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THE ULTIMATE DIY AMPLIFIER?

- Class A Operation!
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- Modular Construction
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SYSTEM A AUDIO AMPLIFIER

Get out the Bullworkers, part two of the System A series describes the Class A power amplifier. Big is beautiful! Design and development by Stand Curtis.

There is one amplifier configuration that is universally accepted as the ideal for audio use: Class A operation. Many early amplifiers operated in Class A, but as output powers rose above 10 W the problems of heat dissipation and power supply design caused most manufacturers to turn to the simpler, more efficient Class B arrangements and to put up with the resulting drop in perceived output quality.

The ETI System A applies the unchallenged excellence of Class A operation to the design of a reference amplifier free of the aberrations of commercially available models. Class A biasing is recognised as the ideal operating mode for an amplifier, offering the uncompromising accuracy demanded by dedicated audiophiles. The superiority of this amplifier depends on the output devices being constantly operated in their linear region, above cut-off and below saturation. Such operation results in the smoothest transfer function and the widest bandwidth.

The System A amplifier has a clarity and a tonal response that produces a superior perspective of depth with a sense of reality: instruments appear in precise position out of a silent background. The musical 'naturalness' of this amplifier is due to its lack of the constrictions of commercially desirable circuitry and the single-minded approach to a no-compromise sound quality.

Why Class A

The amplifier has an excellent technical performance even when operated in the conventional, but less desirable AB mode. With an open-loop (ie no overall negative feedback) distortion of around 0.1% (1 kHz) and a frequency response stretching well outside the audio band, the use of the large amounts of negative feedback (found in most commercial competitors) is completely unnecessary. However, extensive correlation between measurements and subjective performance using a wide variety of amplifier types led to the conclusion that Class A biasing is the optimum for audio amplifier performance.

When biased to Class A, the transistors are always turned on, always ready to respond instantaneously to an input signal; Class B and AB output stages require a microsecond or more to turn on. Thus Class A operation permits cleaner operation under the high-current slewing conditions that occur when transient audio signals are fed into difficult loads.

The continuous operation of the output stage in the linear collector region results in a more desirable distribution of distortion harmonics than is possible in Class B or AB, because the non-linearities in the transfer curve are smoother and free of the abrupt transitions of Class B and AB. The gradual non-linearities resulting from Class A operation produce distortions of low orders; primarily second and third harmonics. These lower order harmonics tend to be far less offensive to the ear than high order harmonics, being far more musical in nature (they are predominant in the harmonic spectra of most musical instruments). Higher order harmonics tend to 'harden' the overall sound. Such is the linearity of the ETI Class A Amplifier that a mere 22 dB of gain reduction is made in the form of negative feedback.

Each amplifier is a completely separate self-contained mono unit. The use of mono amplifiers, while costly in terms of components, provides the maximum stereo signal separation under dynamic operation with complete freedom from cross-modulation effects, giving an improvement in subjective depth and accurate instrument imaging.

A glance at the photographs will also explain why each amplifier is made as a mono-block. A stereo version would be just too heavy, unwieldy, and hernia-inducing for even the most dedicated audio fanatic (but if you know different . . .). Ideally each power amplifier can be located next to its respective loudspeaker and connected to it by very thick but short leads, thereby avoiding the losses associated with loudspeaker cables (30 A cable is suitable).

Protection — A Racket?

This Class A power amplifier is totally free of the usual protection circuits with their unavoidable colourations, distortions, and current-limiting characteristics. Instead we use an output stage having an exceptional power capability for an amplifier of such a low rating. With its substantial heatsinking this amplifier is capable of sustained operation with difficult loads.

The ETI System A amplifier maintains complete control over the driven loudspeaker throughout its operating cycle. The true Class A operation avoids the inherent phase irregularity and inadequate current-sinking ability of comparable Class B and AB designs. The provision of an extremely low-impedance power supply gives the Class A amp a short-term current delivery and, equally important, current-sinking capability far in excess of any known Class AB power amplifier of similar rated output power.

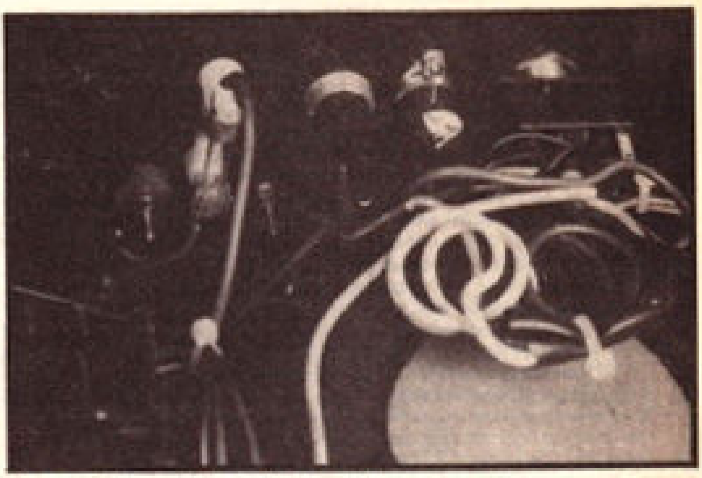
Amp Of Substance

The output stage is quite substantial, using a total of six 250 W power transistors. Fairly 'old-fashioned' power transistors have been used (the MJ4502/802 family) in preference to some of the higher performance devices now available. They have been chosen because the die used to mount the semiconductor junction is of a large area; the device is quite rugged and can handle high currents. The short-term current capability of the output stage is, in fact, of the order of 90 A, somewhat in excess of the current capability of the wiring!

