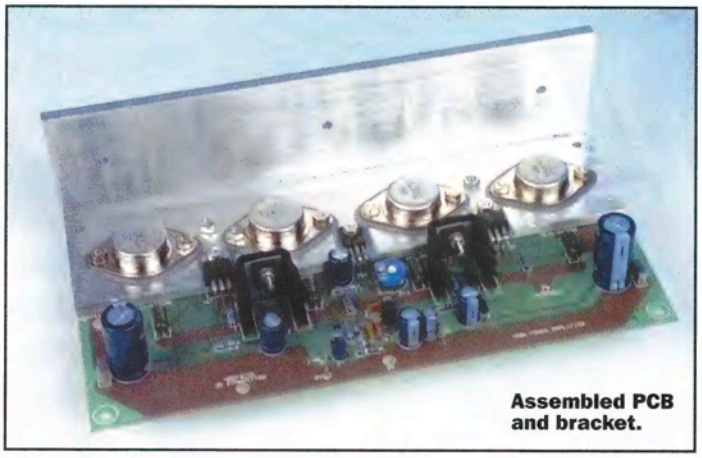
PROJECT

150W POWER AMPLIFIER

Design by RCA,
Revised by Alan Williamson
Text by Alan Williamson and Maurice Hunt

The original 150W Power Amplifier kit (LW32K) is (electrically) perfectly adequate for its intended purpose of high(ish) power sound reinforcement in PA and disco equipment – it is undoubtedly a popular kit, as borne out by the sales history; however, it was felt that, mechanically, its design left something to be desired, since there was a lot of 'spaghetti' between the PCB and output devices, and the heatsink was something of a nightmare to drill accurately, which was also inadequate for full power reproduction into 4Ω. Basically, the kit was in need of revamping.



Assembled PCB and bracket.

PROJECT RATING 2

Kit Available
Order as LP33L Price £34.99

This updated MkII version (LP33L) is much easier to construct, since all components are mounted on a single PCB with minimal wiring – restricted to PSU (+/0V/–), signal input and speaker output. The heatsink bracket is pre-drilled to accept the power transistors, and greaseless insulators replace the Mica + thermal paste types (always a messy job).

Other alterations to the amplifier include adding some extra capacitors, C3 decoupling ZD1, C10 stabilising the bias voltage across TR4 and adding C13 & C14 for local decoupling of the supply. Some of the semiconductors have also changed; TR1 & TR2 have been upgraded to low noise types (2SA1085E), TR3 has changed to BD140 and TR4 & TR5 to BD139.

This amplifier is a bipolar transistor-based design, with a complementary push-pull (Class B) output stage. The advantage of a Class B type over a Class A equivalent is the much lower quiescent current drawn (around 100 times less in this instance). Class A amplifiers are the preferred choice for Hi-Fi applications, due to the lack of crossover distortion, but the Class B type is ideal for PA systems, requiring high output power and where ultimate sound quality is not such an important criterion.

Circuit Description

Refer to the Block diagram (Figure 1) and the Circuit diagram (Figure 2); the capacitors C1 & C2 and resistors R1 & R2 form a band pass filter – setting the bandwidth of the amplifier, C1 limits the low frequency and C2 the high (under no circumstances increase the bandwidth of the amplifier, if you do, it will be at your peril), R1 & R2 also set the input impedance.

TR1 & TR2 form a long-tail pair (also known as a differential amplifier), the gain is set at 26dB (×20). TR3, D2 & D3 and R12 form a constant current source feeding the chain of TR4 & TR5.

TR4 combined with R10, R11 & RV1 form an amplified diode, the resulting constant voltage between the collector and emitter of TR4 sets the bias of the output stage (via the emitter follower drivers, TR6 & TR7).

TR5 is the Voltage Amplifying Stage which is controlled by the overall feedback loop, R13 provides a small amount of series feedback to TR5, C8 also provides feedback to TR5 and forms the dominant pole (the limiting factor in the amplifier).

TR6 & TR7, as previously mentioned, are emitter followers, providing plenty of drive current to the output emitter follower stage, R17 to R20 help to even up any gain differences the output devices.

