).

Start construction by fitting transistors Q1 and Q2. These are small SOT-23/TO-236 surface-mounting devices. They are relatively easy to solder due to their widely spaced pins, but you might need the aid of a magnifying glass and strong light if your vision is not perfect.

First, align Q1 onto the pads, holding it with tweezers, and solder one of the pins to the PCB. Check that it is correctly aligned with the other pads, reheating the solder joint to realign if necessary. Then solder the remaining pins. Mount Q2 similarly.

Don't worry if you add so much solder that the joints on these SOT-23 parts look like small silver balls. This is unlikely to cause any problems; we want to joints to be shiny, and adding a bit too much solder is better than not adding enough!

If you feel the need to remove the excess solder, add a little bit of flux paste and touch the join with a clean soldering iron tip.

Now mount the small (¼W or ½W) resistors. Check each value using a digital multimeter set to read ohms before soldering in place. Don't just rely on the colour bands to determine the value, as these can be difficult to read accurately.

Note that there are two pairs of resistors labelled R1 and R2 on the PCB; they don't have associated values. The nominal values required for these resistors (which define the SOA protection curves) are R1 = 35.328kΩ and R2 = 204.8Ω. We can't get these exact values, but there are two ways we can get close.

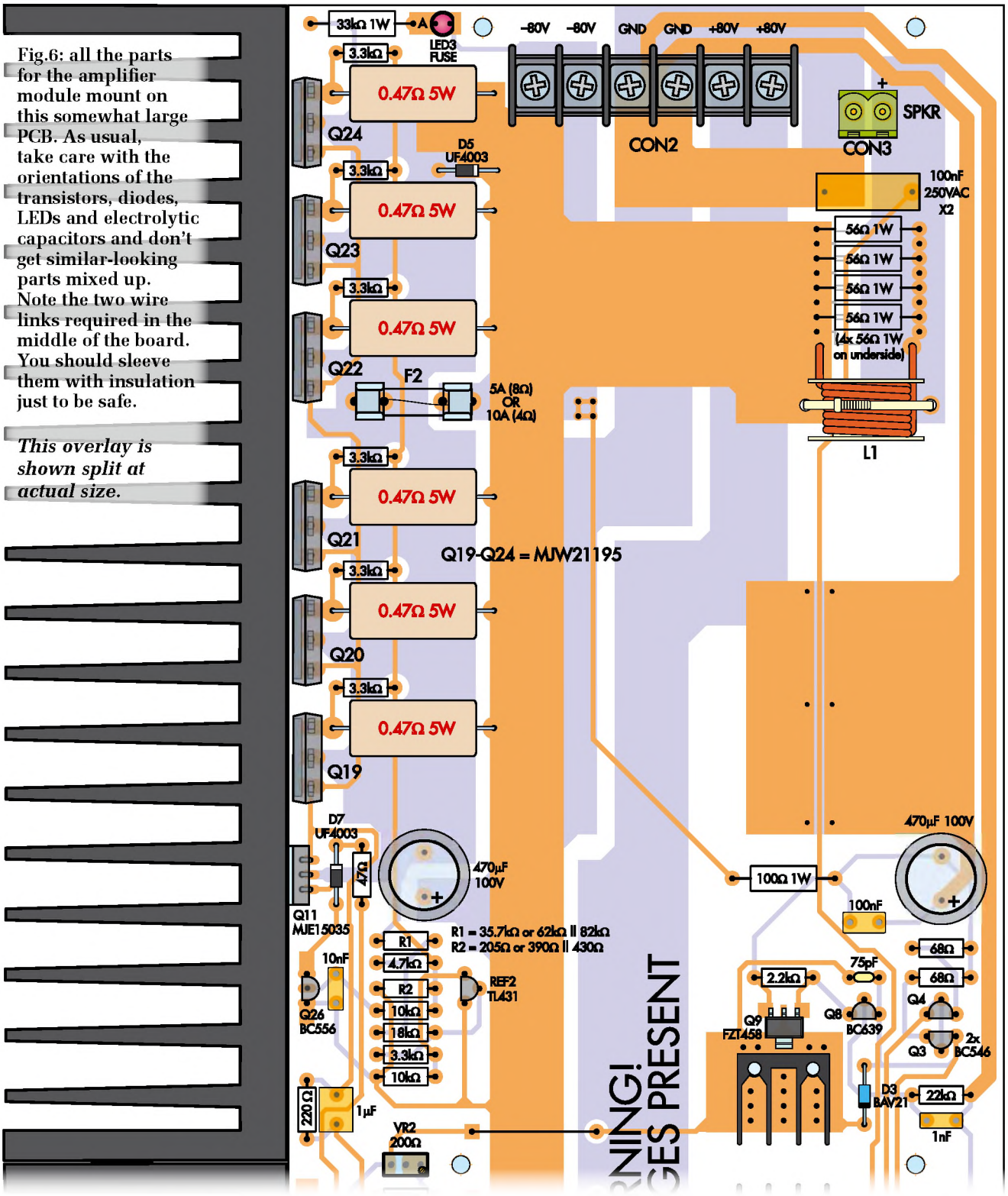


Fig.6: all the parts for the amplifier module mount on this somewhat large PCB. As usual, take care with the orientations of the transistors, diodes, LEDs and electrolytic capacitors and don't get similar-looking parts mixed up. Note the two wire links required in the middle of the board. You should sleeve them with insulation just to be safe.

This overlay is shown split at actual size.

We can use E96 value resistors, with R1 = 35.7kΩ (+1%) and R2 = 205Ω(+0.1%). That is the easy method, and if you buy the set of hard-to-get parts from us, you'll get the 35.7kΩ and 205Ω resistors – see the note in the Parts List in *Part 1* last month.

