174 Roe Street, PERTH.
Western Australia. 6000
Phone: (08) 9428 2188
Fax: (08) 9428 2187
Internet: www.altronics.com.au
Dealers throughout Australia

K 5173

High Performance 200 Watt Mosfet Amplifier Module & power supply

Ideal for subwoofer amps or buy two for a super punchy stereo amp , this mosfet amplifier features very low distortion, high power and better than 100dB signal to noise ratio. All mounted on a rugged steel baseplate.

During the development of this project, we placed considerable emphasis on more than just the performance of the amplifier. The ease of construction and adjustment are vitally important, if a constructor's version is to offer the impressive capabilities of our prototypes.

To this end, the new design uses one single-sided PCB per channel, a minium of inter-wiring and no fussy specialised components. Also, the set-up procedure is simplicity in itself, with only one trimpot to be adjusted for each channel. However, before diving headlong into the amplifiers construction, there are a few general points to discuss.

Safety and Earthing

At the risk of boring experienced constructors, we cannot stress the safety aspect too strongly. As with any project using the 240V mains for a power source (as opposed to plug-packs or batteries), take particular care to cover and insulate any exposed mains wiring, and ensure that the equipment's chassis is well connected to the mains earth. Also note that the amplifier's supply rails have a total voltage of around 140V, which can also be dangerous in the wrong circumstances.

While the amplifier's chassis must be tied to the mains earth, the internal circuitry could be left 'floating' with no direct connection between the 0V (common) line and the cabinet - as featured in many designs. In this situation, the amp's internals are earthed via the shielding braid of the signal cables to the pre-amplifier's earth connection. However, this constitutes a potential safety hazard.

Although it may seem unlikely, this scenario involves an insulation breakdown within the amplifier's power transformer, where its 240V primary winding comes into electrical contact with the lower voltage secondary winding. The amplifier's circuitry (including the 0V line) will then attempt to rise towards mains potential.

Now, if the signal source is directly referenced to the mains earth (as is often the case), the interconnecting lead will appear as a short circuit to the amp's newly acquired mains potential. Naturally the cable's shield will attempt to carry the heavy current and either burn out, or survive long enough for the amplifier's mains fuse to fail. A burnt out cable would allow the amp's circuit to rise to the full voltage, which is then exposed at the rear terminals. Further to this, the signal source may not be earthed to the mains, allowing its circuitry, connectors and (possibly) chassis to be forced up to a lethal potential.

The solution of course is to connect the amplifiers 0V line directly to the mains earth. However, while this satisfied the safety aspect of amplifier earthing, the old problem of earth loops may appear. This tends to happen when the circuitry of both the power amp and preamp are directly earthed to the mains, causing a double earth path to exist via the signal leads and mains earth. This will often induce a noticeable (and unacceptable) level of hum and noise at the amplifier's input, which is ultimately reproduced by the loudspeakers.

So if we must float one piece of equipment to break the earth loop, the preamp must be the logical candidate. By imagining the reversed situation of a transformer failure within the preamp, we would expect the interconnecting leads to easily outlast the mains fuse - which would be of a much lower rating than a power amp's main fuse. Also, the pre-amp's transformer (if correctly chosen) has a far easier life, and is less likely to fail. Of course, the pre-amp's chassis would still be directly connected to the mains earth.

Driver Stages

After extensive practical testing, it became quickly apparent that a well designed MOSFET output stage is quite 'transparent' to its driving circuits. Providing the amplifier has sufficient loop negative feedback (NFB), the final quality of the amplifier is largely set by the earlier stages. With this in mind we set about designing the cleanest possible driving amplifier, so as to complement the MOSFET capabilities.

Our initial tests were based around a relatively simple circuit, as suggested in the application notes published by Hitachi. Hitachi no longer manufacture these mosfets. New devices manufactured by Exicon are now used. And while they do have slightly different parameters to the Hitachi

