Construction Project:

HIGH QUALITY STEREO AMPLIFIER USING VALVES - 1

Here's your chance to build a genuine, newly designed high quality stereo audio amplifier based on thermionic valves — the Stereo Eighty. It's not a rehash of an old project, nor a quirky and 'over the top' design that aims for perfection at any cost. The author has even organised the supply of all components that are nowadays hard to get, and is offering complete kits for less than $1000. What better opportunity could there be to find out for yourself whether the claims made for valve amplifiers are true?

by TEAN Y. TAN, B.E.(Hons.)

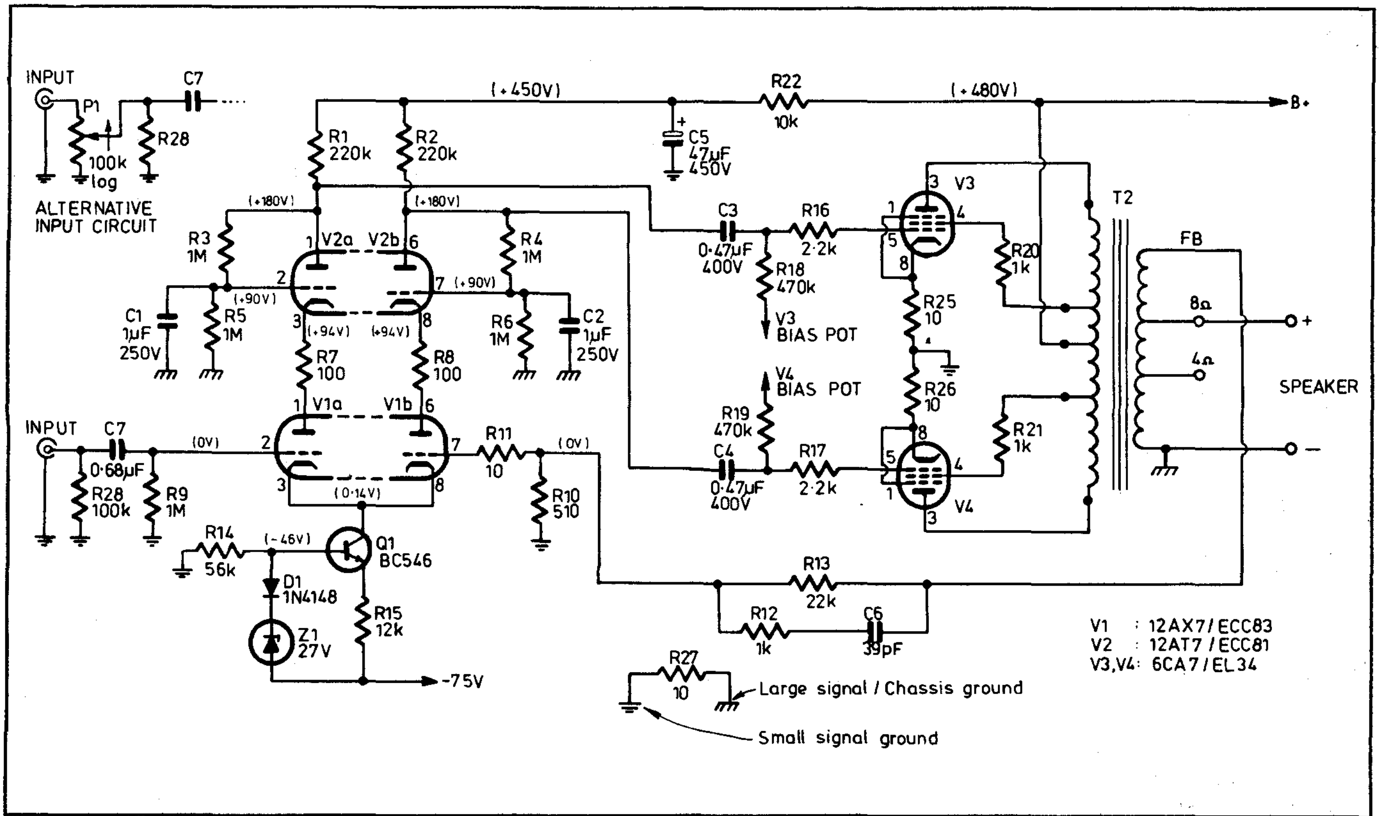
Recently, there has been a resurgence in the use of vacuum tube amplifiers (more commonly referred to as 'valve' amplifiers) for domestic and studio environments. Their re-emergence is largely due to the fact that many people believe valve amplifiers are capable of producing music more accurately than their solid state counterparts.