A slightly more precise method for R1 and R2 is to use paralleled pairs of resistors, one fitted to the top side of the PCB as normal, and the other soldered across the pads underneath afterwards. These are 62kΩ || 82kΩ for R1 giving 35.3kΩ (–0.08%) and 390Ω || 430Ω giving 204.5Ω for R2 (+0.15%).

We don't think the +1% error using 35.7kΩ for R1 matters; the current-sensing 0.47Ω resistors have 5% tolerances, and the protection curves have a built-in safety margin. Still, if you're concerned about it, you can use the parallel pairs instead.

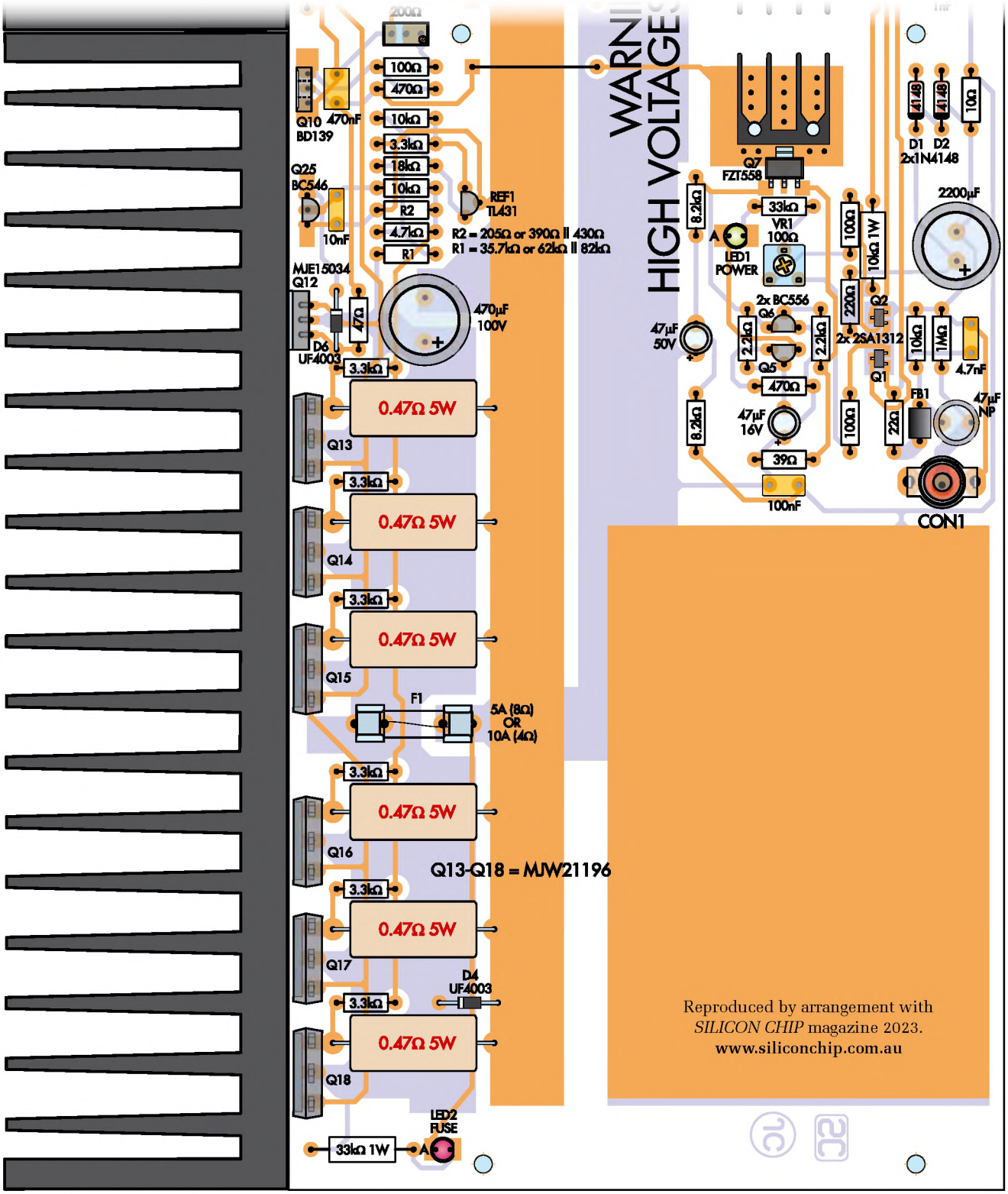
Fit these resistors in the eight positions, using your preferred method.

Now install the two small 1N4148 diodes (D1 and D2) with their striped ends (cathodes) as shown on the overlay diagram and PCB silkscreen. Next, fit the BAV21 diode (D3) with the cathode facing the same way.

The UF4003 diodes (D4-D7) can go in next. They are not all oriented the same way, so check Fig.6 and the PCB silkscreen.

There are two wire links in the middle of the PCB above Q7 and Q9. Make these using 0.7mm diameter tinned copper wire covered in 1mm heatshrink tubing over most of their lengths, leaving just the ends exposed.

Continue by mounting the 1W resistors, again being careful to check the values. For the 56Ω resistors near speaker connector CON3, four mount on the top side of the PCB and four on



the underside. The PCB screen printing shows the resistor positions on both sides.

Next, you need to fit the small-signal transistors in TO-92 packages next. These are Q3 and Q4 (BC546) plus Q5 and Q6 (BC556). Leave Q25 and Q26 off at the moment, as these need to be mounted against the heatsink. However, you can fit the two TL431 references now, also in TO-92 packages (REF1 and REF2). Read the device markings carefully, and be sure to install the correct type at each location.

The three LEDs are mounted about 5mm off the PCB, taking care to orient them correctly and using the green LED for LED1. The longer lead is the anode, and this position is marked with an 'A' on the board.

