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300 W AMP. to build

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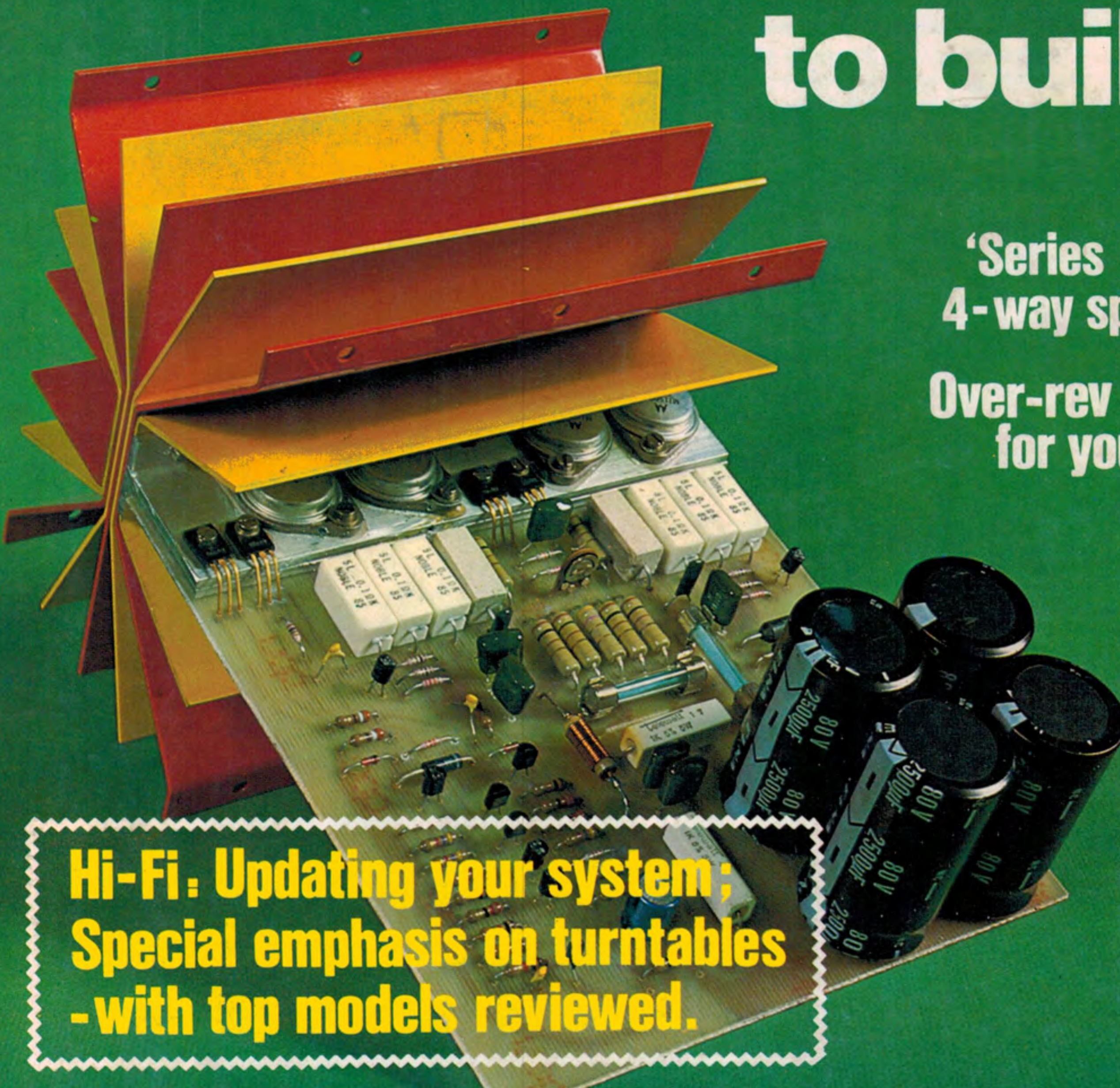


Hi-Fi: Updating your system; Special emphasis on turntables - with top models reviewed.

Project 466

'The Brute' — develops 300W into 4 ohms, 200W into 8 ohms!

Barry Wilkinson

For many audio applications there's no substitute for sheer power — low efficiency speakers, outdoor sound systems, or maybe you like the full flavour of the dynamic range afforded by a high power amp. Whatever your requirement — this 'super power' module should fill the bill.