The power supply is equally substantial, using a 500 VA toroidal mains tranformer and two massive computer grade reservoir capacitors. These components are expensive but essential. The rest of the construction is equally massive with a steel chassis supporting six very large heatsinks. However, construction is straightforward provided that the builder has strong arm muscles, and circuit alignment simple — there are but two adjustments — quiescent current and DC offset voltage nulling.

Construction

The constructional layout shown in the drawings and photographs should be followed as closely as possible. (With such high currents flowing down the cable forms, problems can easily occur if too many changes are made.) The heatsinks and the power supply components are assembled onto the baseplate and wired up in accordance with the wiring diagram. The recommended wire types and gauges should be adhered to.



Close-up of fuse wiring on back panel.

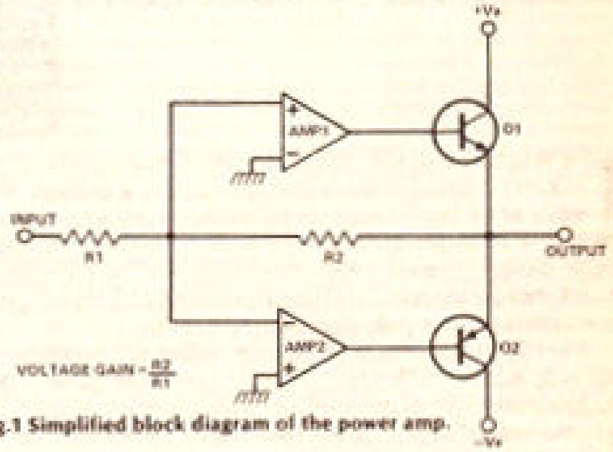


Fig.1 Simplified block diagram of the power amp.

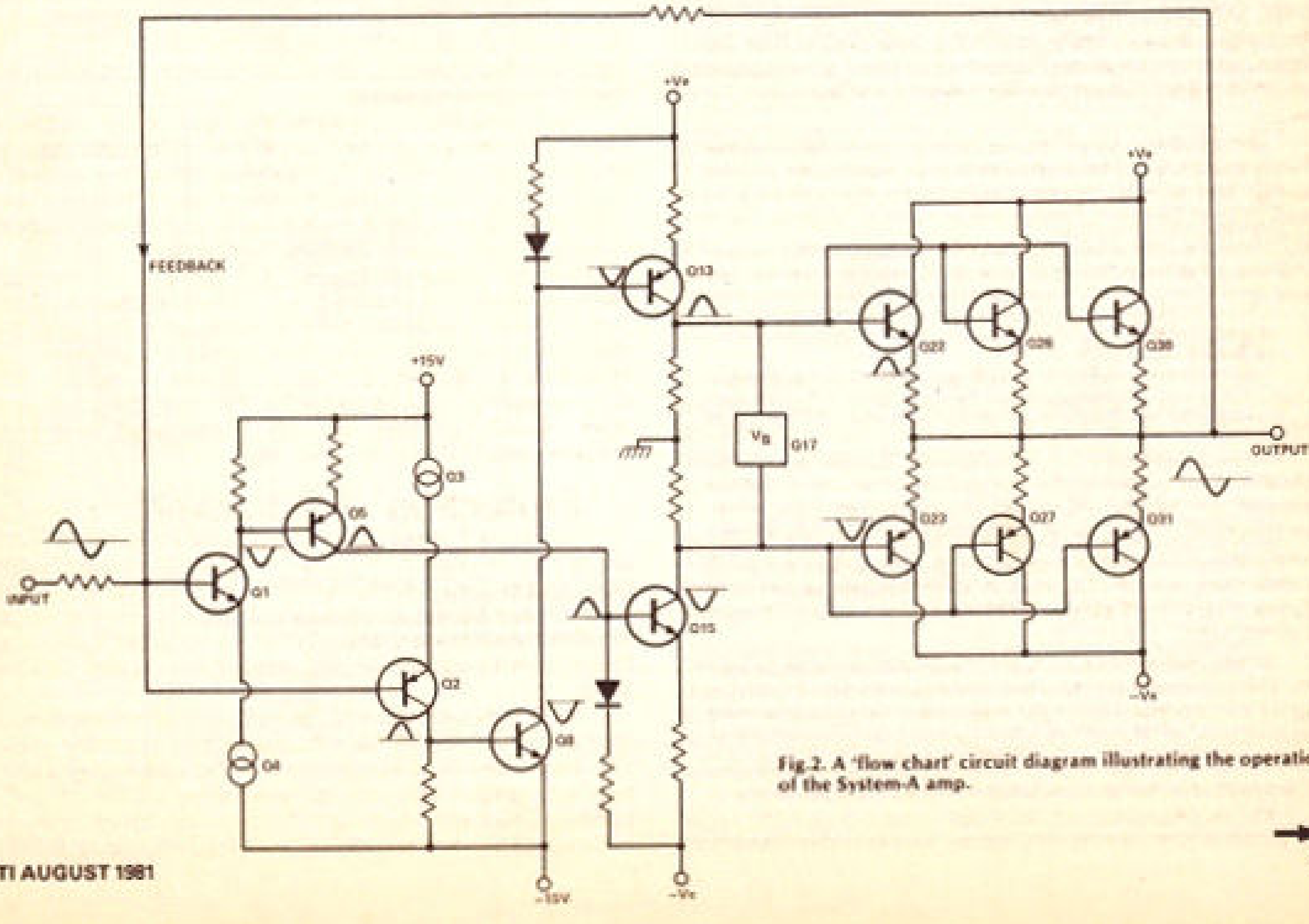


Fig.2. A 'flow chart' circuit diagram illustrating the operation of the System-A amp.