Doc GL822

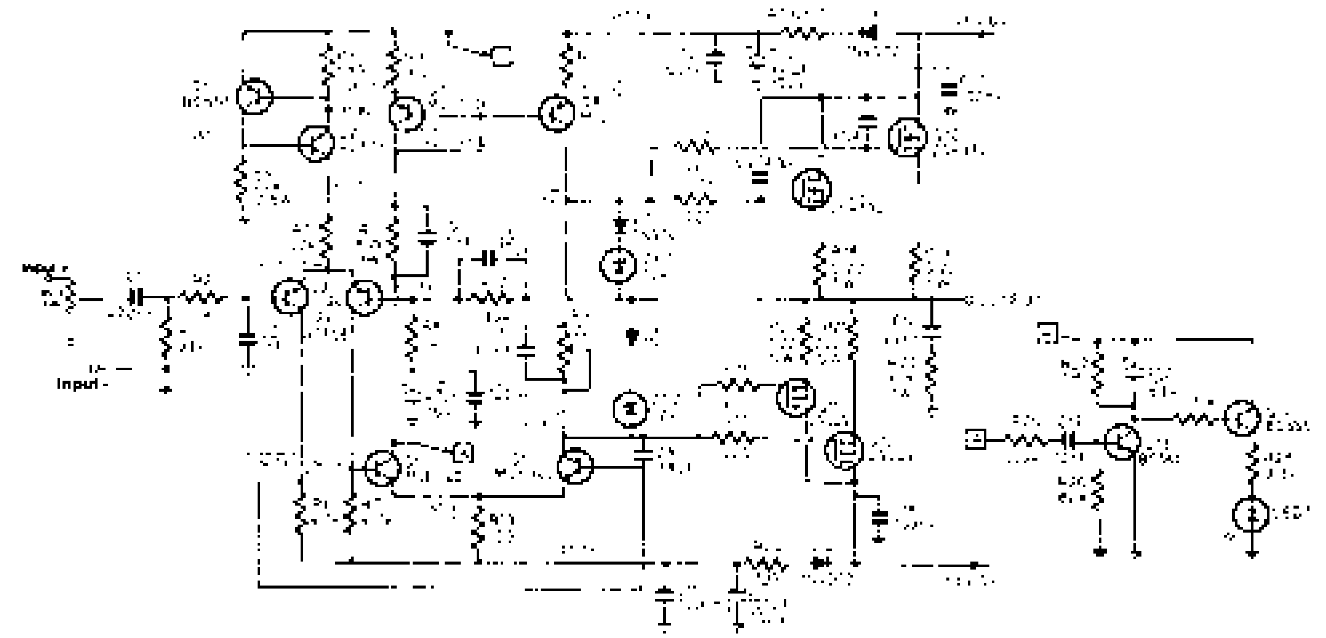


Figure 1: Here is the schematic diagram for the amplifier portion of the Kit.

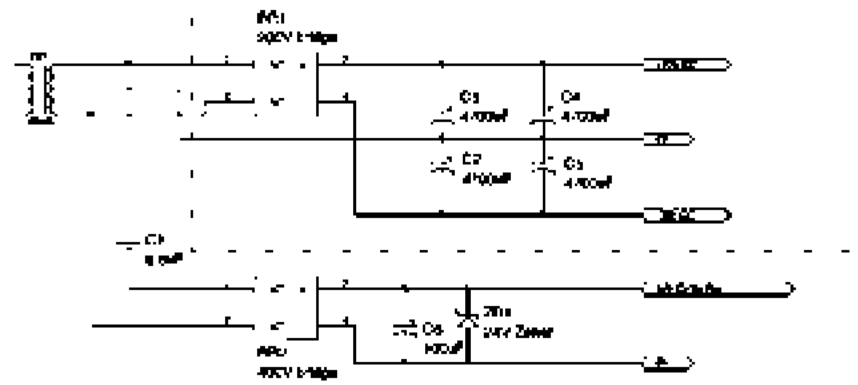


Figure 2: Above is the suggested power supply circuit. The power supply for the fan is derived from the 50V AC rails on the PCB. A further explanation of this fan operation is in the text.

devices, the overall performance remains the same. While the results were very encouraging we pressed on with more elaborate circuits in search of even better results.

To cut a long story short, we found that circuits which employed a number of low gain stages in series (using local and overall NFB), and fully symmetrical multiple driver stages provided only a slight increase in performance. It seems that the sum of the distortions generated from each stage was virtually the same as the total distortion from the simpler circuit. This effect is largely due to the non-linearities produced at the base/emitter junctions of the lower gain stages, which have to cope with larger input signal levels.

So while these more complex circuits offered a small improvement in the overall performance figures, we found these designs much more difficult to stabilise. Of course we'd also had to put up with a more complex and larger PCB and higher component count. As a result, our interest was drawn back to the initial simpler circuit - we were back to square one, but with a host of new techniques for improving and stabilising driver stages.

From this point on it became clear that a refined version of the original base circuit was capable of truly excellent results. With the addition of a few more components and close attention to the layout and PCB routing, the performance and stability was improved to better than that of any of the more complex arrangements.

The Circuit

A quick glance at the actual circuit diagram may not reveal anything particularly new. This is hardly surprising, since the most significant contributions to the amplifier's high performance have to do with the PCB design, and component layout.

Broadly speaking, the circuit simply employs an input differential pair (Q3-Q4) which drives a high-gain voltage amplifier - based on another differential pair (Q5-Q6) - which in turn drives the paralleled sets of complementary MOSFET output devices (Q9/Q10,Q11/Q12).

By the way, you may notice that the main body of the circuit (up to the MOSFETs) looks remarkably like the internals of a high performance bipolar op amp. This is more than a coincidence, since a number of the current sourcing and balancing techniques in the circuit are borrowed from op amp practice. So just like a quality op amp, the amplifier offers differential inputs, high open-loop gain and bandwidth, low output impedance and a high slew rate. However the circuit is worth a general analysis, since its operation is not quite as simple as it looks.