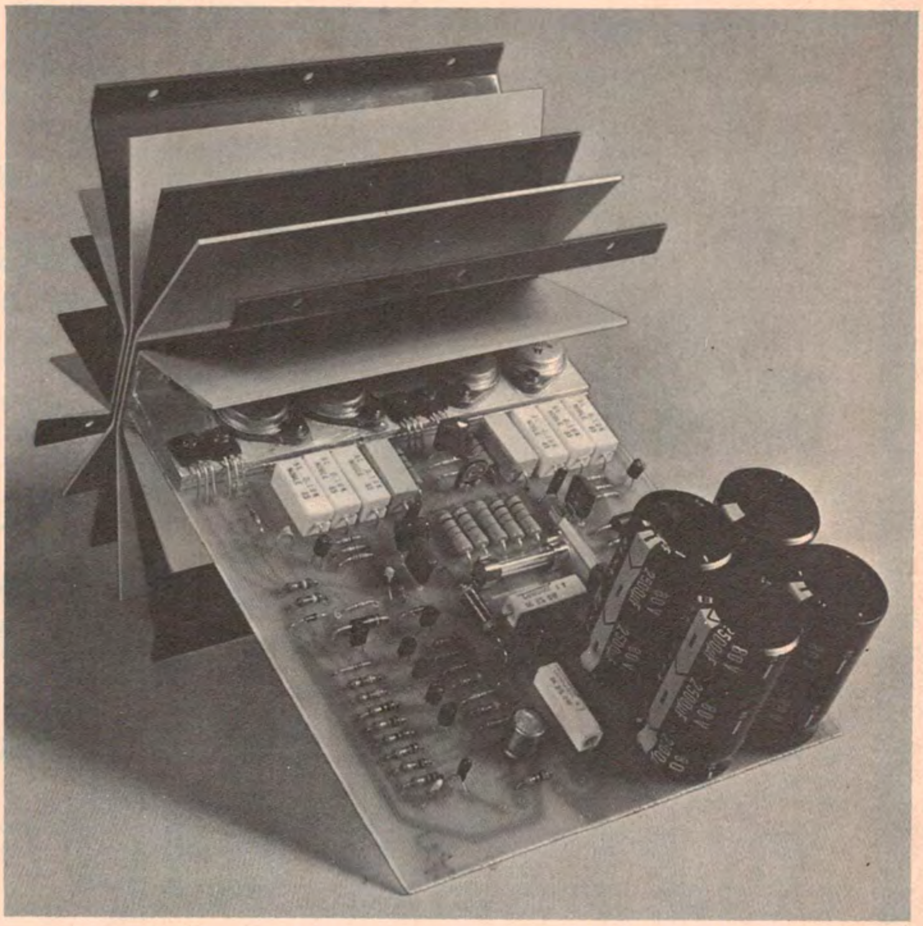
START HERE

Do not pass 'go', do not spend $200

THIS IS a relatively expensive project, compared to our previous amplifier modules, the ETI-480 and the more recent ETI-470. It is not recommended for beginners or inexperienced constructors. Although we have included protection for the output devices in the design it is obviously impossible to protect against circumstances which we cannot forsee. Follow the assembly and advice given in this article — especially regarding heatsinks and power supplies etc, and you'll be well assured of success. We must ***stress*** that any deviation from this design, other than the variations suggested, you do at your own risk.

If this is your first experience with such high power don't be embarrassed to follow the instructions slavishly until you are familiar with the unit and the get 'feel' of the technology. Check ***everything*** as failures can be disastrous, not to mention spectacular, if something goes wrong.

If we haven't put you off by this stage — read on !



SPECIFICATIONS — ETI 466

Power output	
8 ohm load	200 watts RMS
4 ohm load	310 watts RMS
Frequency response	
20 Hz to 20 kHz	+/- 0.5 dB
Hum and noise	
re 200 W into 8 ohm	- 105 dB
Input sensitivity	
8 ohm load	1 V for 200 W output
4 ohm load	1 V for 300 W output
Total harmonic distortion	see graph
Damping factor	
20 Hz - 3 kHz	65
5 kHz	55
10 kHz	45
20 kHz	35

HI-FI AMPLIFIERS are becoming more and more powerful, and with good reason. Modern recordings, especially direct-cut discs, have a useful dynamic range approaching 40 dB between the quieter musical passages and the peaks of the crescendos. If the quieter passages are played at a power output of 100 mW, which is not untypical in a domestic environment, to faithfully reproduce the full recorded dynamic range of a good record without clipping the peaks would require an amplifier capable of delivering 1000 watts! This, coupled with the current trend amongst some manufacturers to build speakers having quite low efficiency, plus the number of people who like their music loud (*and* undistorted) makes the case for high power amplifiers very strong indeed.

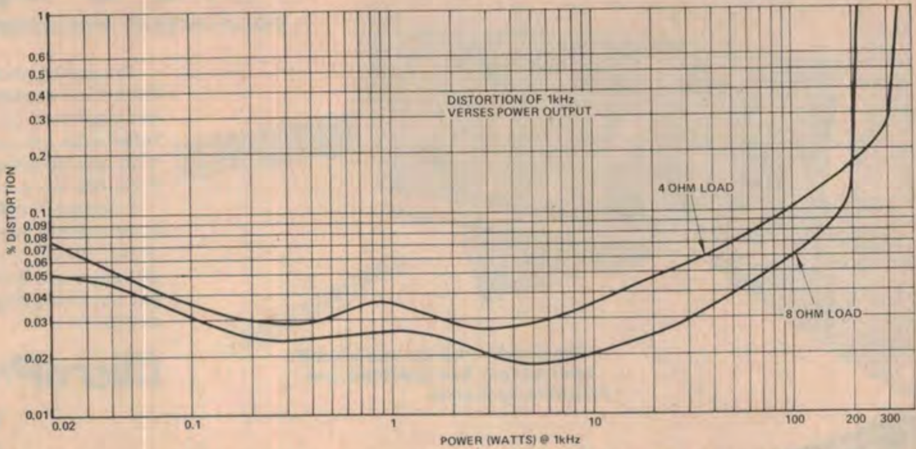
Past amplifier projects have generally been limited to output powers of 50 watts or so. Designed around cheap, readily available transistors, they have proved very popular. We have done the occasional 100 watt amplifier and once described a 'bridge' amplifier capable of delivering 200 watts into an eight ohm load, rather than design an amplifier using expensive, hard to get transistors for that power level.

To gain a worthwhile improvement in subjective performance over an amplifier of 50 watts output, we must go for a four times increase at least, to 200 watts, as the ear has a logarithmic response, and anything less is barely noticeable. That might be stating the case a little simply, but it conveys the general idea.