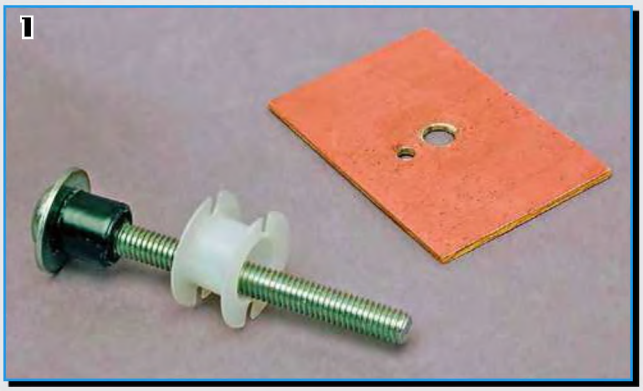
Fit the 75pF 200V capacitor now, along with the 1nF, 10nF, 100nF, 470nF and 1µF MKT capacitors. Follow with trimpot VR1, then VR2 with its adjustment screw towards the bottom of the board, as shown (right edge in Fig.6).

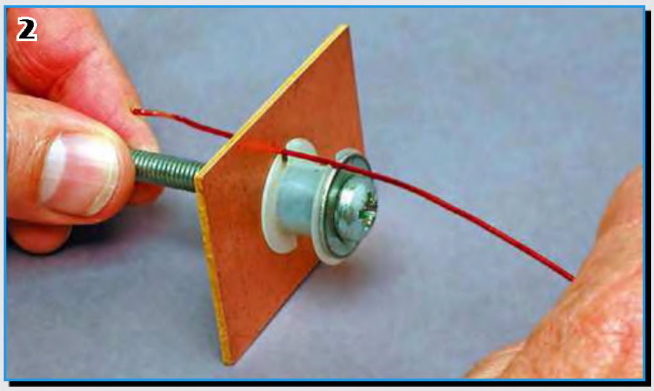
The four M205 fuse clips are next. Press them down fully onto the board before soldering and ensure that the retention clips are on the outside. The best approach to make sure the fuse clips are aligned correctly is to first fit a fuse to hold the fuse clips in position, then solder to the pads on the underside of the PCB.

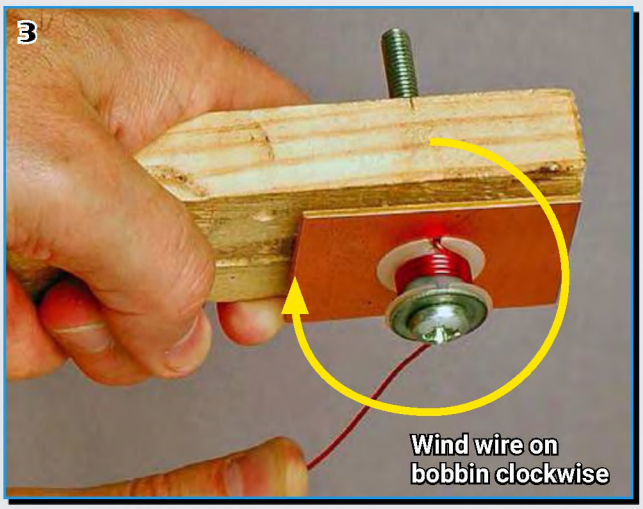
You can now solder in the 12 0.47Ω 5W resistors. These should be mounted about 2mm proud of the PCB so that cooling air can circulate beneath them. A cardboard spacer slid under the resistor bodies before soldering their leads can ensure consistent spacing.

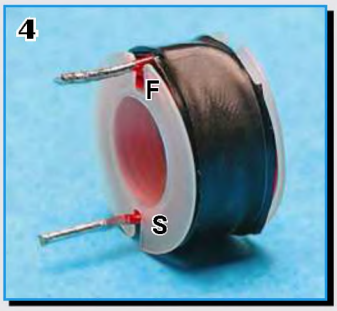
Now fit the connectors, ie, the RCA socket (CON1), the two-way socket for

L1 Winding Jig









These photos show how the winding jig is used to make the 2.2µH inductor. First, the bobbin is slipped over the collar on the bolt (1), then an end cheek is attached and the wire threaded through the exit slot (2). The handle is then attached and the coil tightly wound onto the bobbin using 13.5 turns of 1mm-diameter enamelled copper wire (3). The finished coil (4) is secured using a couple of layers of insulation tape and a band of heatshrink tubing.

The winding jig consists of a 70mm M5 bolt, two M5 nuts, an M5 flat washer, a piece of scrap PCB material or similar measuring approximately 40 x 50mm and a scrap piece of timber (about 140 x 45 x 20mm) for the handle.

In use, the flat washer goes against the bolt's head, after which a collar is fitted over the bolt to take the bobbin. This collar should be slightly smaller than the inner diameter of the bobbin and can be made by winding insulation tape onto the bolt, or from tubing. The collar needs to be of sufficient diameter for the bobbin to fit snugly without being too tight.

Drill a 5mm hole through the centre of the scrap PCB material, plus a 1.5mm exit hole about 8mm away that will align with one of the slots in the bobbin. The bobbin can be slipped over the collar, after which the scrap PCB end cheek is slipped over the bolt, ie, the bobbin is sandwiched into position between the washer and the scrap PCB.

Align the bobbin so that one of its slots lines up with the exit hole in the end cheek, then install the first nut and secure it tightly. Next, fit the handle by drilling a 5mm hole through one end, slipping it over the bolt and installing the second nut.

These photos show how the winding jig is used to make the 2.2µH inductor.

First, slip the bobbin over the collar on the bolt (1), then attach the end cheek and thread the wire through the exit slot (2). Next, attach the handle and wind the coil tightly onto the bobbin using 13.5 turns of 1mm-diameter enamelled copper wire (3). Finally, secure the finished coil (4) around the outside using 20mm diameter heatshrink tubing.

the loudspeaker connection (CON3) and the 6-way power connector (CON2). For CON3, first insert the terminal block plug into the socket and then install the socket into the PCB holes with the wire entries toward the outside edge of the PCB.