The input signal is coupled to the first differential pair Q3/Q4 via the input network composed of C1, R1, R2 and C2. The input capacitor and resistor (C1 and R1) form a high pass filter, which restricts the amp's low frequency response to a -3dB point of 10Hz. Similarly, the overall high-frequency response is restricted to a -3dB point of around 100kHz by the low-pass filtering action of R2 and C2 - this controls the rise time of the input signal to an elas-

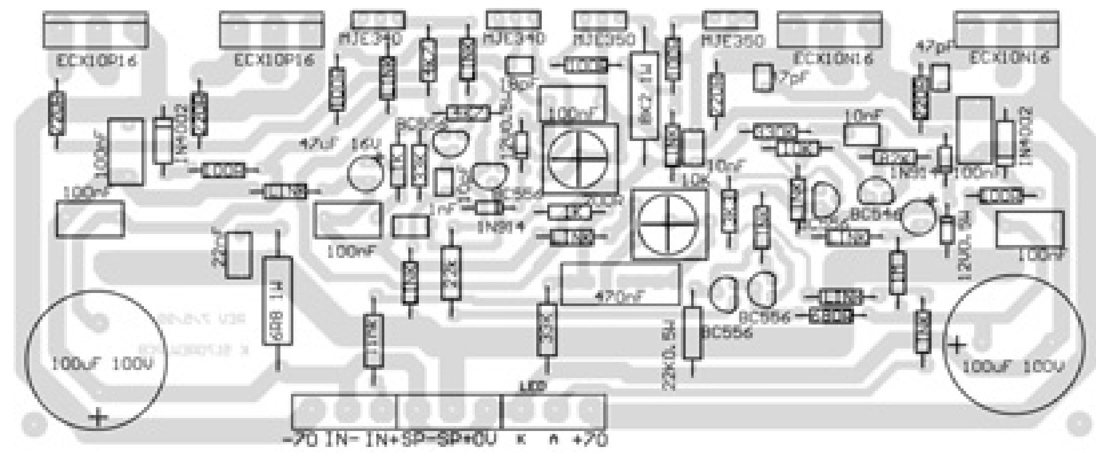


Fig 3: The top PCB overlay. Note this view is looking down from the component side of the PCB. Take care when placing the polarised components as a mistake can make later stages of construction more frustrating.

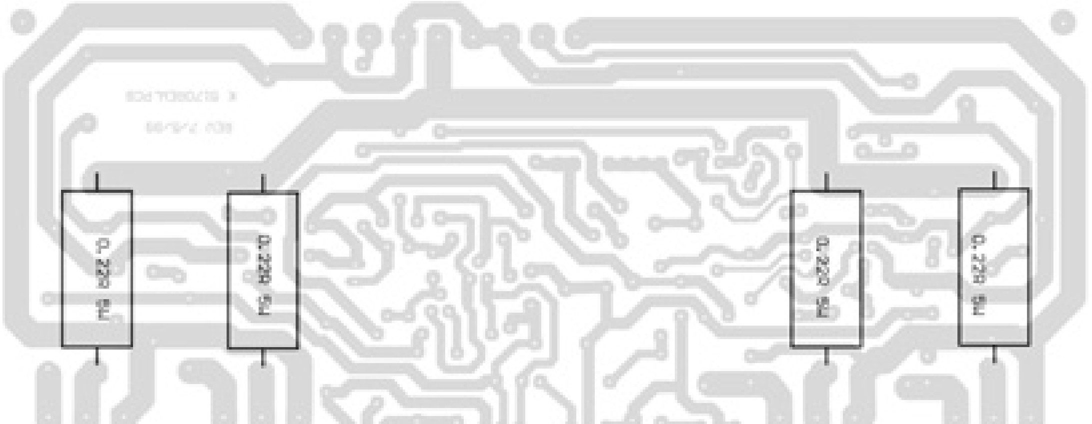


Figure 4: The bottom overlay for the main amplifier PCB . There is only the four resistors to mount underneath the PCB . Stand these off the PCB as they will need room to allow air flow over them . Note that the picture is viewed from underneath the PCB.

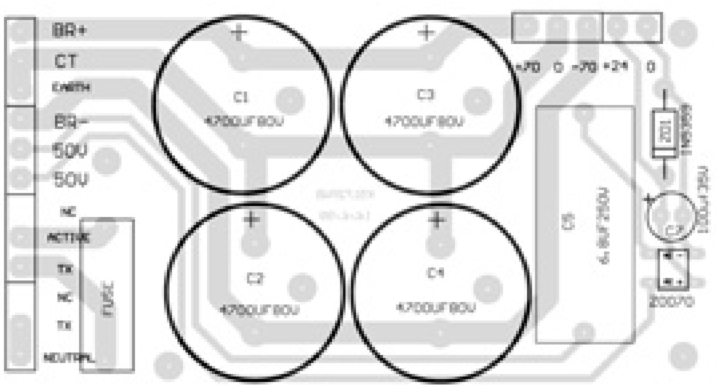
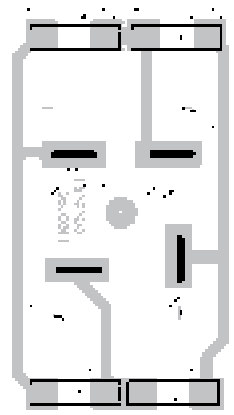


Figure 5 : The overlay for the power supply board. Take care with the polarity of your components , mistakes at this level can prove costly in the long run. The main power tracks underneath the pcb will need fattening up with some solder. This will increase the current handling of the amplifier.