Over the past six or seven years we've had many requests for a *high* power amplifier, but for the reasons stated previously, we have decided against it. It would have been possible to design a unit using a large number of readily available power transistors in the output — in fact, one design we have seen used a total of 24 devices in the output stage! Difficulties for the home constructor in this approach are obvious, regardless of expense.

For various reasons, a bridge amplifier was ruled out when the design of this amplifier was considered. Hence, a plentiful source of suitable output transistors was first sought.

There are really not too many transistors available that meet the requirements. Firstly, adequate safe operating area (SOAR) is of prime importance. Next, and probably of equal importance, is availability. Let's have a look at the SOAR problem first. Some high power transistors don't compare too well with the ubiquitous 2N3055



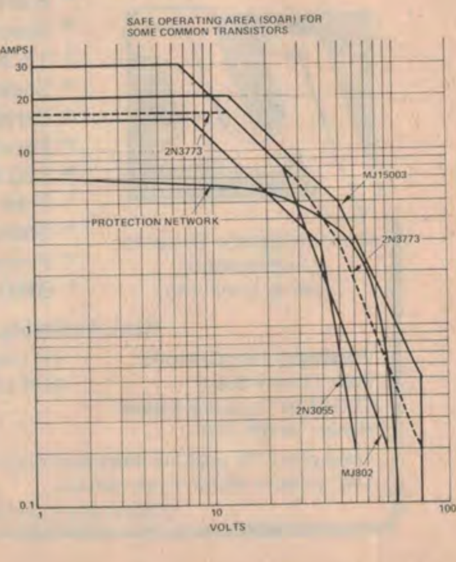
Total harmonic distortion versus power output at 1 kHz. The 'bump' at around 1 W is due to the output stage changing from Class A operation to Class AB operation.

(and its complement, the MJ2955) when operated as an amplifier. Take a look at the set of curves plotted on the accompanying diagram. This compares the safe operating area curves of a number of power transistors. Operation of any power device must be confined to the area inside the device's curve at worst case. If the current/voltage operating point is allowed to fall outside the area of the SOAR curve during any part of the operating cycle for the device, it will be destroyed — with amazing rapidity. Now, the 2N3773 and MJ802 transistors have been around for some time and at first glance would seem good choices for a high power amp, but note that their SOAR characteristics are not much better than the 2N3055. In fact, at 40 V (Vcc) the MJ802 is actually worse. In contrast, the MJ15003 is quite a long way outside the curve for the 2N3055 and therefore has a much higher power rating when used in an amplifier. Hence, the MJ15003 and its complement — the MJ15004, were chosen as the output devices for this design. Secondly, these transistors are widely used in industrial applications and are available from a number of sources, thus they meet the availability requirement. See Shoparound on page 93 for more information.

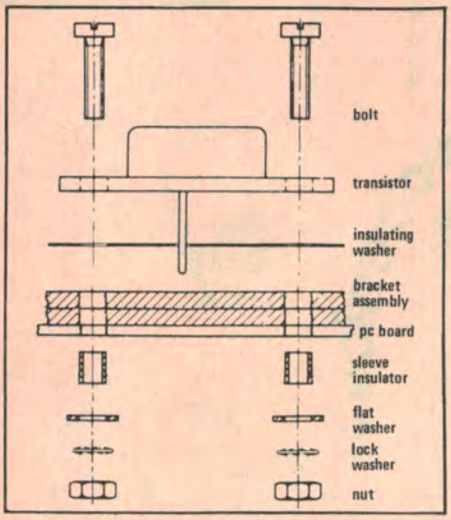
Another problem that arises with a design such as this is protection for the output devices. Amplifiers using transistors such as the 2N3055/MJ2955 can easily be protected with a fuse. In high power amplifiers where supply rails of 60 — 70 volts are necessary, the energy available (from the filter capacitors) will easily destroy the transistor *and* the fuse — in that order. The answer is to use electronic current limiting in the output. This adds complexity, but is cheap insurance against accidental (or deliberate!) abuse. The curve showing the limiting effect on the SOAR characteristics of the MJ15003 for the protection network used in this amplifier is shown on the diagram with the other SOAR curves.

The main cost of the amplifier is in the output stage, transformer and heatsink. We therefore decided to go to a slightly more complex input stage to improve the performance. This type of amplifier usually uses a Class A driver which introduces second harmonic distortion. By using a complementary-differential input circuit we have been able to eliminate the Class A driver and therefore kept the second harmonic distortion very low indeed. The distortion curve shows the distortion is well under 0.1% until almost full power output. The 'bump' in the curve around one watt is the point where the output stage changes from Class A (peak output being less than the bias current) to Class AB operation. ▶

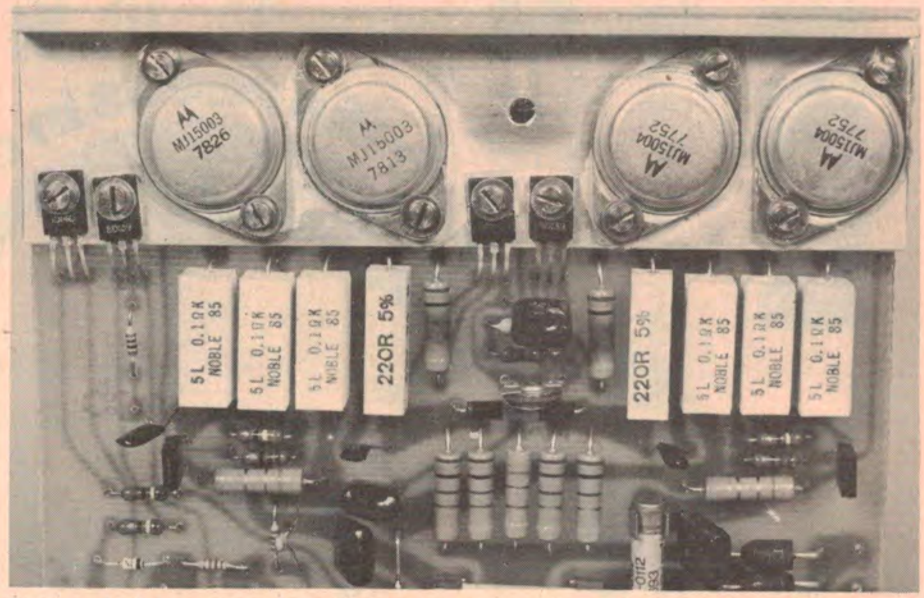
Comparison between the Safe Operating Area characteristics of a variety of transistors, including the MJ15003 used in the output stage of this amplifier.