HOW IT WORKS

This amplifi.r is basically simple, as can be seen from the block diagram (Fig.1). Conventional complementary emitter-followers are driven by two separate voltage amplifiers arranged such that one handles the positive-going signals and the other the negative-going signals. A moderate amount of overall negative shunt feedback is then applied to stabilise the gain. To maintain a balanced and symmetrical treatment of the signal the performance of each 'sub-amplifier' should be the same. Furthermore these amplifiers have been designed to operate independently, without the need for the balancing signal currents from their 'mirror image' halves required in many so-called balanced amplifiers. The simplified circuit (Fig.2) shows that each sub-amplifier consists of two voltage-gain stages. This stage is of a novel arrangement previously used in a Meridian amplifier and subsequently in amplifiers by Lecson and Syntec. In the redesigned form here, the first stage consists of a complementary two-stage common emitter (Q1, Q5) whose gain is about x 2.3. The second stage is a current mirror stage (Q13) which drives the voltage across a load resistor tied to 0 V. The gain of this stage is about x 200. Thus the overall open loop voltage gain is of the order of x 460 and so, as the closed loop gain is x 26.7, the reduction due to negative feedback is x 17.2 or about 24 dB.

Looking now at the final circuit (Fig.3) it will be seen that the input amplifiers are powered from ± 15 V supply rails derived from resistor-zener regulators (R14-ZD1, and R15-ZD2). The current through the first stage (Q1) is held constant, at about 0.36 mA by a floating regulator stage (Q3, Q4) which also provides temperature compensation. The gain of this stage is set by emitter resistor R4 which provides some local negative feedback. The second stage (Q5) is loaded by two series cascode transistors (Q6, Q7), the first having its base tied to ground and the second having its base tied to the − 15 V rail. Thus the maximum collector voltage swing on Q5 is greatly reduced, so reducing the effect of the base-collector capacitance (Miller effect) which would reduce this stage's high frequency bandwidth. In summary, the presence of Q6 and Q7 improves the bandwidth and linearity. The load on Q7 is one half (Q12) of the current mirror and can be visualised as a resistor in series with a forward-biased diode. The second half of the current mirror is a common-emitter stage (Q15, Q16), a simple voltage amplifier except that its collector current equals (or 'mirrors') the collector current of the other half (Q12). This stage is made up of two transistors in parallel which share the current. This arrangement was found to improve the linearity of the stage. The other 'sub-amplifier' (Q2 to Q14) works in exactly the same way but with opposite polarity.

The output stage uses the conventional Darlington emitter follower arrangement, but with three parallel pairs of driver and output transistors. A transistor (Q17) is wired across the bases of the pre-driver transistors (Q18, Q19), providing a bias voltage to set the standing current in the output stage. Q17 is mounted on the heatsink with the aim of keeping this current constant regardless of temperature. Preset resistor PR2 is used to set the value of this current.

It will be seen that both the current mirror stages are driven from power supply rails that are different from those feeding the output stage. The same supply could be used but the signal in the current mirrors would clip well before the output stage, reducing the available output power. In fact the supplies to the current mirrors are made sufficiently high that these stages are still operating in their linear regions when the output stage clips.

The output DC offset voltage is set to zero by preset PR1 in the input stage. In theory there should be no DC offset at the output but, because of component tolerances and consequent mismatching, there always is. PR1 is arranged to make the current in the first stage of one 'sub-amplifier' either higher or lower than in the other and so null out any residual offset.

A simple low-pass filter is created by an R-C network at the input (R2, C2) to reduce the bandwidth of the signal below that of the open loop amplifier and thereby eliminate the generation of any transient intermodulation distortion.

The power supply has to deliver two split rails. The main supply to the output stage is nominally ± 40 V at 4 A, derived from the main transformer windings and rectified by bridge rectifier BR1. This rectifier can get very hot so it is bolted onto the chassis. The secondary supply is a low-current ± 50 V to power the voltage amplifier stages. The output from the extra windings is rectified by BR2 and fed to smoothing capacitors C12 and C13. These capacitors are not wired between supply and ground but between the two supplies; this layout reduces their voltage rating.

The mains supply is fed to the transformer via an on-off switch, a fuse, and a thermal cut-out switch. Two neon indicator lamps are used. LP1 is connected between live and neutral and is the 'power' indicator; LP2 is connected across the thermal cut-out. If this cut-out opens the full supply voltage is applied across LP2 which then illuminates as an 'overtemperature' indicator. (This indicator has never operated yet in the prototypes.) Care should be taken to adequately sleeve and insulate all mains wiring and terminals to ensure safe and reliable operation.

Any bare wire ends should be sleeved using silicone rubber sleeving. This may seem an extravagance but your opinion will change shortly after a short-circuit wipes out £18 worth of transistors! A substantial soldering iron will be needed to solder together the power supply components. The use of a low-power iron will usually result in a selection of dry joints on these connections.