Musical characteristics such as a larger soundstage, better imaging, better dynamics and greater ambience are among terms used by reviewers in describing valve amplifiers. Only the most expensive solid state amplifiers are capable of attaining these characteristics.

As an indication of the sonic quality of valve amplifiers, a large number of them are now sold in both Japan and Hong Kong each year. These amplifiers are also gaining acceptance in the US and United Kingdom. Many brands with different output tubes and power outputs are available in the market. Listen to one in a better hi-fi retail outlet and you're likely to be convinced. Of course valve amplifiers also tend to be expensive, nowadays, due to the cost of the power and output transformers which are sourced from overseas.

But in the project described here, all of the transformers are designed and

Here's the author's prototype for the amplifier, built on a standard rack-type case as a chassis. The kits which will be available from the author will use a slightly different chassis, custom designed for the project.



Each channel of the stereo amp uses four valves, connected as shown in this schematic. V1 and V2 are connected in a cascode long-tailed pair configuration, using transistor Q1 as the common cathode load.

manufactured right here in Australia. In addition to keeping the cost down and providing greater reliability of supply, this has other benefits — it helps Australia's balance of payments, and also assists in keeping Australians employed.

One of the aims of this project has been to provide a high quality and an affordable stereo valve amplifier for audio enthusiasts and music lovers. Imported valve amplifiers are very expensive — over $2500 — largely due to the import duty and high mark-ups imposed by retail stores. This goal has been achieved, and now there is an affordable amplifier which is less than $1000 in kit form, for those who enjoy building their own units. A fully assembled and tested unit is also available.

The amplifier is housed in a rigid case which is made of mild steel and has a powder- coated black satin finish. The paint is sufficiently thick for it to be effectively scratch proof.

The transformers, valves and large filter capacitors are mounted on top of the case. The smaller components such as resistors and capacitors are mounted inside the case on a printed circuit board (PCB). All components are within easy assess to the builder. This should enable anyone with reasonable experience in assembling electronic projects to build the project easily, with a minimum of mistakes and convenience in terms of any future maintenance. Minimum hard- wiring is required between the various components.

The layout of the major components and PCB assembly are such that they are very close to each other, with only short lengths of signal cable used throughout. This improves the overall sonic quality.

The amplifier comes with an optional volume control, so that a CD or DAT player can be connected to it directly if desired. The output speaker terminals can be configured as either four ohms or eight ohms to suit the speaker type. The normal position is eight ohms, to suit most standard voice-coil type speakers, but four ohms would be more suitable for many electrostatic and ribbon speakers.

There is an on-off switch on the front panel, with a red LED to indicate the 'power on' condition. For those who wish to ground their auxiliary equipment, there is also a ground terminal at the rear of the case.

The construction and adjustment details of the project will be explained in the next article.

Design background

The factors which contribute to the sonic quality of a valve amplifier are circuit design, component quality and the use of appropriate construction techniques. All these factors have been taken into consideration when designing this amplifier, and will now be briefly discussed.

The valve amplifier has been around for a long time. Its application in the audio field received more prominence after the publication in 1947 of the technical paper 'Design for High Quality Amplifier' by D.T.N. Williamson, published in the UK magazine *Wireless World*.

Williamson's paper highlighted the fact that he was able to improve linearity, frequency response, phase shift and output resistance through prudent use of negative feedback.