Figure 6 : The bridge mounting PCB. The capacitors reduce the noise radiated out from the mains cable. The view of the picture is of the copper side. The bridge mounts from the component side of the PCB and is soldered to the copper side. It is mounted to the heatsink with the PCB copper side facing the toroidal.



tic level, which reduced the possibility of slew-induced distortion components.

The input differential pair based around Q3 and Q4 essentially functions to compare the input and output (feedback) signals, and generate an error signal which in turn drives the following voltage amplifier stage. To improve its performance and power supply rejection, the common emitter connection is supplied by a balanced, two transistor constant current source formed by Q1, Q2, R3 and R4.

When power is initially applied to the constant current source, current flows through R3, the base emitter junction of Q2, and to ground via R4. This will continue until the voltage across R3 reaches around 0.7V where Q1 conducts, robbing base current from Q2. The reduced emitter current of Q2 then tends to reduce the drop across R3.

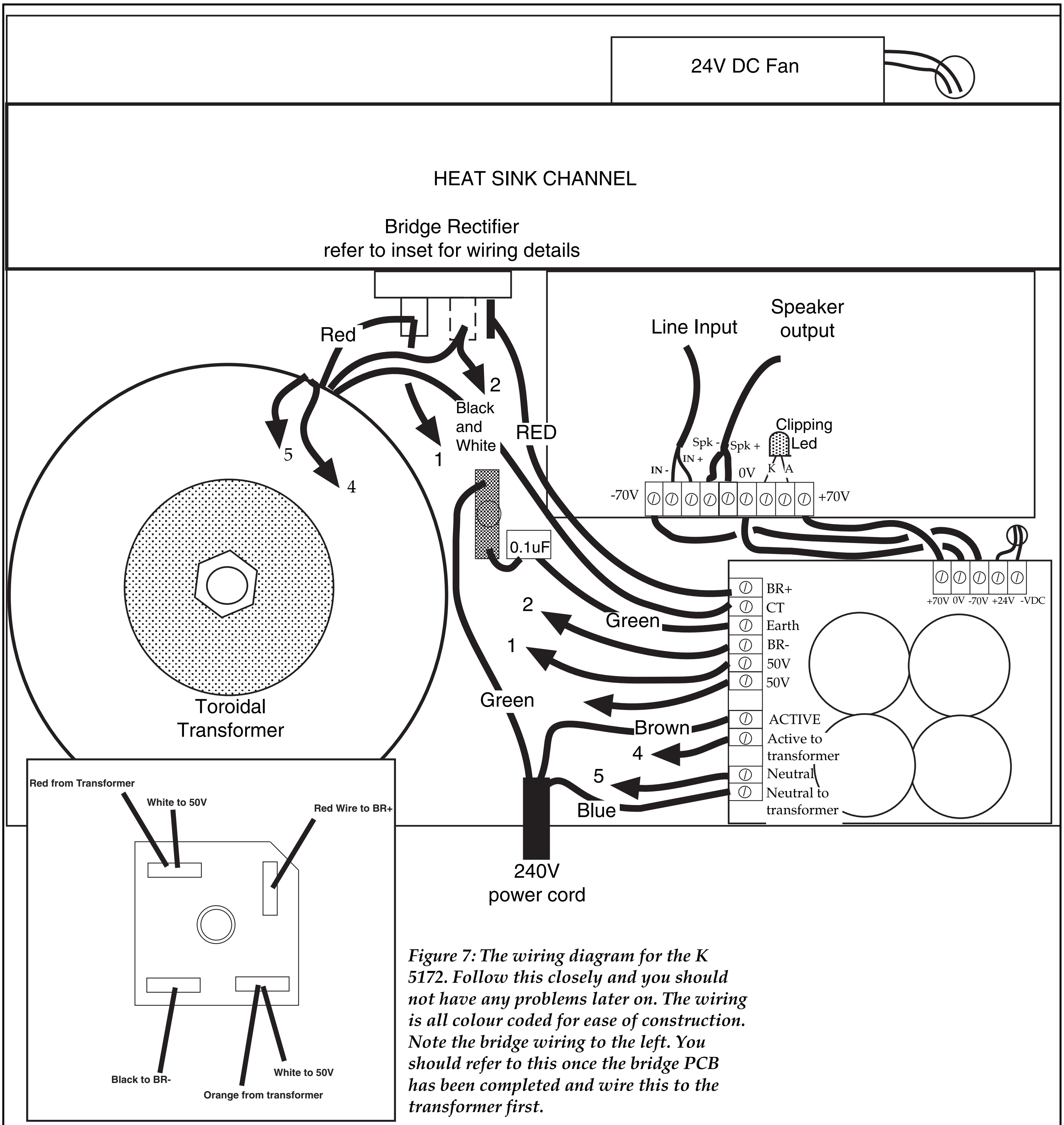


Figure 7: The wiring diagram for the K 5172. Follow this closely and you should not have any problems later on. The wiring is all colour coded for ease of construction. Note the bridge wiring to the left. You should refer to this once the bridge PCB has been completed and wire this to the transformer first.

The circuit reaches a point of equilibrium where the voltage drop across the base emitter junction of Q1 is about 0.7V, regardless of the value of R3. Since this voltage is fixed, the current through Q2 (and the differential pair Q3 and Q4) will be set by the value of R3. With this set to 680 ohms, the current is fixed at around 1mA.

Following the input differential amp is the voltage amplifying stage. This is based around a differential pair formed by Q5 and Q6, and a balanced current mirror load incorporating Q7 and Q8. This section of the circuit provides most of the amplifier's voltage gain, and a highly linear output capable of swinging between the two supply rails.