The coil L1 is wound onto the body of R40. This is not a critical procedure — about 17 to 20 turns of enamelled copper wire should do nicely. The gauge can be anything you have to hand, from 20 to 26 swg. Use some lacquer or epoxy to hold the wire in place on the resistor, scrape the enamel off the ends of the wire and solder them close to the resistor. The whole thing can now be soldered in place on the board.

Particular care should be taken in mounting the power transistors. Good quality insulating washers and bushes should be used and a generous smearing of thermal paste is essential. These transistors should be bolted to the heatsinks very tightly to ensure good thermal contact at all temperatures.

Assembly of the printed circuit board is straightforward enough using the component overlay as a guide. As usual, particular care should be taken to confirm the polarity and alignment of all capacitors, diodes and transistors; and to avoid putting mechanical strain on any of the components. After assembly the board should be checked on the copper side for dry joints and solder bridges. Such defects on power amps usually result in an expensive bang, so don't skip this admittedly tedious chore.

One final point regarding construction. Once the amplifier has been completed and tested, it should be switched on and allowed to reach its normal operating temperature (about 20 minutes). The amplifier should then be switched off and all the screws tightened up. Differences in thermal coefficients of expansion can result in some of the screws becoming slightly loose, particularly those holding the heatsinks to the top and bottom covers.

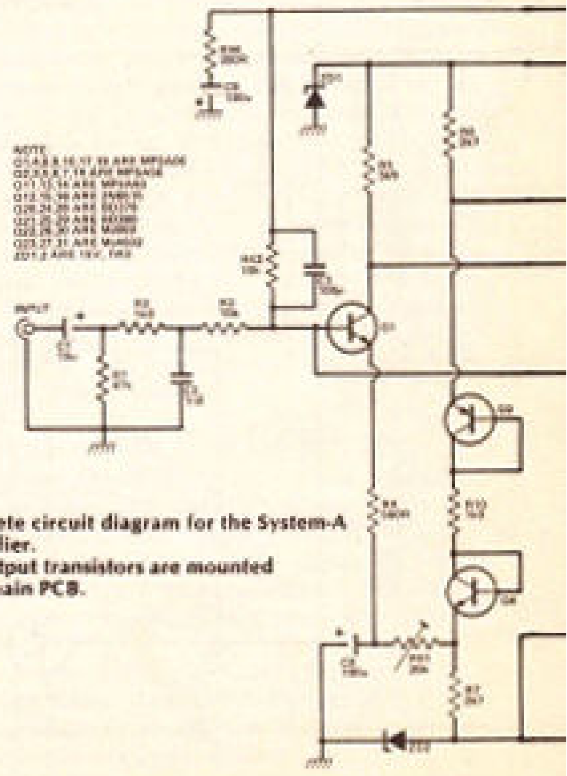
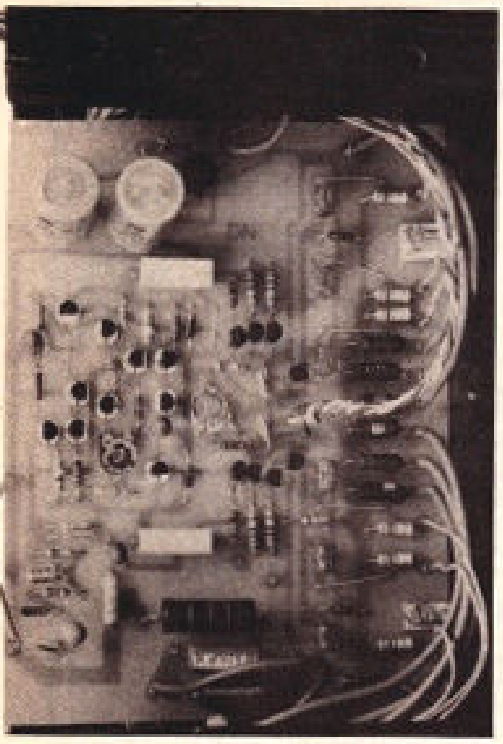


Figure 3. The complete circuit diagram for the System-A class-A power amplifier.
Note that the output transistors are mounted remotely from the main PCB.



Left: a detail shot showing how the PCB is wired into the case.