FEATURES

Powerful bipolar design

Easy to build

APPLICATIONS

PA systems

Disco Equipment

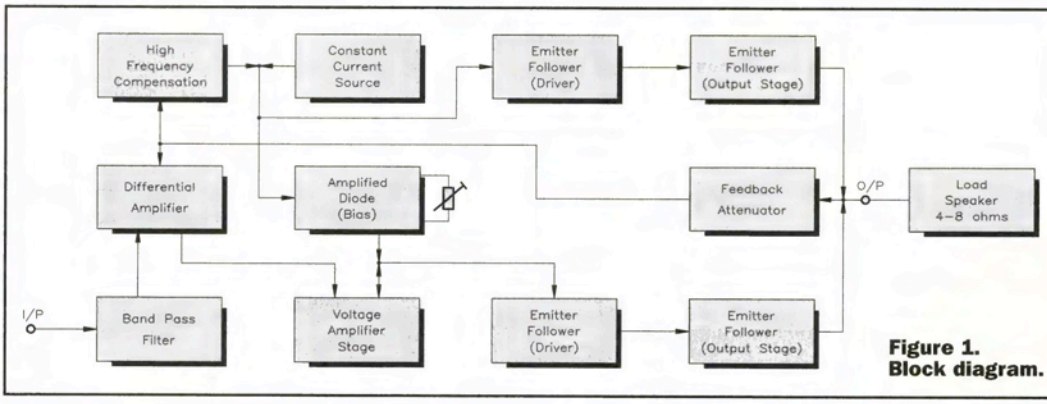


Figure 1. Block diagram.

R7 & R9 attenuate the output signal to the speaker and apply it as global feedback to TR2; R7 & R9 also set the overall gain of the amplifier and also the input sensitivity for full output. At first glance, it would appear that TR1 is not within the feedback loop, but it is indirectly. TR1 & TR2 can be viewed as a 'seesaw', with the emitters as the pivot point. Applying a signal to the base of TR2 will cause it to conduct more or less current (depending upon the polarity), this in turn will affect the 'tail' current (emitter connection) and therefore, TR1 alters its conduction (in the opposite direction) to maintain 'balance' at the 'tail', ergo TR1 is affected by the global feedback.

Construction

Refer to Figure 3, showing the PCB legend and track. Construction is fairly straightforward, but a few tips may be helpful.

Begin with the smallest components first, working up in size to the largest; be careful to correctly orientate the polarised devices, i.e. electrolytic capacitors & diodes. Use the component lead off-cuts for the link.

Use a drop of cyanoacrylate adhesive (super glue) to bond TR1 & TR2 together face to face, or alternatively, use a piece of heatshrink sleeving; this is to achieve thermal matching of these components.

Bolt the heatsink bracket to the PCB using the supplied M3 hardware; refer to Figure 4, showing the exploded assembly of TR4, TR6 & TR7. NOTE, use the M2·5 hardware for the TO126 device (TR4). Fit the other TO126 package transistors (TR3 & 5) to the separate vaned heatsinks as shown in Figure 5, again, using M2·5 hardware – not forgetting the insulators. Assemble the TO3/TO5 power transistors (TR8-11) onto the bracket as shown in Figure 6; once firmly bolted in place (within reason; overtightening will snap the brass bolts – used for superior electrical conductivity over stronger steel bolts – and could cause other component damage), the transistor leads and the heads of the screws can be soldered to the PCB. Using a multimeter set on the highest resistance range, check the continuity between the heatsink bracket and the collectors of TR8 to TR11; an 'out of range' reading should be obtained (i.e. open circuit).

Fit the heatsinks to TR3 & TR5 using the M2·5 hardware, then fit the assemblies to the PCB.

Should you wish to connect the heatsink bracket to 0V (which is normally at earth potential), refer to Figure 7; others may wish not to do so, as hum from earth loops can arise when a stereo configuration with a single power supply is built into a metal case. The problem can be negated by using an EIC bridge (Earth Isolation Circuit) – see the (optional) power supply circuit, shown in Figure 8.