The current mirror (Q7 and Q8) acts as the collector load for Q5 and Q6, which operate at a shared quiescent current of around 20mA, as set by R13 and the collector loads of Q3 and Q4 (R6 and R7 respectively). The current mirror itself is not unlike a programmable constant current source, with the current through Q7 and R9 modifying the amount of current sourced by Q8 - the collector load for Q6.

So, as a differential input signal tends to turn Q5 ON and Q6 OFF, the increased current through Q7 and R9 will bias Q8 on a little harder. Therefore as Q6 is turning OFF, the action is assisted as Q8 (its collector load) effectively becomes a lower impedance. Due to this active collector

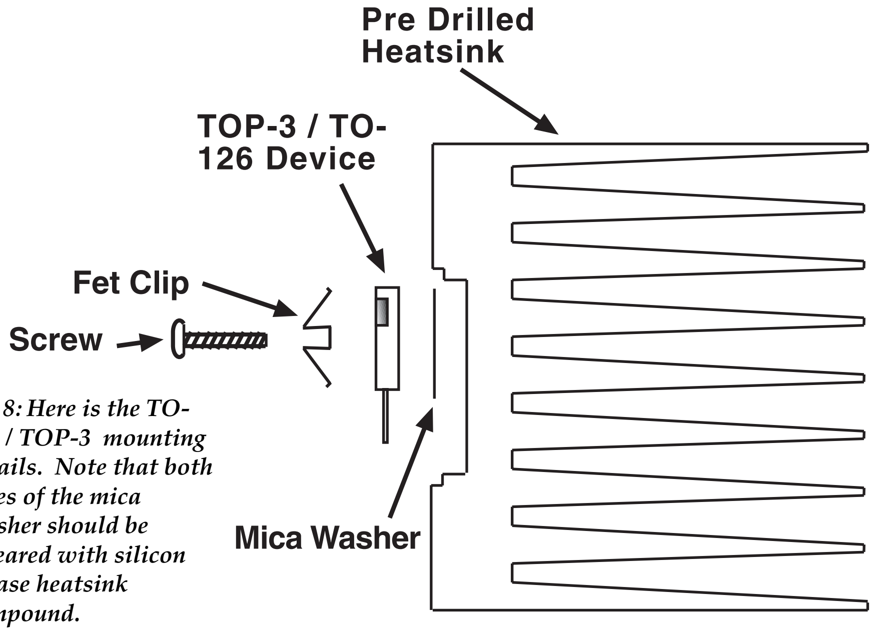


Fig 8: Here is the TO-126 / TOP-3 mounting details. Note that both sides of the mica washer should be smeared with silicon grease heatsink compound.

load, the stage offers an extremely linear output and a very high voltage gain.

To balance the power dissipation and operating points of Q5 and Q6, R11 is inserted in the collector of Q5, while C5 bypasses its effect at higher frequencies. Also, C7 is included to decrease the gain of the stage at very high frequencies, which in turn controls the overall phase shift and ensures stability. The outputs at the collectors of Q6 and Q8 are separated by a fixed voltage as set by RV1, which sets the MOSFET's gate to source bias - thus ultimately their quiescent drain current.

The output stage is formed by the complementary set of MOSFET's Q9-12, with their respective source degeneration resistors R18 to R21, and gate 'stopper' resistors R14 to R17. Since the MOSFET's may be driven to destruction by excessive gate drive, such as an output overload where the NFB applies excessive compensation, the gate to source voltage is limited to about 12V by D1, ZD1, D2 and ZD2.