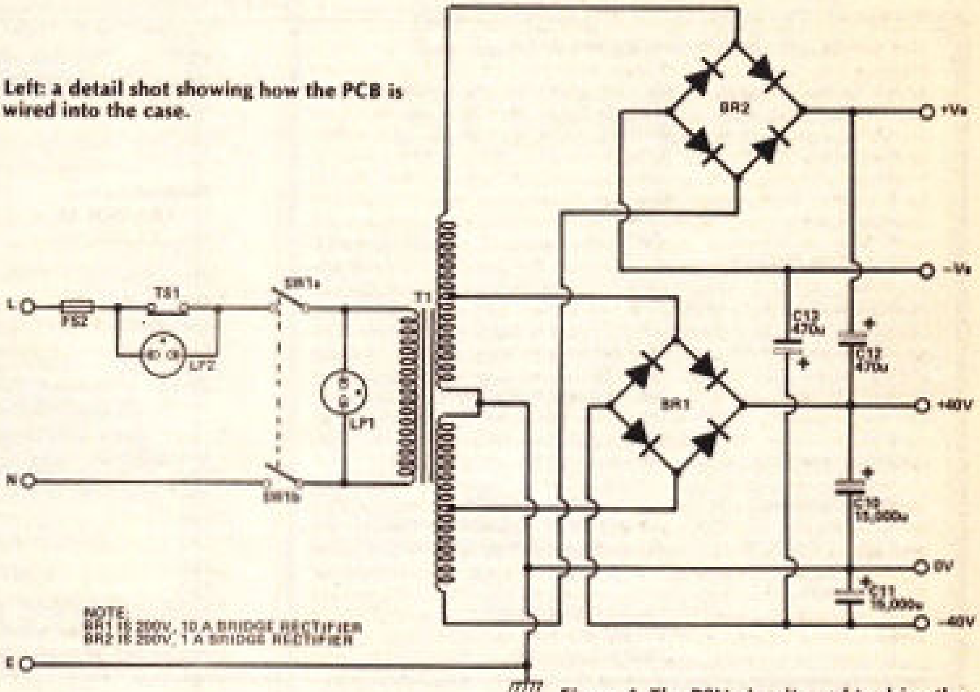


Figure 4. The PSU circuit used to drive the power amps.

BUYLINES

Most of the components specified are readily available from the usual suppliers except for the connectors and the low noise transistors. The board-to-board gold-plated connectors (horizontal, 45°) are type 434-172, and the vertical input-to-board connectors are type 434-188. These are available from RS Components Ltd, and can be ordered via a local stockist.

Kits of parts for the System A amplifier are available from Jelgate Ltd, 215 High Street, Offord Cluny, Cambs. Prices are as follows:

Preamp Kit 1 containing two chassis (preamp and PSU), toroidal transformer, and all the chassis-mounting components; £28.

Preamp Kit 2 containing the A-PR and A-PSU PCBs and all components; £26.

Preamp Kit 3 containing A-MM/A-MC PCB and components; £12 for either version.

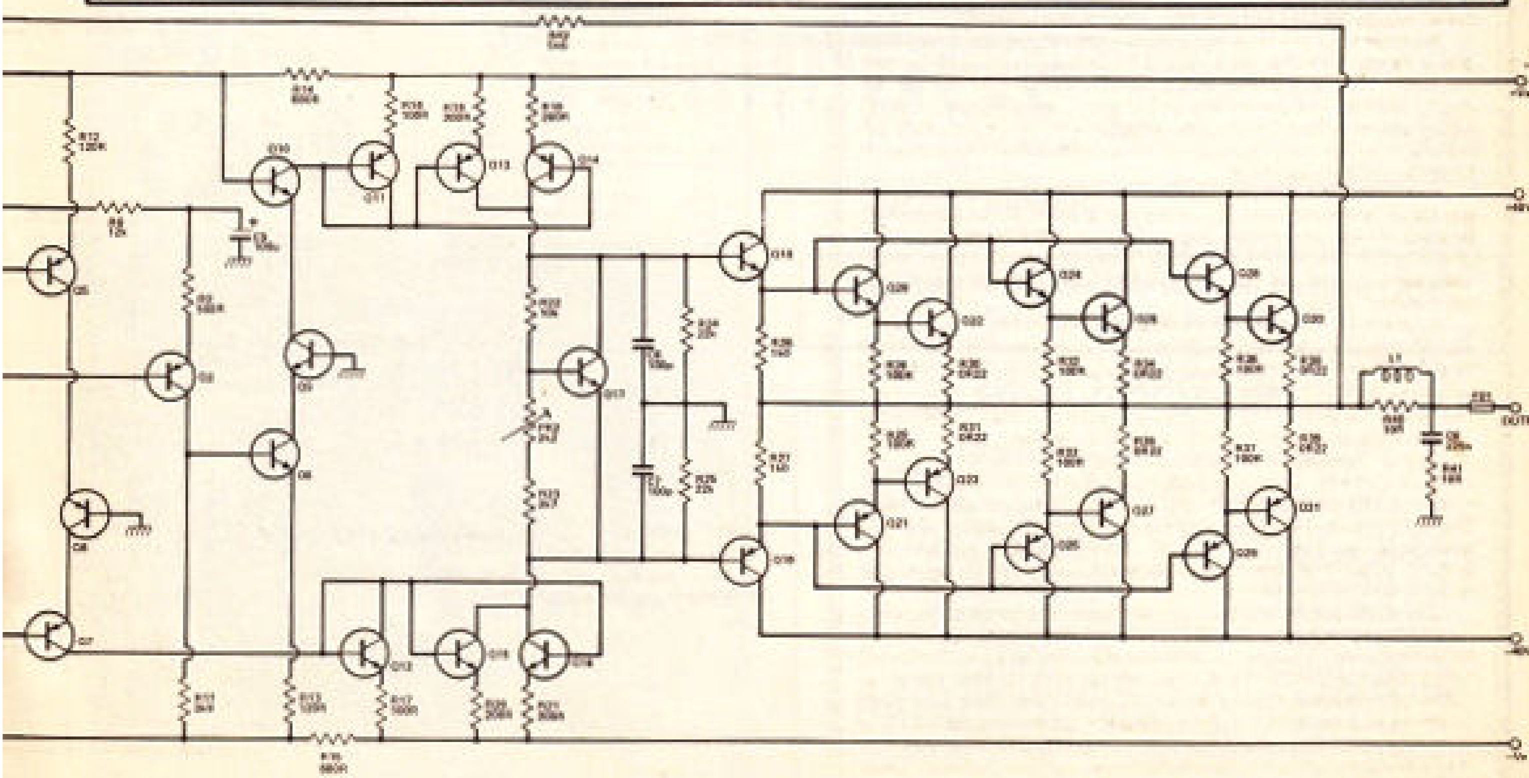
Set of four input transistors, selected for low noise; £2.