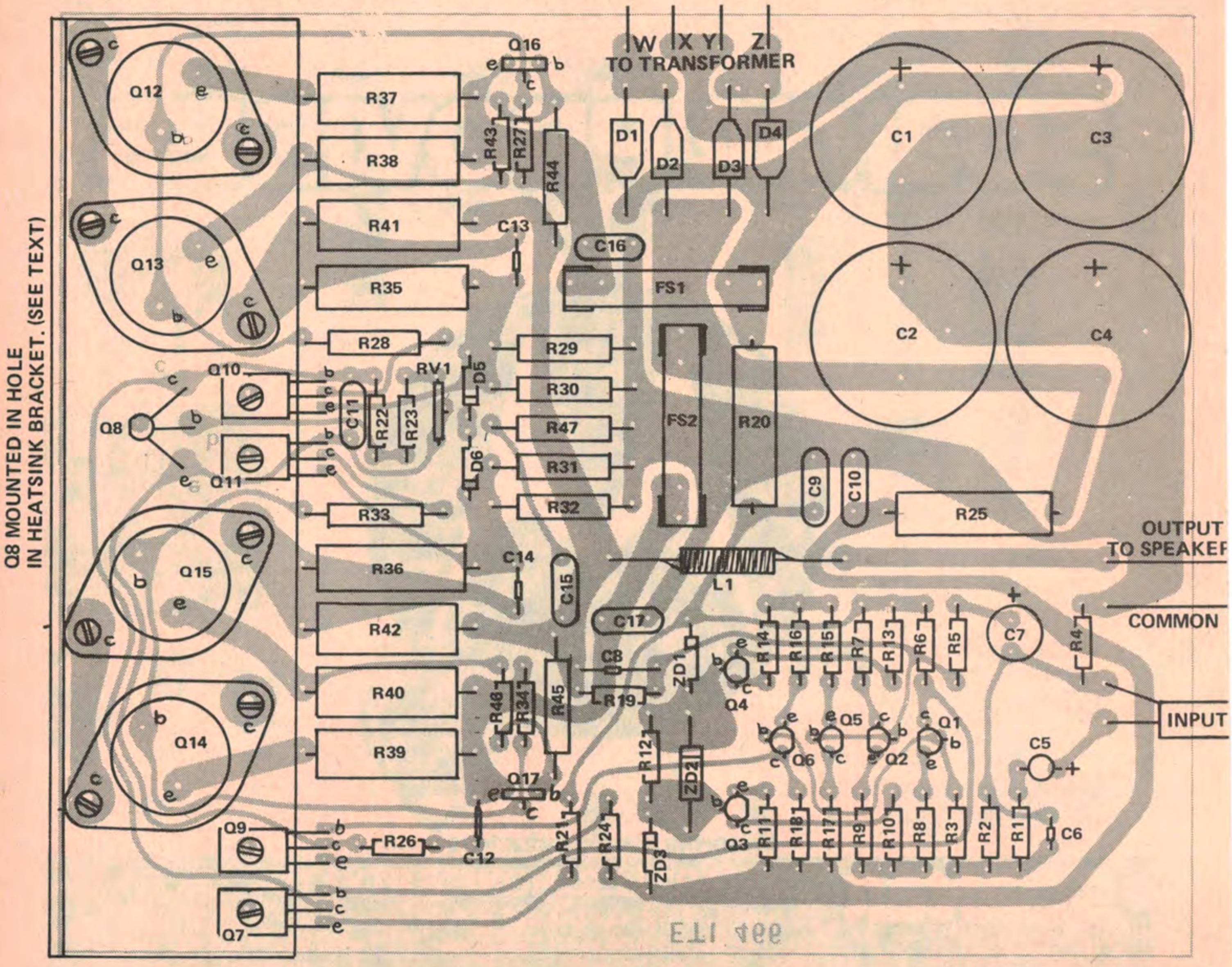
Project 466



Exploded view of how the TO3 output transistors are assembled to the angle brackets and pc board.



Photograph of the completed output stage, prior to mounting to the heatsink assembly.



The complete amplifier, including the power supply components and output transistors, is assembled on a single pc board. An aluminium bracket holds the output transistors conducting heat from the output stage to the heatsink. Only three sets of external connections are made to the pc board; input, output and power supply ac input from the transformer.

Start the construction by making the aluminium bracket shown on page 53. We used two length of 3 mm angle which may be purchased from Alcan Handyman stores. This bracket is 3 mm thick and two must be placed back to back to make the required 6 mm thickness for adequate thermal conduction to the heatsink assembly. If you elect to use a Philips 65D6CB heatsink (see the box on 'Heatsinks'), a single 6 mm thick angle extrusion can be used, fixed to the flat side of this heatsink.