The overall closed-loop gain of the amplifier is set by the voltage divider action of R12, R8, C3 and C4 - as with an equivalent op-amp configuration, this network supplies the amplifier's 'inverting input', while the non-inverting input accepts the input signal.

At audio frequencies the overall gain is set to 34 by the ration of R12 and R8, since R8 is bypassed to ground by C3 and C4. Of course at very low frequencies these capacitors offer a high impedance, which increases NFB and rapidly reduces the gain. Similarly, the gain is reduced at very high frequencies by the bypassing action of C6 on R12. By the way C3 is in parallel with C4 to ensure a low impedance path to earth at high frequencies, where many electrolytic capacitors offer poor performance.

For a further increase in power supply rejection, the amp's driving circuitry has heavily decoupled supply rails by virtue of D3, D4, R23, R24, and capacitors C13 to C16. This guarantees the performance of the earlier stages, even when the output devices are delving heavily transient currents.

Power Supply

Excepting the DC section for the fan , the power supply itself is quite a conventional arrangement based around a 225VA toroidal transformer, with two 45V secondary windings feeding a heavy-duty bridge rectifier. The resulting balanced supply rails are filtered by 8000µF/75V capacitors.

To maintain the lowest possible impedance between the power supply rails and the MOSFETs, we have not included fuses directly in series with the mosfet drains. While this is a little unconventional, we found that this style of direct connection provided significant performance benefits. Also, experience has shown that the mosfet devices are extremely reliable and quite self-protecting, and a catastrophe (that is, a full short circuit across the supply rails) is extremely unlikely - unlike bipolar designs.

The overall protection in our circuit is simply the 3A fuse FS1, which will disconnect the mains supply in the event of a gross overload. For those that are uneasy about this situation, we would recommend the addition of Polyswitch devices in series with the amp's output leads. In fact, a fused supply will provide little protection for a loudspeaker if the amplifier produces a large DC offset at its output, due to a fault condition.

The fan control section of the circuit uses a capacitive reactance arrangement to cause the 6.8µF 630 V capacitor to behave like a resistor.Using the formula $X_C = 1/2\pi FC$ we can calculate the resistance across the capacitor. This is around 470Ω at 50Hz. The capacitor because of it's reactive nature in the circuit will not build up the great deal of heat that you would expect from conventional designs. The remainder of the power supply is very conventional. A bridge to convert the AC to DC , a 100µF capacitor to smooth the ripple and a Zener to clamp the rail to 24VDC.

As an added feature, we have also included a novel overload detector circuit based around transistors Q13 and Q14. While its operation is very straightforward, the circuit utilises a complex effect which occurs within the amplifier during overload conditions. in practice, the circuit will energise LED1 if the amp's distortion rises above about 0.05% - a lower figure than many amplifiers can ever hope to achieve!

The circuit basically detects transient AC signals, extends the pulse length and illuminates the LED for that period. The signal from point A is AC coupled to Q13 by C19 and R25 (which raises the circuit's input impedance). When sufficient energy arrives to bias Q13 ON momentarily, its collector falls - charging C20. This stored voltage holds Q14 in conduction for an extended period, while C20 is discharged by R27 and the transistors base current. During this period, the collector of Q14 rises to the full supply voltage (connection B), energising LED1 via the current limiting resistor R28.

The signal at the collector of Q5 (point A) represents the amplifier's overall error or correction voltage. This occurs since the other half of the differential pair Q6 generates the full output signal swing - if we consider the mosfets as electrically transparent for the moment. Now if the signal at the collector of Q6 represents the corrected output (that is, less the distortion components), and Q5 and Q6 represent a true differential amplifier, we can expect the signal difference to appear at the collector of Q5 - or in effect, the distortion components which are cancelled at the output - thanks to the overall NFB.

In practice this effect is quite easy to detect with an oscilloscope. If for example, the amplifier is driven into clipping, large spikes are generated at point A as the NFB attempts to compensate for the flattened peaks at the output. So in general, whenever the distortion is high at the output

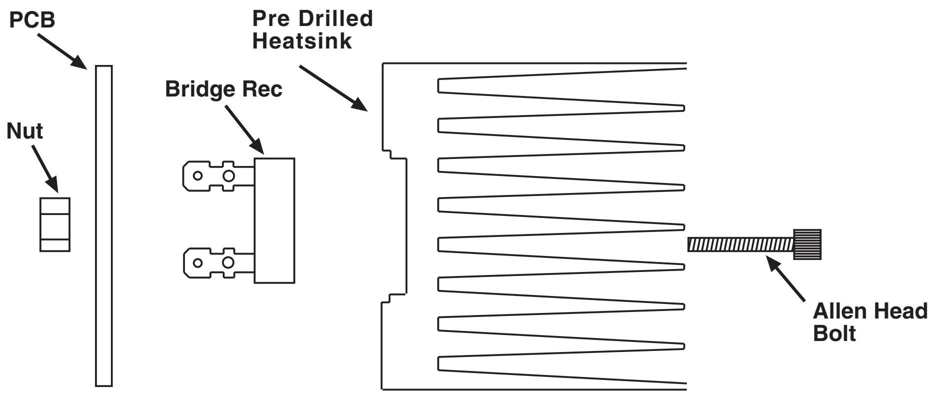


Figure 9: This is the method that you should follow in order to attach the bridge to the heatsink . The mating surface of the bridge should be smeared lightly with heatsink paste in order to facilitate the transfer of heat.