Now mount the 100nF X2 class capacitor located near CON3. The 47µF, 470µF and 2200µF electrolytic capacitors can then go in. The 47µF NP (non-polarised) electrolytic can go in either way around, but the others must all be oriented correctly.

Note that the 47µF capacitor above Q5 and Q6 must be rated to handle at least 50V (eg, a 63V type would be acceptable).

Mini heatsinks

Before fitting Q7 and Q9, you must first attach the heatsinks. Do this by inserting the mounting posts into the PCB holes and soldering these to the underside of the PCB. These will require a lot of heat from your soldering iron before the solder will successfully melt to secure the heatsink. Take care to avoid burning yourself on the hot heatsinks; wait until they are cool before mounting Q7 and Q9.

Now tackle Q7 (FZT558). It would help to spread a little flux paste on all four of its pads before placing the part. Align the device with the PCB pads and solder one of the pins to the PCB. Check for alignment and reheat the solder to realign if necessary. Then solder the remaining pins.

The metal tab needs to be soldered to the PCB right next to the heatsink. Again, you will need to heat it with your iron for an extended period due to the heatsink drawing heat away. Once the solder melts, though, solder the tab as quickly as possible to avoid overheating the device. Now install transistor Q9 (FZT458) in the same manner.

Winding inductor L1

The inductor (L1) is wound using a 0.9m length of 1mm diameter enamelled copper wire on a plastic bobbin (not 2m/1.25mm wire – an error in last

month's Parts List). Use a winding jig as shown above. Without it, it's a much more difficult procedure, and you risk damaging the relatively fragile bobbin. Attach the bobbin to the jig, then wind 13.5 turns of 1mm diameter wire in the clockwise direction as shown, leaving about 20mm free at each end.

When finished, secure the winding with a narrow strip of insulation tape, then slip a 15mm length of 20mm diameter heatshrink tubing over the bobbin and heat it gently (be careful to avoid melting the bobbin). Next, use a small, sharp hobby knife to scrape away the enamel from the protruding lengths of wire around the whole circumference and tin the exposed copper at the ends, ensuring the solder sticks.

The inductor can then be installed on the PCB, oriented as shown. Secure it with a cable tie over the top of the winding and through to the underside of the PCB.

Preparing the main heatsink

The next step is to drill the heatsinks using the drilling templates provided (Fig.7). It is essential to place the holes accurately, so they are centred between the heatsink fins. That way, the screw heads will fit neatly between the fins.

Before drilling the heatsink, you will have to carefully mark out the hole locations using a very sharp pencil, then use a centre punch (or hammer and nail) to mark the hole centres. Next, drill 3mm holes at all the marked positions.

It is best to use a drill press as it's challenging to get the holes perfectly perpendicular to the mounting face otherwise. Use a small pilot drill to begin with (eg, 1.5mm), then step up the drill size to either 2.5mm or 3mm. Use a suitable lubricant when drilling the holes. Kerosene is the recommended lubricant for aluminium, but we found that light machine oil (eg, Singer or 3-in-1) also works well for jobs like this.

The holes have to go between the fins, so check that the hole positions are correct before drilling them.

Don't try drilling each hole in one pass. When drilling aluminium, it's important to regularly remove the bit from the hole and clear away the metal swarf. If you don't do this, the aluminium swarf has a nasty habit of jamming the drill bit and breaking; it and can also scratch the heatsink face. Relubricate the hole and the bit each time before you resume drilling.

At this stage, 2.5mm holes can be drilled in the bottom edge of the heatsink, ready to be tapped with an M3 thread. Do this at two places along the bottom edge on each heatsink. This is for mounting the heatsinks to the chassis later.

Tapping

To tap the underside mounting holes, you will need an M3 intermediate (or starting) tap (not a finishing tap). The trick here is to take it nice and slowly. Keep the lubricant up and regularly wind the tap out to clear the metal swarf from the hole. Relubricate the tap each time before resuming.

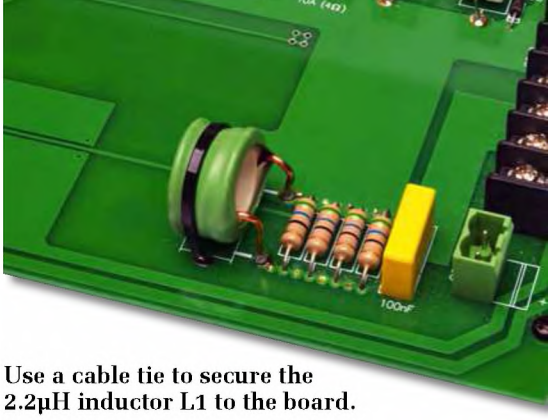
Do not apply undue force to the tap. It's all too easy to break a tap in half if you are heavy-handed. Similarly, if you encounter any resistance when undoing the tap from the heatsink, gently rotate it back and forth and let it cut its way back out. In short, don't force it, or it will break.

Finally, lightly deburr hole edges using an oversized drill bit and clean off any aluminium particles or swarf. Check that the area around the holes is perfectly smooth, or the insulating washers could be damaged. Scrub the heatsink thoroughly using water and detergent and allow it to dry.

Final assembly

Fig.8 shows the transistor mounting details. Start by mounting transistors Q13 to Q24, noting that Q13-Q18 are the MJW21196 transistors while Q19-Q24 are the MJW21195 transistors. Q13-Q18 are mounted on the left-hand heatsink and Q19-24 on the right-hand heatsink. The locations for these are shown in Fig.7 (you can also refer to Fig.6).

These all mount with a silicone insulating washer between each transistor and the heatsink face. They are secured using M3 x 20mm machine screws inserted between the heatsink fins and a flat metal washer and M3 nut against the transistor face. Do *not* tighten the screws yet, so you can move the insulation washers and transistors to allow mounting onto the PCB.