Since then, many more design variations on the 'Williamson Amplifier' have been published. One of the more notable works published is that by Hafler and Keroes on the *ultralinear* amplifier. In essence, an amplifier operating in ultralinear mode is able to achieve high power output at low distortion. Another publication by B. Hedge on the 'long-tailed cascode pair' talks about improving the linearity and high frequency response of the input and driver valves.

The topology of this present design's circuit embodies the principles established by Williamson, Hafler and Hedge, but couples these with contemporary design techniques.

Valve amplifier

Circuit description

The final circuit is one which provides the following advantages:

1. A push-pull cascode configuration is used for the input and driver stages, which improves the linearity and symmetry.
2. A highly stable constant-current source is used to regulate the bias for the input and driver valves.
3. The output valves are individually provided with adjustable bias, to allow crossover distortion to be minimised.
4. Negative feedback is derived from the same winding on each output transformer that is used to drive the speaker, to reduce overall distortion.
5. The amplifier uses the ultralinear configuration and class AB mode of operation, to maximize power output and minimise distortion.
6. The power supply provides a high value of reservoir capacitance, to improve the dynamic response.

Refer to Figs.1 and 2 for subsequent explanation of the circuit.

The two halves of V1, a 12AX7/ECC83 'medium-mu' low noise twin triode, form the input and feedback mixing stage. These are directly coupled to the two halves of V2, a 12AT7/ECC81 twin triode, which forms the push-pull driver stage. As can be seen the two stages are connected in series, using the 'cascode' configuration.

The total bias current I through both stages is determined by the constant-current source formed by transistor Q1, zener diode Z1 and diode D1, and resistor R15. This gives a total current of 2.2mA. Because the transistor acts as a current source, it therefore appears as a common AC cathode impedance of almost infinite value, for the two sections of V1.

This means that they are tightly coupled in the so-called 'long tailed pair' configuration, giving greatly enhanced common-mode rejection ratio. As a result the common-mode component at the output of the driver stage is greatly reduced.

The bias currents in both halves of V1 and V2 will not be exactly equal, because the two halves of both valves are generally not identical. As a result the voltage at pins 1 and 6 of V2 can vary by between 5V and 20V; however this is not a matter of much significance as these points are biased at about 180V. In any case, capacitive coupling is used to transfer signals between the plates of the driver stage and the output valve grids.

The push-pull output stage of each channel uses two high-power EL34/6CA7 pentodes (V3 and V4). These are individually fed with adjustable fixed bias, using four preset potentiometers (two per channel). This allows the quiescent current for each pair to be balanced, for optimum performance.

The quiescent current in each output valve is typically set for between 25 and 30 milliamps, depending on the desired compromise between performance and valve life. With each valve's bias set for a quiescent current of 30mA, class AB operation results and a power output of 40W can be achieved from each channel.