(for whatever reason), sufficient voltage is generated at point A to drive the overload indicator circuit.

Unlike conventional overload indicators which simply sense the output swing, this simple circuit will warn the user of any unacceptable (and dangerous) distortion components - and of course its action is true for any load conditions and supply rail voltages.

Construction

The construction of both PCBs is straight forward. Use the conventional method of checking the PCBs and then begin to place the lower profile components , maintain care with the polarity of those components where necessary. Progress to higher profile components and finish off the PCB with the largest of the components. Leave the MOSFETS out and the T0126 transistors out at this stage as they must be placed carefully onto the pre-drilled heatsink. Check all your joins and make sure there are no bridges to short the unit out. Turn the main PCB over and solder the 0.22 Ω resistors to the pads indicated in figure 4, mounting them slightly raised off the PCB to allow air to circulate underneath them.

You should now turn your attention to the base plate. Mount all the standoffs in place for the two boards to go into and mount the earth terminal with a rivet gun, the Earth wire from the mains can be directly soldered to the terminal at this stage. There is a 0.1µF capacitor that is soldered to the terminal and then to the earth lead that will get connected to the PCB.

All of the transformer wiring should be carried out referring to figures 7 and 8. The PCB which you have mounted the bridge to should be mounted next in accordance with figure 9, applying heatsink paste to the surface of the bridge to contact the heatsink prior to mounting it.Check the spacing of the FETs and mark the height that they need to sit above the PCB off the pre-drilled heatsink. Use static precautions when handling these devices. Solder these into place at the appropriate height.

You can now mount the Mosfet devices (and main PCB) to the heatsink. Apply heatsink paste to both sides of the Mica washers and then proceed to use the yellow coloured screws (taptites) and the spring clips to mount the Mosfets. Check these and the other transistors are isolated from the heatsink, if not try loosening off the bolts , reposition the mica and tighten the bolts again. Refer to figure 8 for this procedure. The main PCB can now be attached to the two spacers on the base plate. If the spacers are not of sufficient height then use the 3mm nuts provided to increase the length of the spacer to appropriate levels.

Complete the wiring to the power supply PCB and the transformer/ bridge rectifier and then attach the PCB to the proper location at the front of the base plate. Again follow the wiring on figure 7 to complete this.

Attach the transformer to the base plate with the appropriate hardware and slide in the fan plate to the heatsink channel which also should be secured by self tappers. The fan is attached to the plate in the spot indicated in figure 7 with the long black self tapping screws, do not over tighten these as the plate will dislodge from the mountings if you do. Finish off the remaining wiring from the main PCB to the power supply PCB.

Before you power the unit up it will pay to thoroughly check all your soldering and wiring and isolation of the MOSFETS one more time for peace of mind. Any mistakes found after you power up may cost you additional money.

The unit is not housed so it may be worth your while to find a suitable housing and the connectors to finish off your amplifier, or if you have a housing in mind install the unit in the one you have selected.

Powering Up

Before applying power to the unit, install 10 ohm resistors in series with each supply rail, and rotate RV1 fully anticlockwise. Visually check this position on the trimpot since it may not have an end-stop, allowing the wiper to slip past the minimum resistance point to a maximum setting - or in practice, the maximum quiescent!

If the 10 ohm resistors go up in smoke, turn the unit off and thoroughly re-check your work. However if all is well (naturally!) check the power supply rail voltages and the amp's output voltage - these should be close to ±69 volts, and 0V (±30mV) respectively (+)0.3V.

To set the amplifier's quiescent current, monitor the voltage across one of the 10 ohm resistors and adjust RV1 for a reading of 0.8 volts. Once you are happy with the setting, turn the amp off and install the other fuse - then turn the unit back on and repeat the entire procedure for the other channel. Check the quiescent current of both channels over a period of about ten minutes and if necessary, readjust RV1 for the correct reading.

This adjustment is far less sensitive (or critical) than the equivalent setting on a bipolar amp, and will increase by a significant amount as the amp warms up. However once each mosfet reaches an idling current of around 100mA (say after the amp has delivered a substantial level of power), the NTC effect will come into play, causing the output stages to thermally self-stabilise. Nevertheless, if you feel that the general (idling) temperature of the heatsink is too high, back off the quiescent current adjustment (RV1) by a small amount - but note that this will slightly compromise the distortion figures.

Precautions

Here are a few precautions we think may be of service to you.