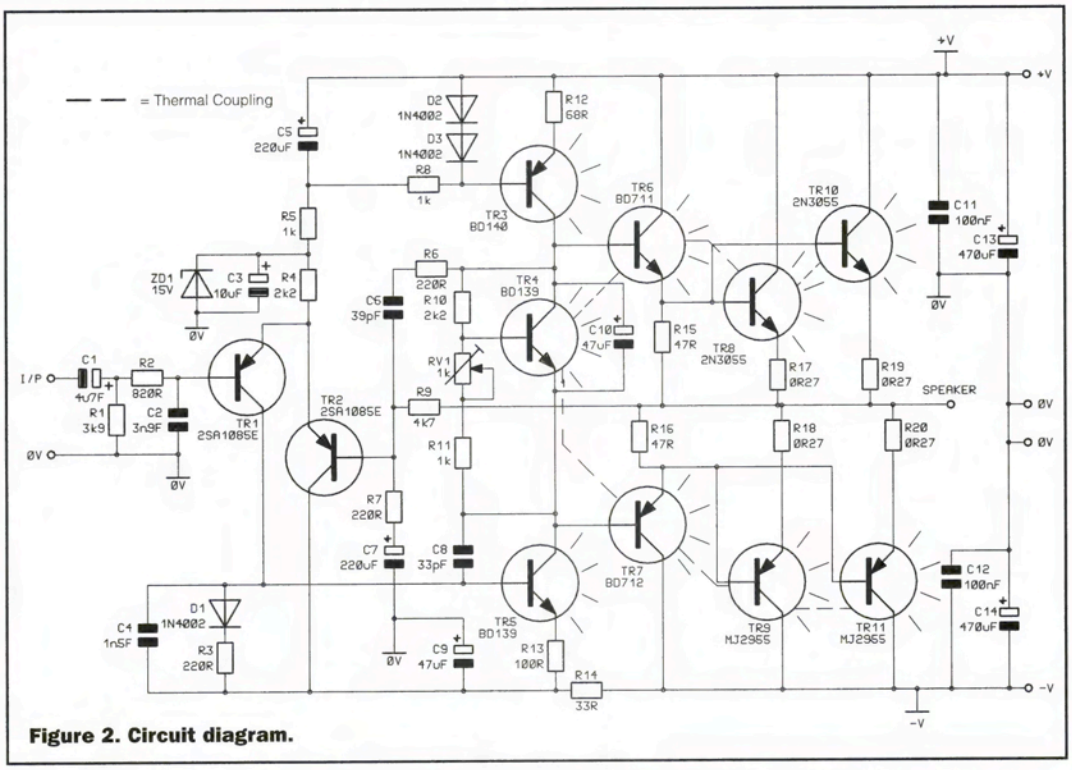
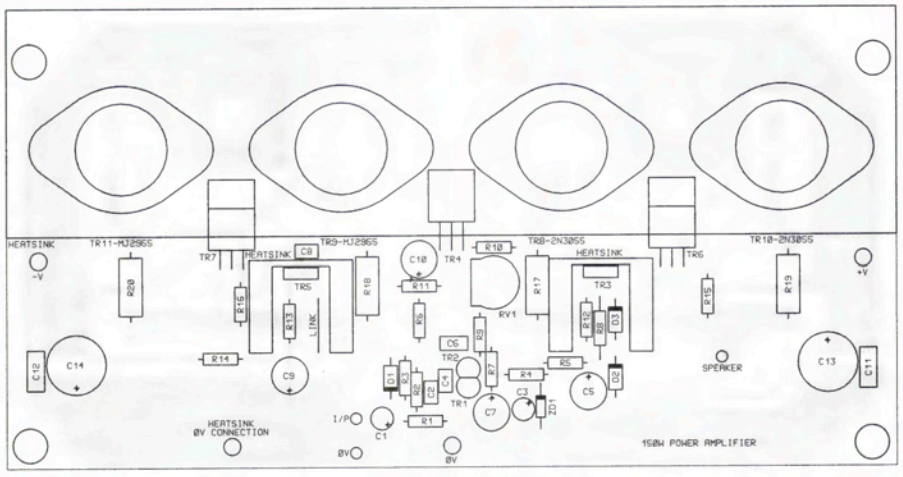


Figure 2. Circuit diagram.