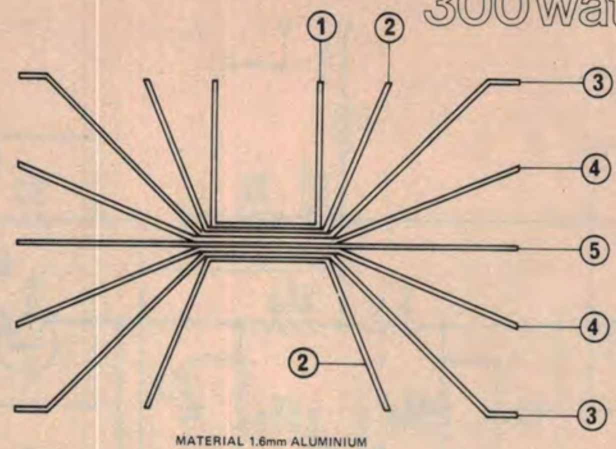
The easiest way to make the bracket assembly and ensure correct alignment of all the holes is to cut the two lengths of angle somewhat longer than necessary. The extra length will be cut off later. Clamp the two pieces back to back and drill a small hole at each end so that they can be clamped together with nuts and bolts through this excess. This allows you to shift the bracket assembly in a vice or what have you without getting them out of alignment. Next, mark out the position of the transistor holes (use the pc board as a guide if you have it to hand already) on the broad side of one bracket and then the holes in the narrow side – the latter secure the bracket assembly to the heatsink. Use a scriber or other sharp-pointed instrument. Then drill the holes.

The hole for the thermal feedback transistor (Q8) *must* be a neat fit. The best way to accomplish this is to drill a slightly smaller hole and carefully enlarge it with the correct size drill. A reamer gives a conical hole and is not really suitable. Those holes marked 'C' on the bracket drawings can be tapped to take a 4 BA bolt if you plan on using the sheet metal heatsink described later.

Once you have drilled all the holes in the bracket assembly, cut off the excess at each end and file the edges smooth. Also, ensure that no 'burrs' are left on the lips of each hole. Chamfer then with a large drill held in your hand.

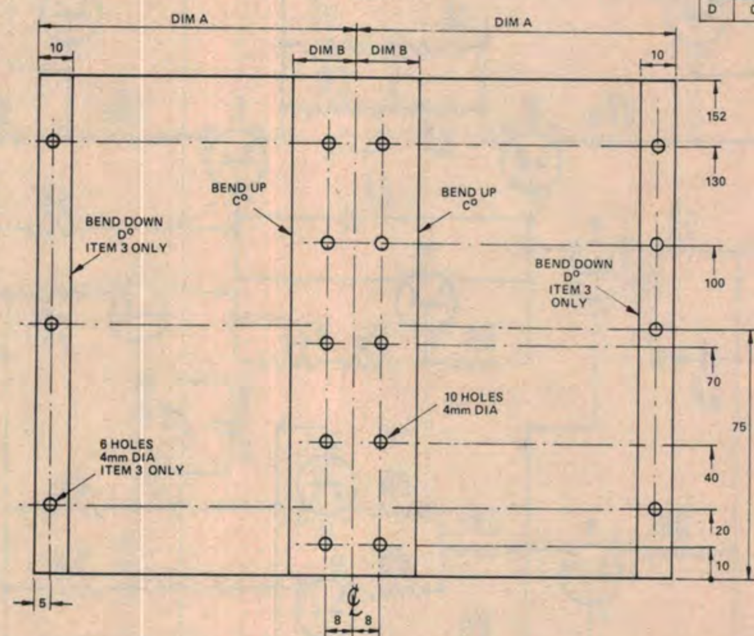
The next step is to make the heatsink assembly – that is, if you're not using one of the commercially-made alternatives suggested.

If you have access to a sheet metal ▶



Dimensions and bending details for the sheet metal heatsink assembly we used.