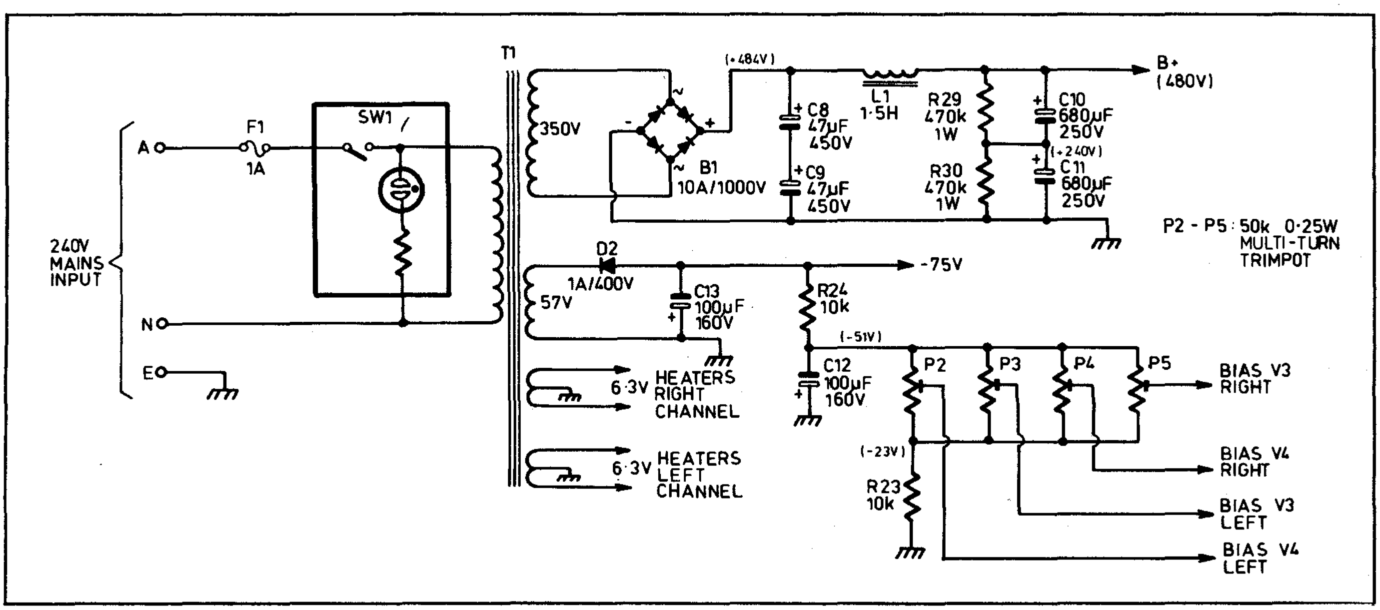
Output valves V3 and V4 have their screen grids connected to taps on the output transformer primary windings, in the correct ultralinear configuration. Each tap is at approximately 43% of its valve's half of the primary winding, which is the point shown by Hafler and Keroes to produce minimum distortion and highest output power, because of the 'pseudo pentode' operation.

Although I recommend the ultralinear configuration shown, together with biasing for class AB operation, some audiophiles may wish to experiment with other configurations and bias levels, in order to determine for themselves the effect on sound quality.

One possibility is setting the biasing so that the output valves operate in class A mode. The effect will be lower distortion, but also lower power output: a maximum of 25W total per channel. The operating life of the output valves will also be considerably shortened.

Another possibility is to change the output stage configuration, so that the valves operate in triode mode. This is done by simply connecting the screen grids (pin 4) to the plates (pin 3), instead of connecting them to the transformer taps. Again, the power output will be considerably reduced, in either class A or class AB mode, compared with the ultralinear connection.

The triode configuration is strongly favoured by many valve amplifier manufacturers, including Audio Re-



Here is the power supply circuitry for the complete amplifier. Rectifier bridge B1 is used to produce the high tension voltage, while diode D2 is used to generate the negative bias for the various valves. Preset pots P2-P5 are used to set the bias on each of the output valves, and ensure that each output stage is balanced.

search Corporation. With this design, the builder is free to experiment with the different output configurations and bias conditions, in order to achieve the best compromise in terms of desired sound quality and valve life.

Despite this flexibility, the circuit is quite straightforward. Under no- signal conditions, the grids of both halves of V1 are very near ground potential. The input signal is fed to the grid of V1a, while the negative feedback signal from the output transformer secondary is fed back to the grid of V1b via the divider R13/R10, with components R12 and C6 used to shape the phase response and ensure loop stability at high frequencies. More about these shortly.

The 12AX7/ECC83 has a medium transconductance and low noise, making it ideal as an input valve. Its transconductance variation from unit to unit is not as widespread as with 6DJ8/ECC88, which has higher transconductance. This enables the circuit to have a consistent open loop gain. The transconductance of each half of V1 is about 1.6mA/V.

Each plate of V1 is directly coupled to the cathodes of the two halves of driver stage V2, which has its grids grounded for audio frequencies via C1 and C2. In this configuration, the effective AC load for each half of V1 is close to the physical driver load resistor (R1 or R2), in parallel with the top resistor of each driver's grid divider (R3 or R4), and also the bias series resistor for the associated output valve (R18 or R19). As a result the voltage in of each input stage/driver stage pair is about 100, measured at points A and B. To improve linearity in the circuit, the gain at points A and B should be equal.