Power Amp Kit 1 containing all the metalwork, heatsinks and chassis-mounting components; £105.

Power Amp Kit 2 containing transformer, capacitors, power supply components and power transistors; £65.

Power Amp Kit 3 containing A-PA PCB and components; £23.

All these prices are exclusive of VAT and carriage. The cases are all ready-painted and screen-printed. Items can be bought separately; a comprehensive price list can be obtained from Jelgate.



PARTS LIST

Resistors (all ¼ W, 5% except where stated)

R1	47k
R2,10,26,27	1k0
R3,22	10k
R4,9	560R
R5,11	3k9
R6	12k
R7,8,23	2k7
R12,13	120R
R14,15	680R 4 W
R16,17,28,29,32,33, 36,37	100R
R18,19,20,21	200R
R24,25	22k
R30,31,34,35,38,39	0R22 2W5
R40	10R 1 W
R41	10R 2 W (not wirewound)
R42	5k6
R43	18k
R44	300R

Potentiometers

PR1	20k miniature horizontal preset
PR2	2k2 miniature horizontal preset

Capacitors

C1	10u 35 V tantalum
C2	1n0 polystyrene
C3	100p polystyrene
C4,5,9	100u 6V3 tantalum
C6,7	100p miniature ceramic
C8	220n polycarbonate
C10,11	15,000u 50 V electrolytic (Sprague type 36D)
C12,13	470u 63 V electrolytic (PCB type)

Semiconductors

Q1,4,8,9,10,17,18	MPSA06
Q2,3,5,6,7,19	MPSA56
Q11,13,14	MPSA93
Q12,15,16	2N6515
Q20,24,28	BD379
Q21,25,29	BD380
Q22,26,30	MJ802
Q23,27,31	MJ4502
ZD1,2	15 V, 1W3

Miscellaneous

SW1	DPST mains switch
TS1	Thermal cut-out switch
LP1	Red neon
LP2	Orange neon
FS1	1¼" 5 A—10 A (to suit loudspeaker)
FS2	20 mm 3.15 A

Toroidal transformer, 1¼" chassis-mounting holder, 20 mm panel-mounting holder, phono input socket, loudspeaker screw-terminals, chassis and heatsinks, mounting hardware.

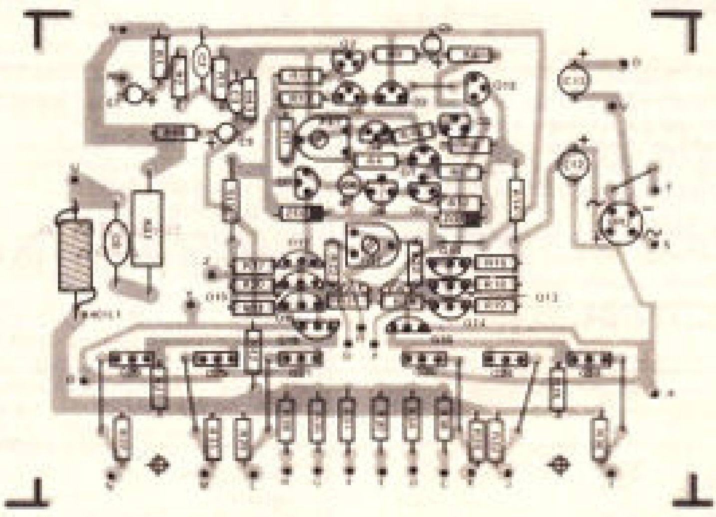
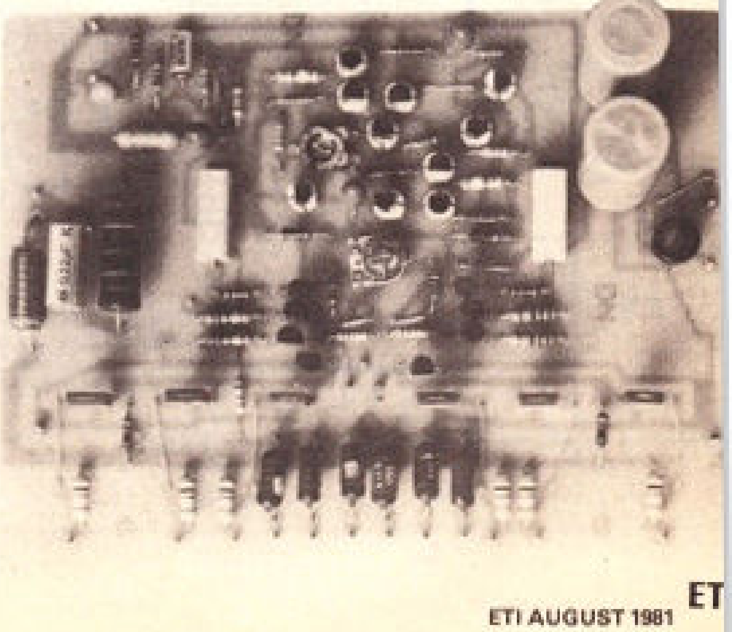


Figure 5. Component overlay for the power-amp PCB.