Figure 3. PCB legend and track. (60% of actual size).



Thoroughly check your work for misplaced components, solder whiskers, bridges and dry joints. Finally, clean all the flux off the PCB using a suitable solvent.

Before attempting to power up the module for testing, double check EVERYTHING!

Testing and Use

First of all, an adequately sized heatsink (or heatsinks) and a suitable power supply are required.

In order to keep the amplifier as reliable as possible while delivering continuous full power into a load, a large heatsink is required to limit the temperature rise to an acceptable level of say, +55°C above the ambient room temperature of +25°C, giving a total heatsink temperature of +80°C.

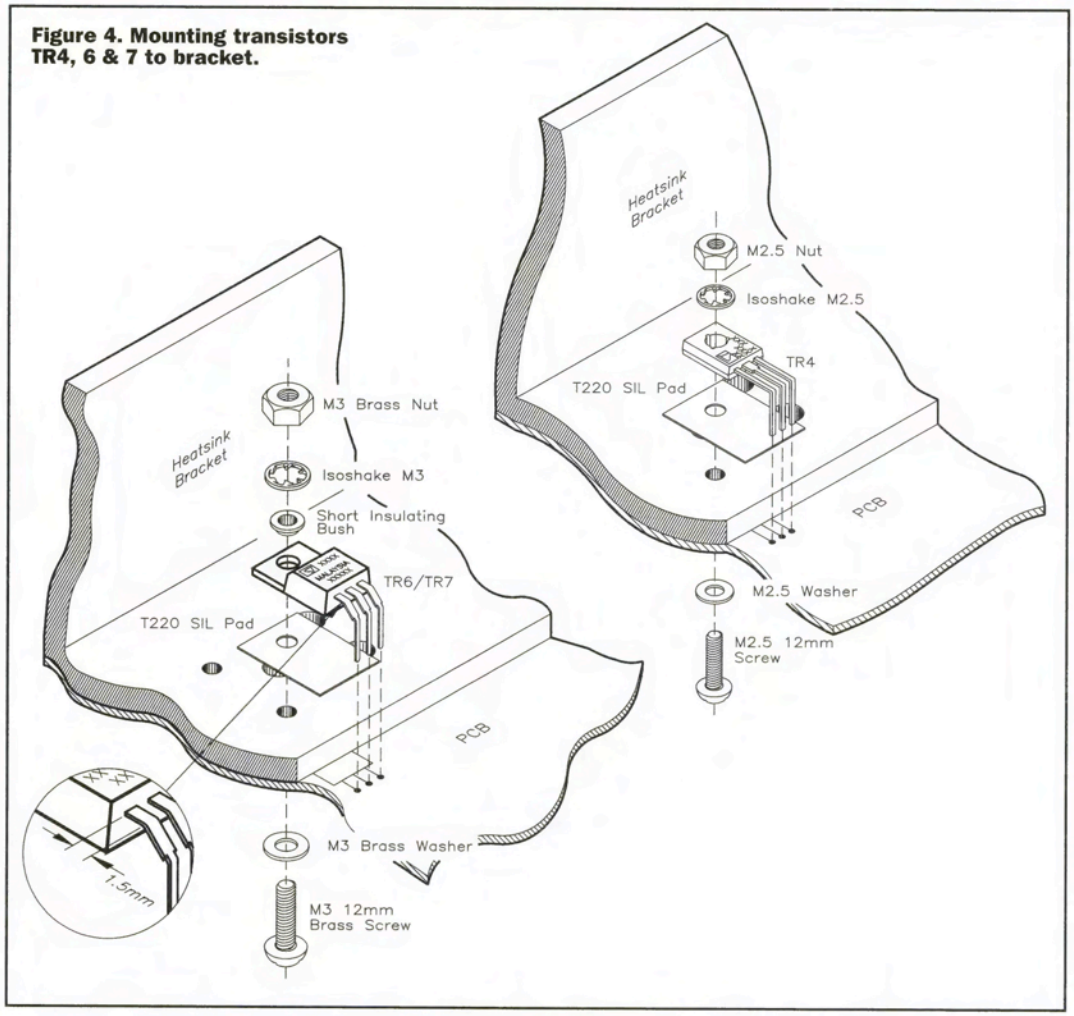
For continuous full power into 8Ω, a pair of 2E-type (2·4°C/W) heatsinks (HQ70M) are recommended; and for 4Ω use, a minimum of three 2E-type heatsinks are recommended. Note that the supplied aluminium heatsink bracket must be drilled to accept the heatsink(s) of your choice. It is important to remember to apply a small amount of thermal conducting paste (not supplied) to the heatsink and bracket for a reliable thermal