Low feedback

The benefits of negative feedback are widely known and will not be elaborated here. The circuit configuration used employs a low feedback design of less than 8dB (return difference). The feedback is taken from the secondary winding of the output transformer, and results in an overall gain for the amplifier of about 25 - 28dB.

It is the author's belief, based on experience, that a low feedback amplifier has a more 'open' sound.

Since this is a low feedback design, circuit stability is not a real problem. Capacitor C6 and resistor R12 are used for 'lead' compensation, to improve stability at high frequencies. However for those builders who prefer an extended high frequency response these components can be removed without affecting the overall stability.

Components R7, R8, R11, R16 and R17 are 'stoppers', used to ensure stability and reduce the amplifier's sensitivity to RF interference. Similarly resistors R20 and R21, in series with the output valve screen grids, are included to improve stability and minimise distortion. The latter have a nominal value of 1k, but those who require greater power output can reduce their value to 470 ohms if desired.

MEASURED PERFORMANCE

Frequency response
(1W into 8 ohms):
3Hz - 40kHz, +/-3dB

Power bandwidth
(30W into 8 ohms):
10Hz - 35kHz (- 3dB)

Signal to noise ratio
(relative to 30W):
93dB

Maximum power output
(both channels driven, into 8 ohms):
38W RMS/channel

Input sensitivity:
700mV input for 35W output
into 8 ohms (gain approx. 25)

Damping factor
(1kHz, 8 ohm load):
2.57 (Output valve Iq = 30mA)
3.76 (Output valve Iq = 60mA)

Total harmonic distortion:

Power level Frequency	Output valve Iq = 30mA	Output valve Iq = 60mA
1W at 1kHz	0.12%	0.03%
3W at 1kHz	0.20%	0.05%
10W at 1kHz	0.70%	0.18%
30W at 1kHz	2.30%	0.70%
35W at 1kHz	2.70%	0.95%
30W at 40Hz	3.5%	1.5%
30W at 10kHz	3.1%	1.8%

Intermodulation distortion
(two tones, 4:1 ratio):

Power level	Output valve Iq = 30mA	Output valve Iq = 60mA
10W	2.4%	0.3%
30W	6.0%	1.3%

Although the grid of V1a is nominally at ground potential, coupling capacitor C7 is used to prevent any possibility of noisy volume control operation due to grid current.

Resistors R25 and R26 in series with the output valve cathodes are basically to allow convenient monitoring of each valve's quiescent current, using a DMM.

Since the resistors have a value of 10 ohms, they will have a voltage drop of 100mV for each 10mA of quiescent current. With this low value the resistors do not make any significant contribution to valve performance, although in theory they will introduce a small amount of negative current feedback and protective self-biasing.

The power supply (Fig.2) uses a single untapped HT secondary winding on the transformer T2, with a voltage of 350V. This feeds high-voltage silicon bridge rectifier B1. Series-connected capacitors C8 and C9 are used for the capacitor-input L-C filter, which uses inductor L1 (1.5H) to provide excellent hum filtering. Output reservoir capacitors C10 and C11 provide a total of around 340uF of capacitance, to cope with peak current requirements and achieve good dynamic response.

Resistors R29 and R30 are used to ensure that the capacitors share the applied DC voltage equally, despite differences in leakage current.

Negative bias for the valves is produced from a separate 57V transformer winding, with a half- wave rectifier using diode D1 and capacitor C13. R-C filtering can be used here, due to the very low current requirements. Using readily available 100uF capacitors for C13 and C12, together with a 10k resistor for R24, we are able to maintain the hum on the bias supply to a very low level.

Resistor R23 is used to limit the range of the output valve bias adjustment pots P2-P5, to make adjustment easier and also prevent the risk of damaging the valves due to accidental removal of bias.

The input valve current sources, based around Q1, are supplied directly from the negative rail available across C13.

The valve heaters for each channel of the amplifier are powered from separate windings on the power transformer, to minimise any possible crosstalk. Each winding has a centre tap, which is earthed to ensure low hum coupling into the valve cathodes.