Next month: we conclude the amplifier project with the PSU and interwiring details.

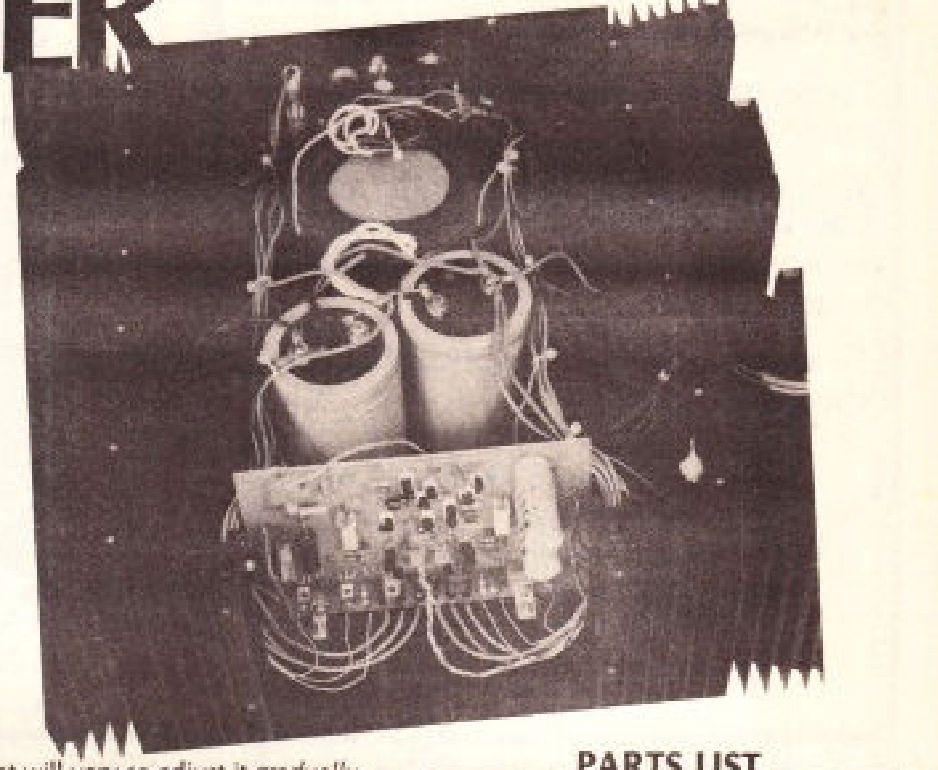


PIN CONNECTIONS

A	+40 V	N	Q31 base
B	−40 V	O	Wire link to pin Y (underside of PCB)
C	Q30 emitter	P	Q17 collector
D	Q26 emitter	Q	Q17 emitter
E	Q22 emitter	R	Q17 base
F	Q23 emitter	S	Transformer
G	Q27 emitter	T	Transformer
H	Q31 emitter	U	Output
I	Q30 base	V	Wire link to pin Z (underside of PCB)
J	Q26 base	W	Input
K	Q22 base	X	Ground
L	Q23 base		
M	Q27 base		

SYSTEM A AUDIO AMPLIFIER

Stan Curtis concludes the System A with the testing and setting-up procedures.



This amplifier is straightforward to test providing a logical sequence is followed. The first test is without the main PCB fitted and without the power-transistors connected to the power supply. Check that there is no leakage between the collector of any power transistor and heatsink using a high-resistance range of your meter. Next check the output transistor junctions (base-collector, base-emitter, collector-emitter and so on) at the PCB end of the wiring loom. If all is well the power transistors can be forgotten for the moment.

Next, the power supply. Fit a mains fuse; switch on and check that the voltage across the reservoir capacitors is ±40 V (within 2 V). Allow these capacitors to discharge and then fit the PCB assembly, connecting all the wires except those to the power transistors. Both the presets should be set to mid-travel and the power again switched on. The secondary supply rails can now be measured and should be about ±50 V. The output DC offset voltage (junction of R28, R29) should be measured and should be adjustable to zero by turning PR1. If the offset voltage cannot be adjusted you have a fault on the board.

If all is well, disconnect the supply and again wait for the power supply to discharge. Now connect up the power transistors to the PCB but with a current meter (able to measure greater than 3 A DC current) in series with the positive supply to the three collectors (Q22, Q26 and Q30). Ideally a voltmeter should be connected between the output rail and ground. Say a short prayer and switch on. You should find that PR2 (turned clockwise) will increase the current and PR1 should still adjust the DC offset voltage. Adjust the current to about 1 A and, using a loudspeaker and convenient signal source, quickly check that the amplifier works. If it does, the amplifier can be set up properly; but be warned that this takes several hours. Set the current to 3 A and allow the amplifier to heat up. The current will vary so adjust it *gradually* every 10 minutes or so until it is stable. The DC offset can now be nulled to zero but as this can interact with the current some alternate adjustments will be needed. After a couple of hours the amplifier should be stable and ready for use.