SPECIFICATION

Operating voltage:	±50V DC maximum
Operating current (quiescent):	70mA
Amplifier classification:	Bipolar push-pull (Class B) output stage
Maximum signal amplitude:	28·5V (rms) into 8Ω* 26·5V (rms) into 4Ω*
Maximum continuous output power:	100W (rms) into 8Ω* 175W (rms) into 4Ω*
Frequency response:	30Hz to 20kHz (–1dB) 15Hz to 37kHz (–3dB)
Total harmonic distortion:	<0·1% at 1kHz
Damping factor:	80
Sensitivity for full output:	1V rms
PCB dimensions:	196 × 101mm

* Above measurements taken with amplifier powered by the specified PSU, producing ±44V DC.

Figure 4. Mounting transistors TR4, 6 & 7 to bracket.



The budget choice would be BR1, 2× 10,000μF and a 300VA transformer for stereo 8Ω use or mono 4Ω (500VA for stereo 4Ω).

And for those with deeper pockets, who are trying to get the most from the amplifier, the choice would be a mono construction, with a 500VA transformer, D1-4 and 2× (or 4× if you can afford it!) 22,000μF audio grade capacitors.

The four capacitors across the bridge rectifier (BR1) are included for EMC reasons (strictly speaking, they are not necessary for D1-4, as they are 'fast [but soft] recovery types'); in fact, they ruin the performance of the bridge rectifier by slowing down the forward conduction and reverse bias recovery time, and increase reverse leakage current. However, by slowing down the recovery action of the diodes, the PN junction is less likely to radiate an EM pulse (a bit like clapping your hands together slowly).

On completing the power supply, make absolutely certain that the large electrolytic capacitors are connected with the correct polarity; you wouldn't want these to explode on switch-on, and we don't want pieces of customer scattered everywhere!

Figure 6. Mounting transistors TR8-11 to bracket.