	ITEMS				
	1	2	3	4	5
A	58	65	95	80	75
B	15	17	19	21	–
C	90°	67.5°	45°	22.5°	0°
D	0°	0°	45°	0°	o



HEATSINKS

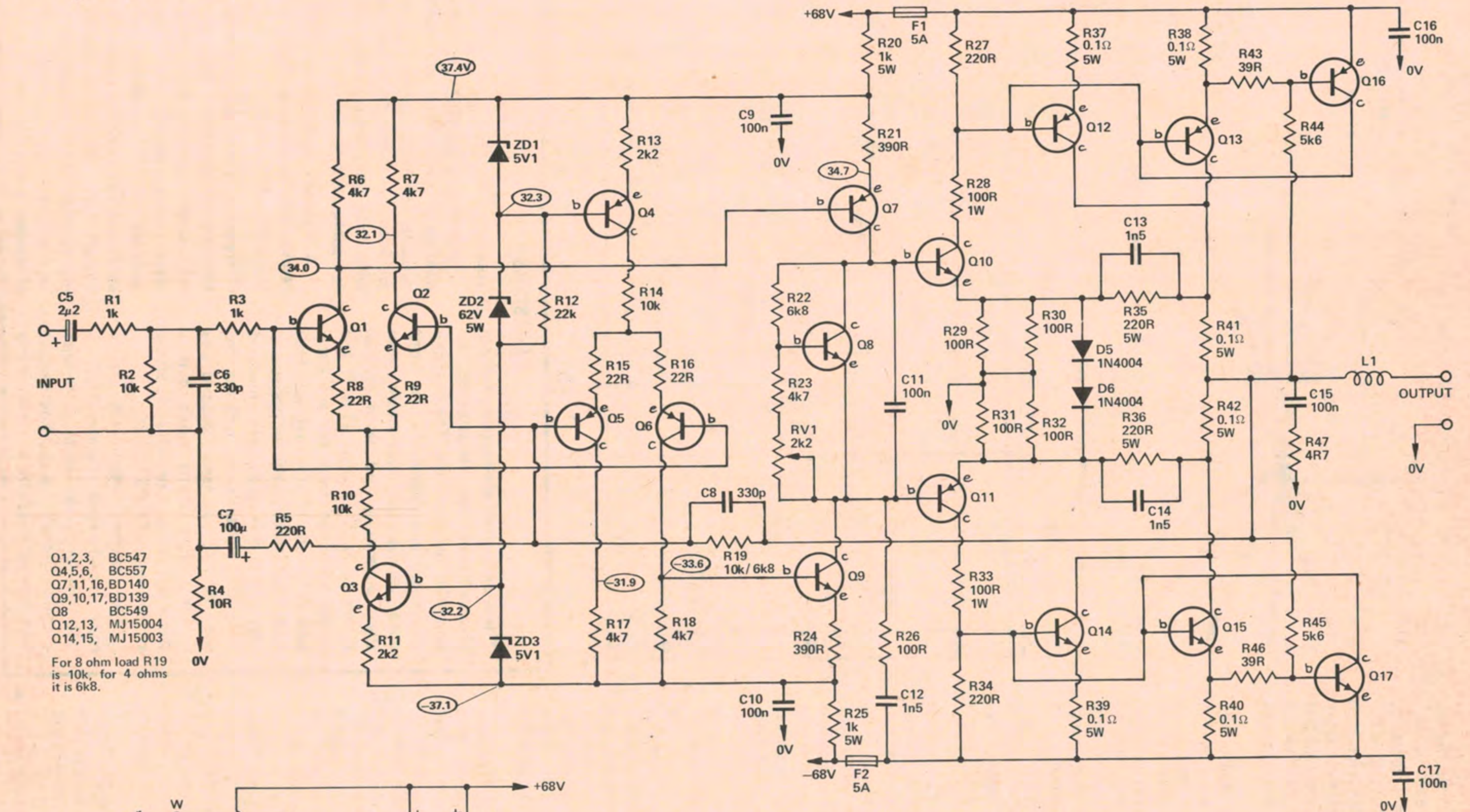
There are several alternatives you can choose from for heatsinking the amplifier output stage. The heatsink described, and shown in the front cover photograph, was made from sheet aluminium and has a thermal rating of 0.55°C/watt. This is the rating we recommend for any heatsink if the amplifier is to drive a four ohm load, particularly for pop group use. If it is driving an eight ohm load in typical domestic use, half the fins may be left out (every second one – the yellow ones!) resulting in a thermal rating for this heatsink arrangement of 0.75°C/watt.

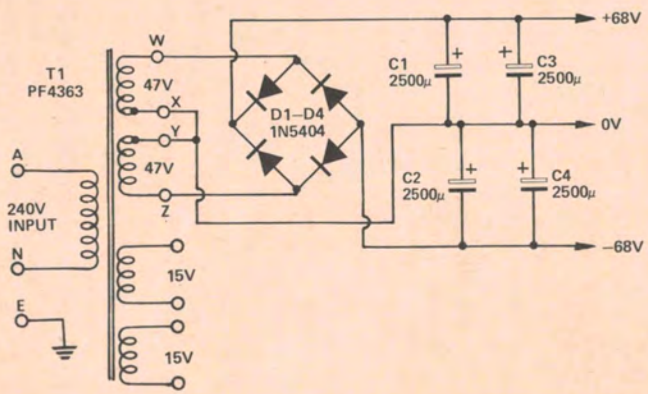
The nearest equivalent in a commercially-made heatsink is a 140 mm length of Redpoint R type – which nobody (to our knowledge) has had the foresight to stock in this country. Tch, tch.

The Philips 65D6CB heatsink has a rating of 0.65°C/watt and would be suitable for this amplifier in most applications, except for a pop group with four ohm loudspeakers, unless fan cooling is added.

A heatsink with about 1°C/watt rating and substantial fan cooling is another alternative.

Remember that dissipation in the heatsink will be about 200 watts at full power output. That means a temperature rise of 110°C above ambient if the amplifier is run continuously. Poached eggs anyone? Temperature rise with music or intermittent use is considerably less, of course, as average power dissipated is much lower.





Complete circuit diagram of the amplifier. Note that L1, not listed in the parts list below, is wound on a 1 W resistor – see text. Voltage readings are included as a guide.

The power transformer shown will power a pair of amplifiers (stereo) driving 8 ohm loads in typical domestic situations, but only a single module under other circumstances, particularly if driving a 4 ohm load.

When supplying two modules from a single transformer simply parallel W, X, Y and Z on each pc board and connect these to the transformer.

For stereo applications use separate earth returns for each speaker to the common on the pc board and separately join the two commons.

If the module is to be used in applications other than a domestic hi-fi set up and driving a 4 ohm load, we recommend you add another MJ15003/MJ15004 pair and associated components. The angle bracket and heatsink assembly will need to be extended.

bender, making your own heatsink is certainly the cheapest way out. The complete drawings are given back on page 49. Referring to these, note that dimension 'A' and dimension 'B' varies for each fin, the appropriate measurements being given in the table accompanying the drawings together with the angle of bend for each fin. Don't forget to allow a small angle for the 'spring' in the metal. Angles can be within a few degrees as they aren't that critical to heatsink efficiency. Don't be too sloppy though.

We used 1.6 mm thick aluminium sheet to construct the heatsink – *do not substitute a thinner gauge.* The bolts which secure the heatsink assembly to the bracket assembly also hold the whole heatsink assembly together.