Use a cable tie to secure the 2.2µH inductor L1 to the board.

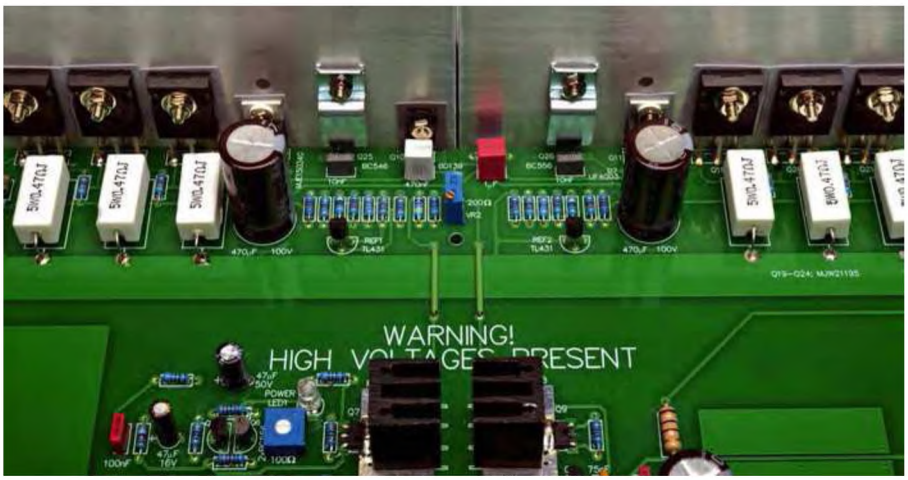
Q12 (the MJE15034) on the left-hand heatsink and Q11 (the MJE15035) on the right-hand heatsink need silicone TO-220 insulating washers and an insulating bush inserted into the device's tab hole before being secured with an M3 x 15mm screw and M3 nut. Also leave these loose for the moment.

Q10, the BD139, mounts with the metal face toward the heatsink and a TO-220 silicone washer between the heatsink and transistor. Attach it with an M3 x 15mm screw and M3 nut, and again, leave the screw connection loose.

Now mount the PCB on six M3-tapped 9mm spacers and sit it on a flat surface. Lower each heatsink, one at a time, inserting the transistor leads through the appropriate holes. Once they're in, push the board down so that all four spacers (and the heatsink) are in contact with the benchtop.

This adjusts the transistor lead lengths and ensures that the bottom of the board sits exactly 9mm above the bottom edge of the heatsink.

Check that the correct transistor is in each position and adjust the PCB assembly horizontally so that each extends an equal 1mm beyond the side of the heatsink. Now tighten all the transistor screws just enough that they are held in place while keeping the insulating washers correctly aligned. The rear of each heatsink should be flat against the transistor mounting edge of the PCB.



A close-up of the mounting arrangement of the transistors to the heatsink.