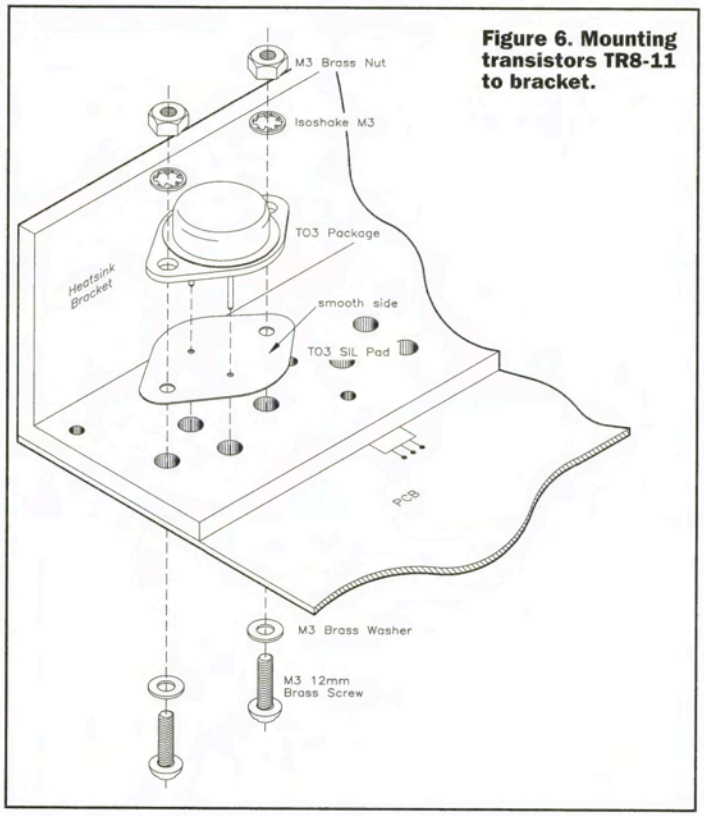


Figure 5. Mounting transistors TR3 & 5 to bracket.

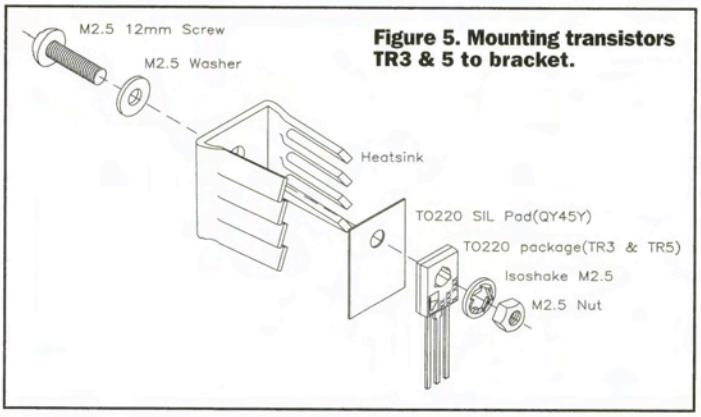
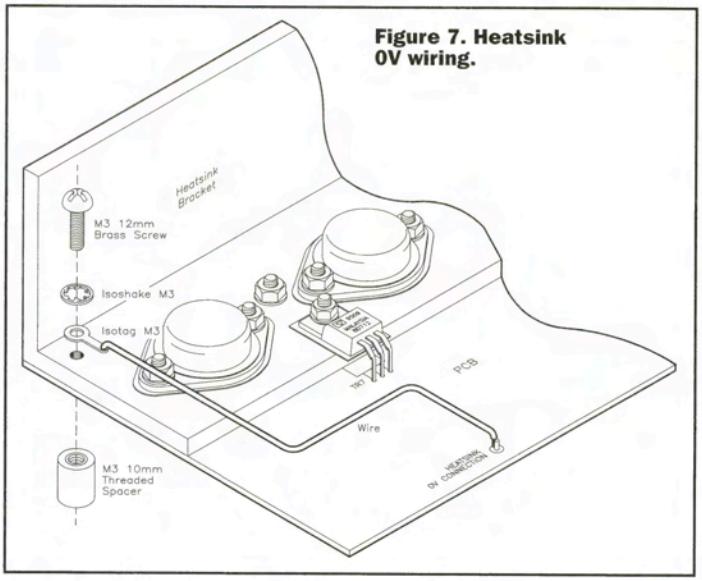
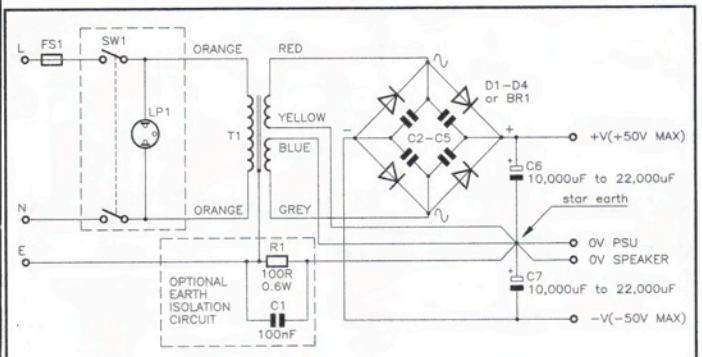


Figure 7. Heatsink 0V wiring.



bond. When mounting the amplifier into a box, ensure that the track side of the board is elevated at a height of at least 10mm from the box base – use insulated spacers (e.g. FS36P-40T) at each corner of the PCB.