It is easiest to drill the heatsink fins *before* bending them up, but you *must* mark out and drill the holes *accurately.* Mark one outer fin very carefully. Assemble the fins in order, making sure they are carefully aligned, then clamp the whole assembly and drill right through. Carefully de-burr all the holes.

At this stage you can do a trial assembly of the heatsink and bracket assemblies to see how it all mates – or not. If you have taken care with the drilling, then all should be well. Having confidence in your ability, we shall press on.

If you decide to paint the heatsink as we have (see the front cover !), rather than having it anodised black, the mating surfaces should all be masked before spraying.

If you intend to use a Philips 65D6CB heatsink, the bracket holes may be marked on the heatsink using the already-drilled 6 mm thick bracket as a template. The holes can be drilled to the root diameter of a 4 BA bolt and suitably tapped.

The whole heatsink 'business' is not assembled at this stage, final assembly comes later. Be patient my little chickens !

The next part is the easy part (! . . . . Ed.). Having got the mechanicals off your chest, the electronics needs attention.

The components may be assembled to the pc board starting with the smaller resistors and capacitors. Carefully follow the overlay drawing. When you come to the 0.1 ohm, 5 W resistors note that they should be mounted about 2 - 3 mm off the board to allow a free air flow around them. Next mount the power supply electrolytics. Note that the recommended types have three pins projecting from the base. This is to provide mechanical rigidity. All three pins are soldered to the board and the capacitors can only be inserted one way round. The inductor L1 is made by winding a layer of 26 swg enamelled wire (or the nearest equivalent gauge) along the body of a 1 W resistor. The number of turns is not critical, just wind enough wire on the resistor to cover the body with one layer. The value of this resistor may be anything over 100 ohms. Two 5 A fuses are mounted on the pc board, held in place with fuse clips.

Next comes the semiconductors.

▼

HOW IT WORKS – ETI 466

The amplifier can be divided into three separate parts. These are: the input stage – which consists of Q1 - Q9, a high gain, low power driver; the output or power stage – which only has a voltage gain of four but enormous power gain; and the power supply.

The input stage is a complementary-differential network, each 'side' with its own current source. Each transistor in this stage is run at a collector current of about 0.7 mA. Emitter resistors are employed to stabilize the gain and improve linearity. The output of Q1 - Q6 drives Q7 and Q9. The latter are virtually two constant-current sources run at about 7 mA collector current. With an input signal these 'current' sources are modulated out of phase – the collector current of one decreases while the other increases. This configuration provides quite an amount of gain.

In between the bases of these two transistors is Q8, the thermal sensing - bias transistor. The voltage across Q8 may be adjusted by RV1, thus setting the quiescent bias current for the output stage.

The output stage, Q10 - Q15, has a gain of about five, set by R39 and R29 plus R30. Diodes D5 and D6 prevent reverse biasing of Q10 and Q11 (otherwise the output would be limited.

Protection of the output transistors is provided by Q16 and Q17 which monitor both current and voltage in the output transistors and bypass the base current if the limit is exceeded.

The power supply is a full-wave rectifier, with a centre-tap on the transformer giving the 0 V rail, providing +/- 68 volts. A total of 5000 uF is used across each supply rail for filtering. The amplifier input stage works on a reduced supply rail, derived from ZD1-ZD3 via R20 and R25.

Frequency stabilisition is provided by capacitors C8, 13, 14 and the RC networks R26/C12 plus R47/C15. Frequency response of the amplifier is set by C5 and C7 (lower limit), C8 sets the upper frequency limit.

The transformer has two additional windings of 15 Vac each. These are not used here but are suitable for powering a preamplifier.

PARTS LIST - ETI 466

Resistors all ½W, 5% unless noted

R1	1k
R2	10k
R3	1k
R4	10R
R5	220R
R6, R7	4k7
R8, R9	22R
R10	10k
R11	2k2
R12	22k
R13	2k2
R14	10k
R15, R16	22R
R17, R18	4k7
R19	10k (6k8 for 4 ohm loads)
R20	1k 5W
R21	390R
R22	6k8
R23	4k7
R24	390R
R25	1k 5W
R26	100R
R27	220R
R28–R33	100R 1W
R34	220R
R35, R36	220R 5W
R37–R42	0.1 ohm, 5W
R43	39R
R44, R45	5k6 1W
R46	39R
R47	4R7 1W

Potentiometers

RV1	2k2 trim

Capacitors

C1–C4	2500μ 80V RTP electro
C5	2μ2 35V tantalum
C6	330p ceramic
C7	100μ 25V RB electro
C8	330p ceramic
C9–C11	100n polyester
C12–C14	1n5 polyester
C15–C17	100n polyester

Semiconductors

Q1–Q3	BC547
Q4–Q6	BC557
Q7	BD140
Q8	BC549
Q9, Q10	BD139
Q11	BD140
Q12, Q13	MJ15004
Q14, Q15	MJ15003
Q16	BD140 or BC640
Q17	BD139 or BC639
D1–D4	IN5404
D5, D6	IN4004
ZD1	5V1 300 mW (IN751A)
ZD2	62V 5W (IN5372B)
ZD3	5V1 300 mW (IN751A)

Miscellaneous

ETI 466 . . . . pc board
Heatsink - see text
Transformer PF4363 (47 + 47V - 300 W)
4 fuse clips, 2 x 5A fuses

Leave Q7, 8, 9, 10 and Q11 plus the output stage devices Q12, 13, 14 and Q15 until last. Be *careful* with the orientation of the diodes.