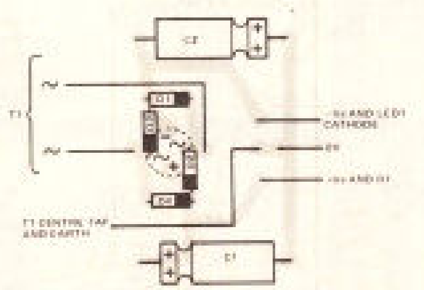


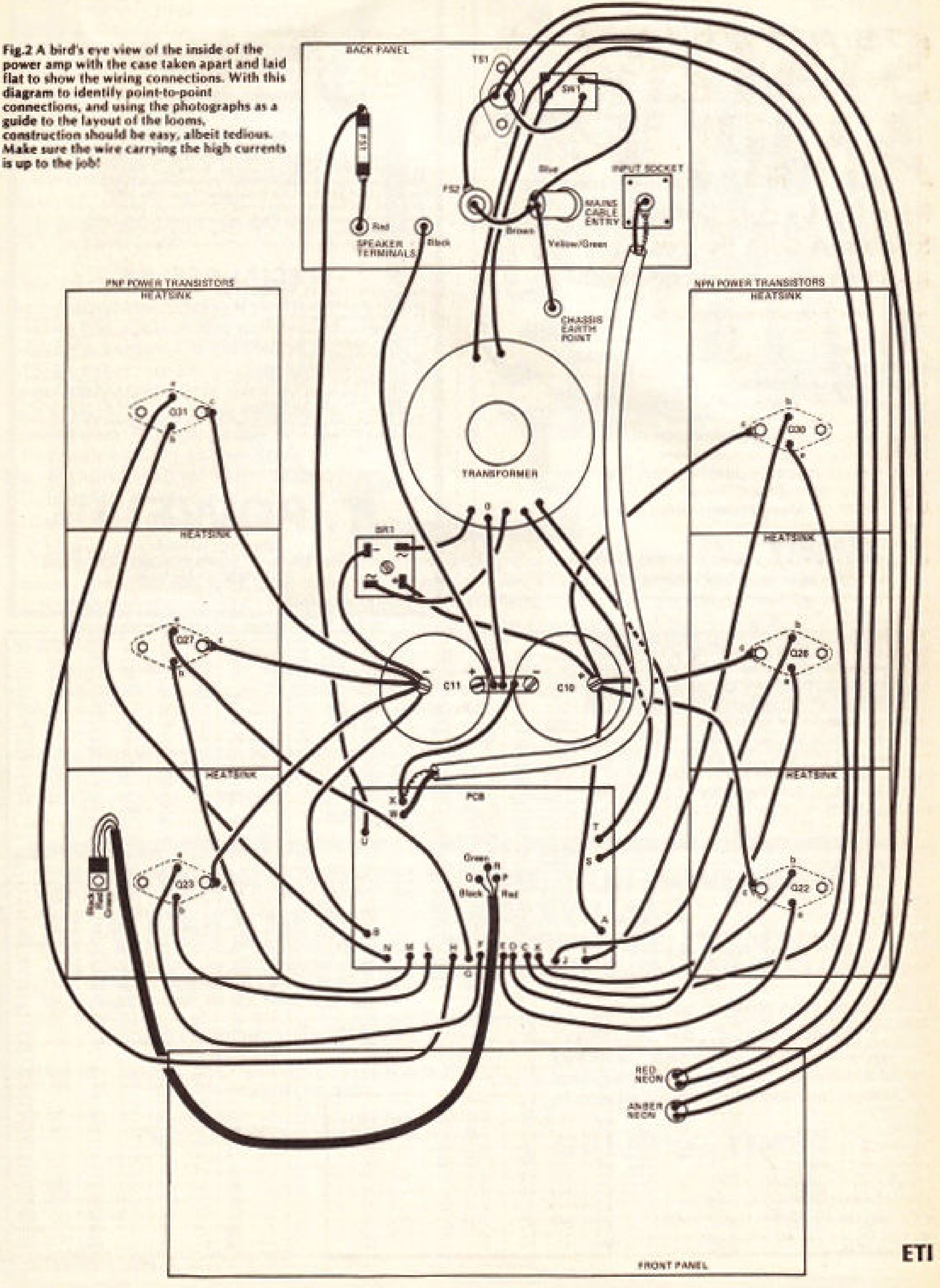
Fig.1 The long-awaited preamp power supply overlay (and Parts List at top right). Provision has been made on the board for either four diodes or a small bridge rectifier, as shown.

The foil pattern published in the July ETI for the preamplifier main board (A-PR) was incorrect, and we apologize to readers who have experienced difficulties. To correct the fault, break the track joining Q12 base to Q8 collector, and solder an insulated link between Q12 base and Q9 collector. Do this for both channels. The PCBs being sold by Jelgate and our PCB service are correct.

PARTS LIST

Resistor	
R1	2k7 ¼W 5%
Capacitors	
C1,2	1000u 25 V axial electrolytic
Semiconductors	
D1-4	1N4002 or similar
LED1	TIL209 or similar
Miscellaneous	
SW1	DPDT mains switch
Transformer (15-0-15, 20 VA), 1 A quick-blow fuse and fuseholder, case.	

Fig.2 A bird's eye view of the inside of the power amp with the case taken apart and laid flat to show the wiring connections. With this diagram to identify point-to-point connections, and using the photographs as a guide to the layout of the looms, construction should be easy, albeit tedious. Make sure the wire carrying the high currents is up to the job!



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