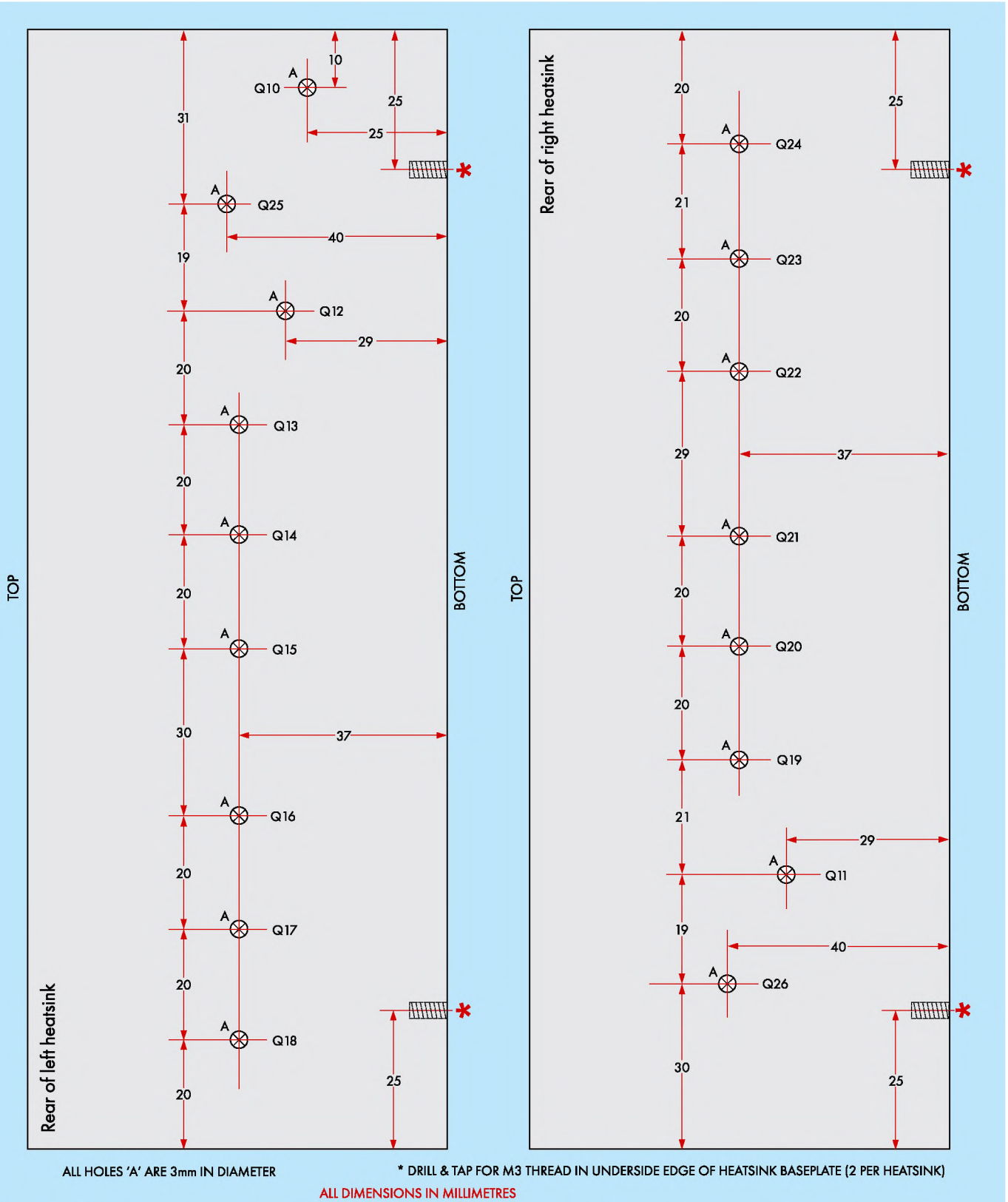


Fig.7: drill the two side-by-side heatsinks as shown here. You can drill the transistor mounting holes through the heatsink using a 3mm bit and then mount the transistors using screws, nuts and washers. The underside edge is drilled to 2.5mm and tapped for M3 in two places on each heatsink so that it can be mounted to the chassis.

The next step is to lightly solder the transistor leads from the top of the PCB, or at least as many leads as you can easily access from the top. Then carefully turn the whole assembly upside down and prop the front edge of the board up by placing books or something similar under the board so that the PCB is maintained at right angles to the heatsink.

If you don't have anything handy that you can stack to a suitable height, you can cut a couple of cardboard cylinders to 63mm (eg, from discarded paper towel rolls) to use as temporary supports.

If you don't do this, it will sag under its own weight and remain in this condition after the leads are soldered.

Now you can solder the remaining transistor leads and add extra solder to any that need it. Make sure the joints are good since they can carry many amps at full power. When finished,

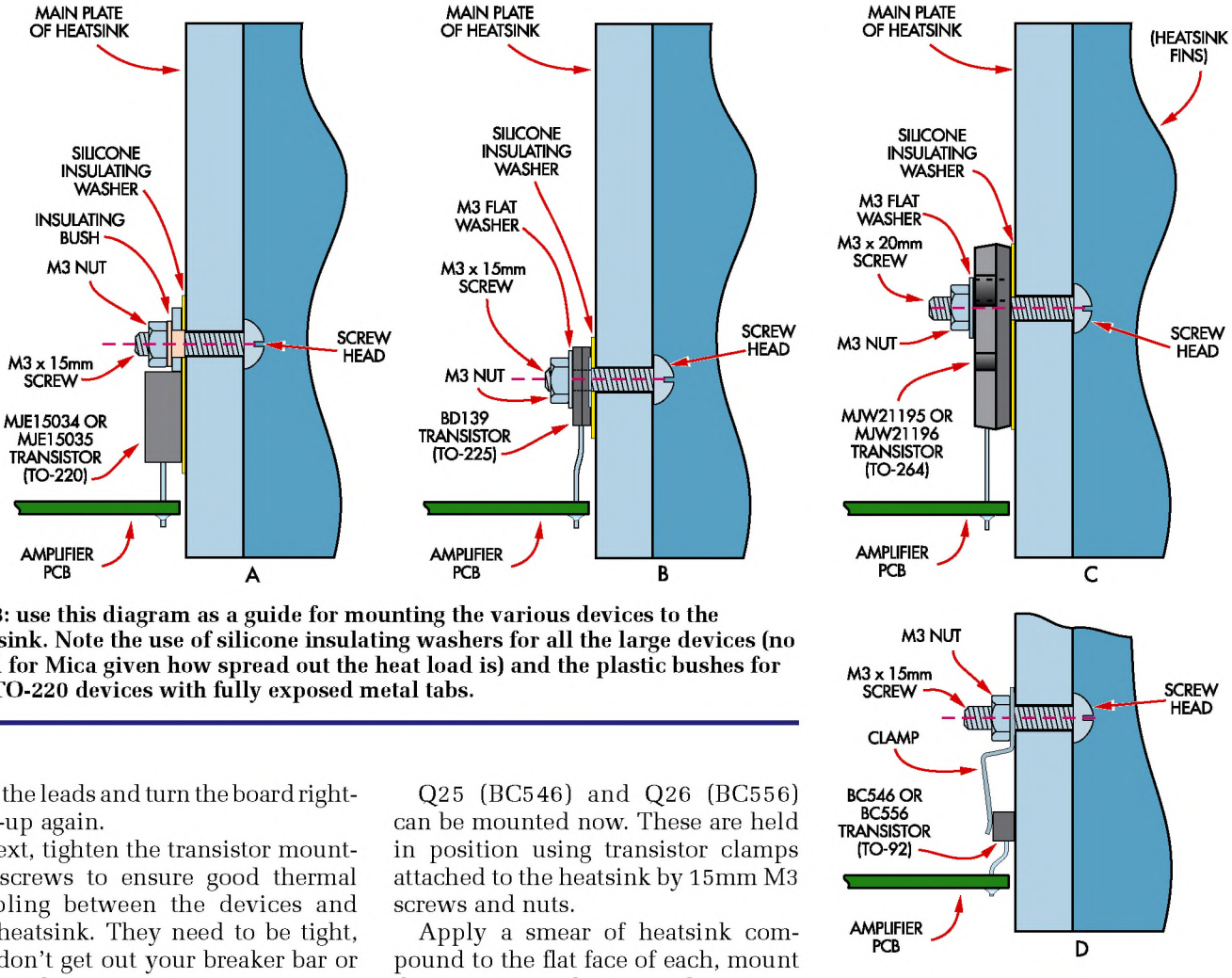


Fig.8: use this diagram as a guide for mounting the various devices to the heatsink. Note the use of silicone insulating washers for all the large devices (no need for Mica given how spread out the heat load is) and the plastic bushes for the TO-220 devices with fully exposed metal tabs.

trim the leads and turn the board right-way-up again.