The component overlay for the non-copper side of the PCB. Take care not to confuse the two types of TO-126 transistors.

The wiring should be all thoroughly checked and even re-checked. If you can , it may be a better idea to use the circuit to do this .

Parts List

Resistors
All 1/4W 5%, unless noted:
4 0.22 ohms 5W (R18-21)
1 6.8 ohms 1W (R22)
2 10 ohms (quiescent adjust resistors)
5 100 ohms (R9, 10, R13, R23-24)
4 220 ohms (R14-17)
1 680 ohms (R3)
2 1k (R2, R8)
1 3.3k (R28)
2 4.7k (R6, 7)
1 8.2K 1W (R11)
1 10k resistor
1 22k 1/2W (R4)
1 22k (R5)
2 33k (R1, R12)
1 82k (R26)
1 330k (R25)
12 0Ω resistors (links)
1 1M (R27)
1 200 ohm 10 mm horizontal trims (RV1)
1 10K 10 mm horizontal trims (RV2)

Capacitors
1 10pF ceramic (C6)
1 18pF 100V ceramic (C8)
2 47pF 50V ceramic (C9, C10)
1 1nF metallised polyester (C2)
2 10nF metallised polyester (C5, C19)
1 22nF metallised polyester (C12)
6 0.1µF metallised polyester (C3, 7, 13, 15, 17, 18)
1 0.47µF metallised polyester (C1)
1 1µF 63VW PCB electrolytic (C20)
1 47µF 16VW PCB electrolytic (C4)
2 100µF 160VW PCB electrolytic (C16, 14)
1 100µF 35VW PCB electrolytic
1 0.1µF MKT metallised polyester
4 4700µF 80VW electrolytic capacitors
4 0.22µF 250VW monolythic capacitors.
1 6.8µF metallised polyester capacitor.

Semiconductors
5 BC556 PNP transistors (Q1-4, Q14)
1 BC546 NPN transistors (Q13)
2 MJE350 PNP transistors and insulating kits (Q7,8)
2 MJE340 NPN transistors and insulating kits (Q5, 6)
2 ECX10N16 power MOSFETs and insulating kits (Q9, 10)
2 ECX10P16 power MOSFETs and insulating kits (Q11, 12)
2 1N4002 diodes (D3, 4)
2 1N914 diodes (D1, 2)
2 12V 400mW zener diodes (ZD1, 2)
1 5 mm red or yellow LED
1 24V 5W 1N5359 zener diode
1 Bridge rectifier 400V Dip package
1 Glass passivated 200V 35A bridge rectifier.

Miscellaneous

6 6G x 3/8" self tapping screws
4 6G x 1 1/2" self tapping screws
1 M4 x 25mm bolt
1 Brass earth terminal rivet
1 24VDC 80mm Fan
4 Rubber feet
4 M3 tapped spacer 15mm long
2 M3 tapped spacer 25mm long
10 M3 x 6 mm bolt
2 M3 x 10 mm bolt
2 M3 nuts
1 M4 x 10mm bolt , nut and star washer
2 100mm cable ties
2 M3 spring clips
2 M4 spring clips
1 Tube of heatsink compound
1 45V + 45V 300VA toroidal transformer
1 Base plate and fan channel plate
1 300mm length of Channel heatsink
1 Mains lead
1 M0205 3A fuse
1 Fuse holder PCB mount with cover.
2 Taptite (yellow brass) M2.5 x 10 mm screws
2 Taptite (yellow brass) M3 x 10 mm screws
1 400mm length of white HD hookup wire
1 400mm length of black HD hookup wire
1 300mm length of green HD hookup wire
1 Bridge mounting PCB code : Bridge1
1 Main PCB code : K5170REW.PCB
1 Power supply PCB code : Alt5172
2 Small rolls of solder

WARNING

MAINS POWER CAN BE DANGEROUS

This device is powered from 240V Mains Power. Energy Authority Regulations should be observed before connection of any power lead, plug etc.

The Australian Standard Wiring Colour Code for Mains is:

ACTIVE	**- BROWN**
NEUTRAL	**- BLUE**
EARTH	**- GREEN** or **GREEN** with a **YELLOW** stripe

Please be very careful to ensure all mains connectors are correct before powering this product. If you have any doubt whatsoever, and/or have an eyesight colour deficiency, we strongly urge you to have all mains wiring checked by a qualified person.

Dear Kit Constructor,

At Altronics we take great pride in the quality and presentation of our kits. If you find any deficiency in this kit or have any constructive comments whatsoever, please write to us.

Altronics
Attention: The Kit Manager
P.O. Box 8350,
Perth Business Centre
W.A. 6849
email : peter@altronics.com.au

Important Note:

Please note that we can offer a warranty only on the components supplied with this kit, except the semiconductors. Because we are unable to guarantee your labour, there is no warranty on either partially or fully built kits.

We are able to offer a repair service, but once construction has commenced, this service is chargeable.

Doc GL822