Figure 8 shows a suitable power supply circuit; however, the choice of components is determined by configuration (mono or stereo) load impedance (8Ω or 4Ω) and how deep your pockets are!



PARTS LIST

REF	DESCRIPTION	STOCK CODE
R1	Min Res 100R 0.6W	M100R
C1	HV Cap 100nF	FA21X
C2,3,4,5	Polyester 100nF	BX76H
C6,7	10,000uF to 22,000uF Can	LE04E or FA18U or FA20W
D1,2,3,4 BR1	P600D or BYW80–150 K04	UK60Q or UK63T BH48C
T1	300VA or 500VA 35VAC	YK22Y or YK23A
FS1	Fuse 20mm T2.5A or T6.3A	DA00A or DA02C

NOTES:–

T1 IS 300VA FOR MONO–8 OHM OR 500VA FOR MONO–4 OHM OR STEREO–8 OHM

C6 & C7 IS 10,000uF FOR MONO–8 OHM OR 22,000uF MONO–4 OHM OR STEREO–8 OHM

FS1 IS A T2.5A FOR 300VA OR T6.3A FOR 500VA TRANSFORMER

Figure 8. PSU circuit diagram.

Once the heatsinks have been added to the amplifier and a power supply constructed and tested (keep the transformer, rectifier and capacitors close to each other to reduce the wiring length; make the 0V connection between the two electrolytics the 'star earth' point), testing of the amplifier can begin. Figure 9 shows the general interconnection of the amplifier to the ancillary items.

Connect the power supply to the amplifier using THICK cable (2·25mm domestic ring mains cable is ideal), and keep the wiring lengths as short as possible. Fitting fuses in the supply lines is NOT recommended (it's amazing how much distortion a fuse can add); a correctly chosen transformer primary fuse will blow just as quickly as one in the DC supply line. Similarly, fuses fitted at the speaker output are not recommended; if you are worried about protecting your speakers from a DC offset caused by a faulty amplifier or PSU, use the 'Amplifier Monitor' kit (LP32K).

Thick cable should be used for the speaker output and return to the 'star earth', and a low capacitance screened cable should be used for the signal input.

Power up the amplifier without a load connected, watch out for things getting hot, and should something begin to smoke, switch off immediately and check your wiring. Also look for short circuits; re-check the insulators of the transistors mounted on the heatsink bracket.

Should everything be OK up to this point, switch off the power and connect a multimeter (set to read 50V DC minimum) between the speaker output and 0V; switch the power back on and note the meter reading; 0V should be observed. Re-select the meter to range to 2V DC minimum, a reading of no greater than ±0·2V should be observed. Switch off the power and disconnect the meter.

There are two possible methods of setting the bias; the first is to connect an ammeter in series with the +V supply line, adjust RV1 (anticlockwise to increase) for a reading of 70mA, wait 15 minutes for thermal equilibrium to be achieved, then re-adjust for a reading of 75mA.

The second method is to measure the voltage across the output transistor emitter resistors (R17-20); sum the four voltages together then divide by four for an average reading of 3·7mV. Wait 15 minutes, then re-adjust RV1 for an average reading of 4mV across each of the resistors; NOTE, the transistors are not matched and therefore, a variation of up to 1·5mV may be experienced between devices.

Connect an 8Ω 200W load to the amplifier and apply a music signal (via an attenuator set to minimum) to the input of the amplifier; slowly turn up the volume and listen for any peculiar distortions.

Further power/distortion/bandwidth testing can be carried out if you own the appropriate equipment, i.e. signal generator, oscilloscope, distortion meter and a dummy load of adequate power rating (to save your ears from the assault).