Next, tighten the transistor mounting screws to ensure good thermal coupling between the devices and the heatsink. They need to be tight, but don't get out your breaker bar or impact driver.

Checking device isolation

Now check that the transistors are all electrically isolated from the heatsink. Do this by switching your multimeter to a high-ohms range and measuring the resistance between the heatsink mounting surface and the collectors of the heatsink-mounted transistors.

For transistors Q13-Q24, it's simply a matter of checking between each of the fuse clips closest to the heatsink and the heatsink itself on each side of the *Amplifier*. That's because the device collectors in each half of the output stage are connected together and run to their respective fuses. You should get a reading above 10MΩ, and quite likely 'OL' because it should be too high for your DMM to read.

Testing shorts for transistors Q10 (the V_{BE} multiplier), Q11 and Q12 is different. In this case, you have to check for shorts between the centre (collector) lead of each device and the heatsink.

If you do find a short, undo each transistor mounting screw in turn until the short disappears. It's then simply a matter of locating the cause of the problem and remounting the offending transistor. Be sure to replace the insulating washer if it has been damaged in any way (eg, punched through).

Q25 (BC546) and Q26 (BC556) can be mounted now. These are held in position using transistor clamps attached to the heatsink by 15mm M3 screws and nuts.

Apply a smear of heatsink compound to the flat face of each, mount the transistor clamps and position each transistor so the clamps will hold them in place at approximately the centre of the transistor body. Then tighten the screws. Turn the PCB assembly upside-down and solder and trim the transistor leads.

Now you must remove the three support spacers from the edge of the board adjacent to the heatsink. This edge of the board must be supported only by the heatsink transistor leads. This avoids the risk of eventually

When finished, our 500W Amplifier will have fans attached at the back of the heatsink via a metal bracket on the base of the case.

cracking the PCB tracks and pads around the heatsink-mounted transistors due to thermal expansion and contraction as the assembly heats up and cool down.

Coming up next

That completes the assembly of the *Amplifier Module*. Next month, we will describe the power supply, how to power up and test the *Amplifier* and give full details on building the *Amplifier* into a vented aluminium metal case (shown on the previous page with its lid removed) and keeping it cool, even under full load conditions.

Parts List – Complete 500W Amplifier

1 assembled 500W Amplifier Module (as described in *PE*, April and May 2023)
1 assembled Amplifier Clipping Indicator set up for ±80V DC supplies (see *PE*, April 2023)
1 assembled Fan Controller and Loudspeaker Protector with three 120mm PWM fans (see *PE*, February 2023)
1 12V 15W switch-mode mains supply **[Jaycar MP3296, Altronics M8728]**

Chassis

1 3U Aluminium rack enclosure, 558.80mm x 431.80mm x 133.35mm, made from:
1 Bud Industries RM-14222 Rackmount Chassis Kit (front, back and sides) **[Digi-Key 377-1392-ND]**
1 Bud Industries TBC-14253 Solid Rackmount Cover (for base) **[Digi-Key 377-1396-ND]**
1 Bud Industries TBC-14263 Perforated Rackmount Cover (for lid) **[Digi-Key 377-1397-ND]**
4 equipment mounting feet **[Jaycar HP0830/HP0832, Altronics H0890]**
1 400mm length of 20 x 20mm x 3mm aluminium angle **[hardware store]**
1 220 x 60mm front panel label

Power Supply

1 800VA toroidal mains transformer with 2 x 115V AC and 2 x 55V AC windings **[RS Components 1234050]**
1 toroidal transformer mounting disc (drill hole out to 8mm diameter) **[RS Components 6719202]**
2 Neoprene washers for toroidal transformer **[RS Components 6719218]**
1 35A 400V bridge rectifier (BR1) **[MB354, KPC3504 or similar]**
1 208 x 225 x 0.8mm insulating sheet (Prespahn, Elephantide or similar) **[Jaycar HG9985]**
1 295 x 125 x 3mm plastic sheet (Perspex, Polycarbonate, PVC, acrylic or similar)
1 IEC mains input connector with fuse **[Jaycar PP4004, Altronics P8324]**
1 IEC mains connector insulating boot **[Jaycar PM4015]**
1 IEC mains power cord
1 M205 3.15A slow-blow fuse (F3)
1 DPDT mains switch with red neon lamp (S1) **[Jaycar SK0982, Altronics S3242B]**
1 3-way 6A mains-rated terminal strip **[Jaycar HM3194, Altronics P2130A]**
8 10,000µF 100V electrolytic capacitors **[Jaycar RU6712 with mounting brackets]**
6 15kΩ 1W resistors
2 5mm LEDs (LED4, LED5)
6 5mm yellow insulated crimp eyelets **[Jaycar PT4714, Altronics H2061B]**
6 6.3mm blue insulated female spade crimp connectors **[Jaycar PT4625, H1996B]**
10 150mm cable ties
7 adhesive panel mount cable anchors
assortment of heatshrink tubing

Wire and cable

300mm of 7.5A or 10A Earth wire (green/yellow striped) [can be stripped from three-core mains flex]
1 1.5m length of twin-core 7.5A sheathed mains cable
5m of 0.5mm diameter copper wire (eg, copper picture frame wire)
400mm of dual-core shielded microphone cable (or single-core if RCA input socket is used)
2m of red 25A-rated hookup wire, 2.9mm^2 **[Jaycar WH3080]**
2m of black 25A-rated hookup wire, 2.9mm^2 **[Jaycar WH3082]**
1m of figure-8 wire, 2.93mm^2 per conductor **[Jaycar WB1732]**
1m of figure-8 wire, 2.5mm^2 per conductor **[Jaycar WB1712]**
2m of figure-8 wire, 0.76mm^2 per conductor **[Jaycar WB1708]**
1m of figure-8 wire, 0.44mm^2 per conductor **[Jaycar WB1704]**