Now you can assemble the heatsink bracket to the pc board, plus Q7 to Q15 inclusive.

First smear heatsink compound on the two mating surfaces of the bracket assembly. Note that insulating washers are used on all the transistors, Q7 to Q15, mounted on the bracket assembly (except Q8 of course). Smear both sides of each washer with heatsink compound. Place the bracket pieces on the board – component side – and secure Q7, Q9, Q10 and Q11 with nuts and bolts. Only tighten the nuts finger tight at this stage. Now, take the whole board and place the bracket ends against a flat surface – such as the flat heatsink fin – and juggle the brackets until the end faces are flush. Check that all holes line up and then tighten the nuts and bolts.

The TO3 power transistors Q12, 13, 14 and Q15 may now be assembled to the bracket and pc board using the accompanying assembly diagram as a guide. We used spaghetti insulation to sleeve the bolts but pieces of heatshrink tubing would be better.

Don't solder any leads yet.

Allow time for the heatsink compound to spread under compression and finally tighten all nuts. Last of all insert Q8. Smear the inside of the hole it sits in with heatsink compound to ensure good thermal contact.

Now you can solder all the transistor leads.

Check the component placement against the overlay now, just to ensure all is in order. If you wish, you can test the amplifier up to the driver stages for correct operation before assembling the unit to the heatsink. Remove the fuses before applying ac input from the transformer. Refer to the 'powering up' procedure. If there are any problems, look for errors in component placement or orientation – particularly with diodes. If all is well, assemble the module to the heatsink and you're ready for the big test.

Powering up

The set of output transistors are expensive to replace, therefore we recommend you follow this test procedure in the interest of conserving supplies of same.

The power supply ac input should be connected to the transformer (see the overlay) but no power applied. You'll need a multimeter of at least 20k ohms/V sensitivity.

1) Remove the two fuses.
2) Solder a small link across C11.
3) Solder a wire between this link and the output pad.
4) With no load connected and no input signal, switch the power on.
5) Check the supply rail voltages. These should be about 68 volts each (plus and minus).
6) Check the voltages on the cathode of ZD1 (should be about +37 V) and the anode of ZD3 (about -37 V) with respect to 0 V.
7) If these two voltages differ with respect to each other by a volt or so, check other voltages around the input stage to determine the reason.
8) Check the dc voltage on the output (with respect to 0 V). It should be within 20 mV of zero.
9) Inject a sinewave signal into the input at a level of about 20 mV (RMS). Don't use a higher input level. Output should be 1 V RMS.
10) Switch off the main power and allow the filter capacitors to discharge. Remove the input signal.
11) Solder a 10 ohm ½W resistor across each fuse holder. Rotate the trimpot RV1 such that it is set at maximum resistance. Remove the short across C11 and the link from there to the output pad.
12) Switch on. . . . . if the 10 ohm resistors immediately vaporise you either have a short or some fault in the output stage!
13) If all is well, check the dc output voltage. It should be near zero.
14) Measure the voltage drop across one of the 10 ohm resistors placed across the fuse holders and adjust RV1 to give a reading of 1.0 V.
15) Switch off, allow the filter capacitors to discharge and remove the two 10 ohm resistors. Replace the fuses.
16) Connect suitably rated loudspeakers, warn the neighbours, connect a signal source to the input (turn down the volume), switch on the power and put the amp through its paces.

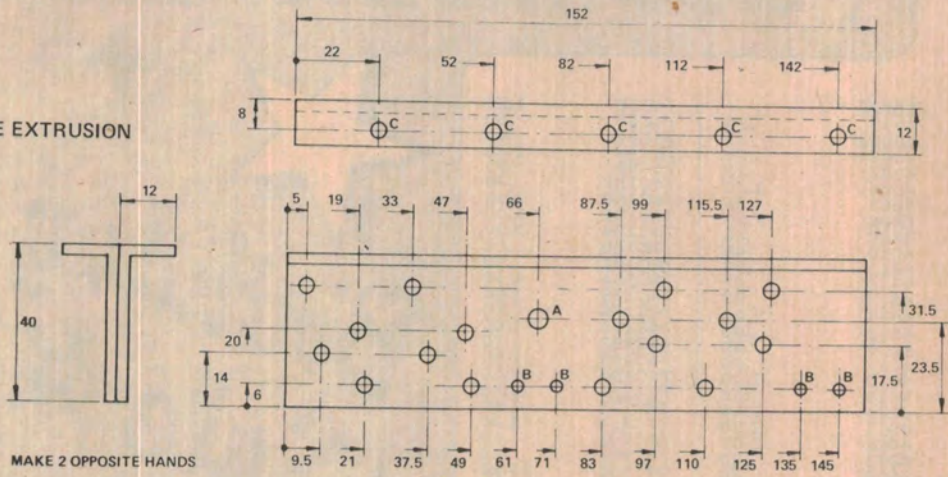
At this stage we'll leave the applications of this module up to you. No doubt you have plenty in mind already.

We are preparing a follow-up article for a later issue in which we may cover such things as preamps, bridge operation, design parameters and variations etc. For the moment, our existing preamp designs, such as the ETI-422 and ETI-471 will drive this module quite well.

Keep reading. ●

HOLES MARKED A 4.5mm DIA
HOLES MARKED B 3mm DIA
HOLES MARKED C TAP 4BA OR 4mm DIA
ALL OTHERS 4mm DIA

MATERIAL 40 x 12 x3 ALUMINIUM ANGLE EXTRUSION



Drilling details for the heatsink bracket assembly. All dimensions are in millimetres. Suitable aluminium angle stock is available from Alcan Handyman stores.