Happy listening. ELECTRONICS

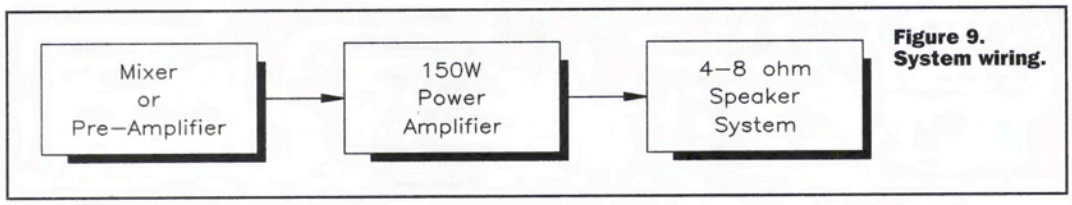


Figure 9. System wiring.

PROJECT PARTS LIST

RESISTORS (All 0·6W 1% Metal Film, Unless Stated)

R1	3k9	1	(M3K9)
R2	820Ω	1	(M820R)
R3,6,7	220Ω	3	(M220R)
R4,10	2k2	2	(M2K2)
R5,8,11	1k	3	(M1K)
R9	4k7	1	(M4K7)
R12	68Ω	1	(M68R)
R13	100Ω	1	(M100R)
R14	33Ω	1	(M33R)
R15,16	47Ω	2	(M47R)
R17-20	0Ω27 2·5W	4	(S0R27)
RV1	1k Horizontal Preset Potentiometer	1	(UH00A)

CAPACITORS

C1	4μ7F 63V Radial Electrolytic	1	(AT76H)
C2	3n9F Ceramic	1	(WX75S)
C3	10μF 63V Radial Electrolytic	1	(AT77J)
C4	1n5F Ceramic	1	(WX70M)
C5,7	220μF 16V Radial Electrolytic	2	(AT41U)
C6	39pF Ceramic	1	(WX51F)
C8	33pF Ceramic	1	(WX50E)
C9,10	47μF 63V Radial Electrolytic	2	(AT80B)
C11,12	100nF Polyester Layer	2	(WW41U)
C13,14	470μF 63V Radial Electrolytic	2	(AT84F)

SEMICONDUCTORS

D1-3	1N4002	3	(QL74R)
ZD1	15V 1·3W Zener	1	(QF57M)
TR1,2	2SA1085E	2	(QY12N)
TR3	BD140	1	(QF08J)
TR4,5	BD139	2	(QF07H)
TR6	BD711	1	(WH15R)
TR7	BD712	1	(WH16S)
TR8,10	2N3055	2	(YH98G)
TR9,11	MJ2955	2	(BL38R)
	T03 SIL Pad	4	(QY44X)
	T0220 SIL Pad	5	(QY45Y)
	Short Insulating Bush	1 Pkt	(JR78K)
	M3 12mm Brass Screw	2 Pkt	(BF52G)
	M3 Brass Nut	2 Pkt	(BF58N)
	M3 Shakeproof Washer	2 Pkt	(BF44X)
	M3 Brass Washer	2 Pkt	(BF62S)
	M3 Solder Tag	1 Pkt	(LR64U)
	M2·5 12mm Screw	1 Pkt	(JY31J)
	M2·5 Nut	1 Pkt	(JD62S)
	M2·5 Washer	1 Pkt	(JD77J)
	M2·5 Shakeproof Washer	1 Pkt	(BF45Y)
	T0126 Heatsink	2	(JX21X)
	1mm Single-ended PCB Pin	1 Pkt	(FL24B)
	Green/Yellow Wire	1m	(XR38R)
	PCB	1	(GJ73Q)
	Bracket	1	(BL97F)
	Instruction Leaflet	1	(XZ37S)
	Constructors' Guide	1	(XH79L)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items are available as a kit, which offers a saving over buying the parts separately.

Order As LP33L (150W Power Amplifier) Price £34.99

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately, but are not shown in the 1996/97 Maplin Catalogue.

150W Power Amplifier PCB **Order As GJ73Q Price £5.99**

150W Power Amplifier Bracket **Order As BL97F Price £8.49**