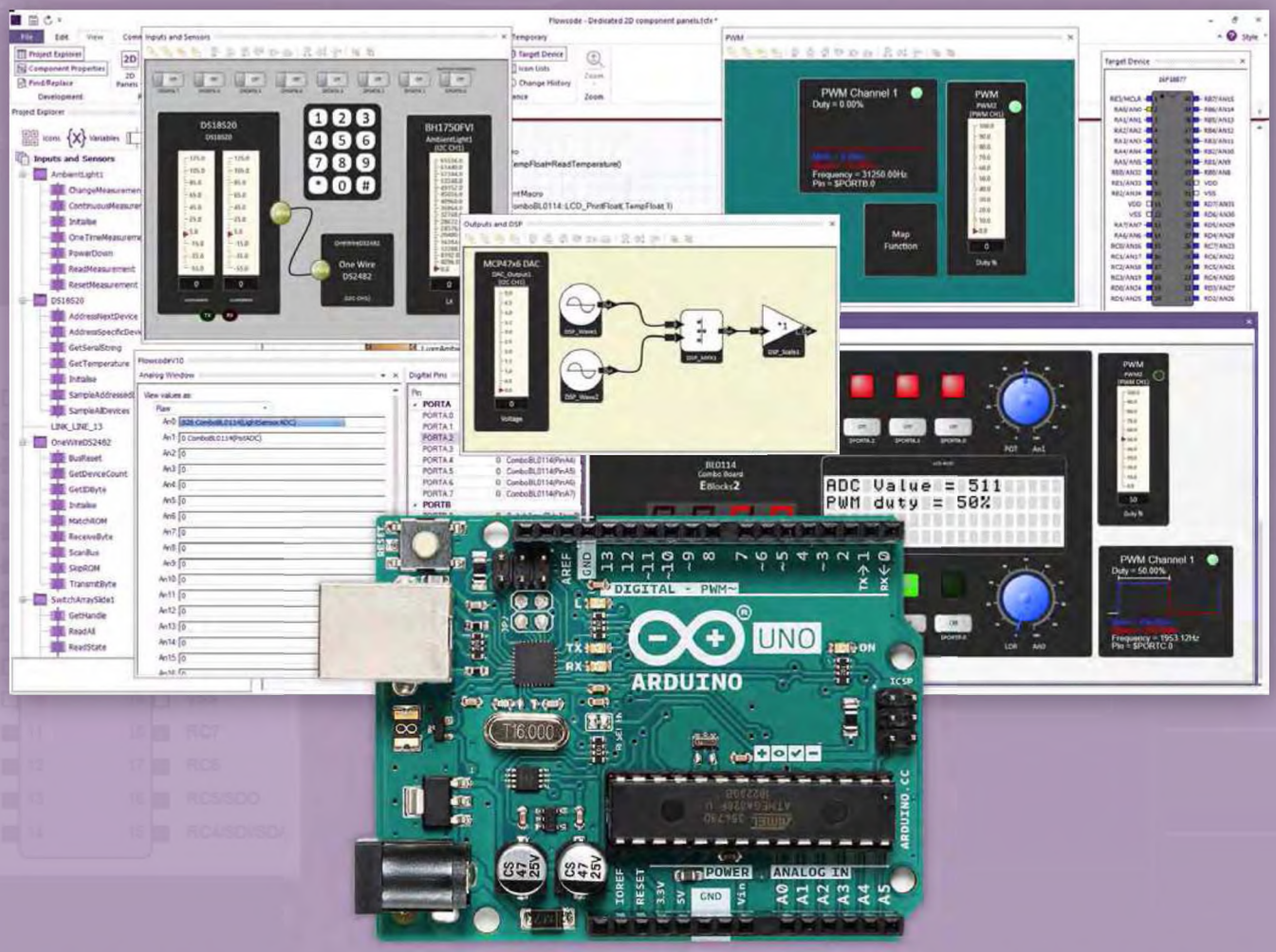
Hardware, including screws

2 No.4 x 6mm self-tapping screws (or two M2 x 6mm machine screws and two M2 nuts)
1 M8 x 75mm bolt, M8 hex nut and washer for transformer [hardware store]
8 M4 x 50mm machine screws
1 M4 x 20mm machine screw
3 M4 x 15mm machine screws
22 M4 x 10mm machine screws
4 M4-tapped joiners
39 M4 hex nuts
3 M4 star washers
2 M3 x 15mm machine screws
4 M3 x 12mm countersunk head machine screws
10 M3 x 10mm machine screws
11 M3 x 9mm Nylon standoffs
2 M3 x 6mm machine screws
22 M3 x 5mm machine screws
12 M3 hex nuts

Other parts

1 SPDT 30A relay, 12V coil (RLY1) **[Altronics S4211]**
3-pin female XLR panel connector **[Jaycar PS1054, Altronics P0903]** (or insulated panel-mount RCA socket)
1 panel-mount pair of heavy-duty loudspeaker terminals **[Jaycar PT0457, Altronics P9257A]**
1 RCA line plug
1 panel-mount bezel for 5mm LED **[Jaycar SL2610, Altronics Z0220]**
3 6.3mm yellow insulated female spade crimp connectors **[Jaycar PT4725, Altronics H1842A]**
1 560nF 100V MKT capacitor
2 10kΩ lug-mount NTC thermistors **[Altronics R4112]**

Here is the complete parts list for the 500W Amplifier needed for the final constructional article next month.
As always, use the above references to determine part specifications if the above suppliers are not local to you and you need to purchase from more convenient or cheaper alternative sources.



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