Finally, a few words about grounding. Some care must be taken in grounding any valve or transistor amplifier. Here a 'star' grounding technique is used throughout. The PCB ground, power supply ground, chassis ground and mains earth are all connected at a single point on the tagstrip supplied, which has one leg screwed to the case/chassis.

Using this method, ground loop hum is extremely low at the speaker output terminals, and virtually inaudible. Note that the input stage grounding is decoupled from that for the rest of the circuit via R27, to minimise earth loop currents.

The grounding technique used will be discussed again in the next article.

Component quality

As mentioned earlier, components play an important role in the sound quality of any amplifier. Here good quality components are used throughout, without going 'overboard'. If the very best components were used, then the amplifier would not be within reach of most music lovers. But by making a sensible choice of components, we are able to achieve good sonic quality without allowing the cost to escalate unduly.

Metal film resistors are readily available nowadays, at a very reasonable price. While there are even debates among audiophiles on the type of metal film resistors which gives the best sonic quality, in this project we use the normal type — i.e., no special brand. These resistors give a cleaner sound over their carbon counterparts.

The capacitors are the most critical components which affect the sound quality. It is not advisable to use polyester capacitors for signal coupling, because of their high distortion. The normal choice is polystyrene for low values and polypropylene at higher values. The latter have been chosen for this project as coupling capacitors, while polycarbonate capacitors are used for bypassing.

The 12AX7, 12AT7 and EL34 valves have been chosen for their sonic quality, while at the same time being readily available off-the-shelf.

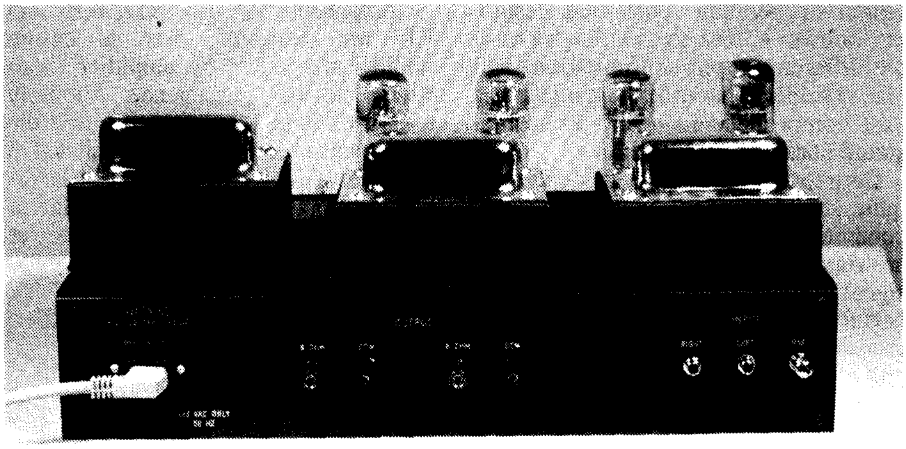
The prices of these valves are reasonable (by today's standards), with the 12AX7/12AT7 costing about $10.00 each and the EL34 around $18.00 each. The circuit is designed such that the output valves should last for a long time, if the bias is set for low quiescent current class AB operation.

The critical component in any standard transformer-coupled valve amplifier is of course the output transformer. The output transformers used in this project are designed and manufactured in Victoria, Australia.

They have a very impressive specification, with a frequency response of 13Hz — 60kHz +/-1.0dB. A grain-orientated iron core is used to give this frequency response. Under testing, each transformer can deliver full rated power (35W) from 23Hz to 20kHz, without excessive distortion.

The power transformer comes from the same local source, and is a husky unit designed to provide more than enough power for both channels. The total power rating for the transformer is 250VA, which gives a capacity for at least 100VA per channel, plus the power for the heaters which is another 50VA.

For those who require a volume control, a high quality dual-ganged logarithmic potentiometer is available. This pot is especially matched to enable the same output to be achieved from both channels. Also included is a volume control knob.



A rear view of the amplifier, showing the input connectors at far right, the speaker terminals in the centre and the mains input connector at the left. The power and output transformers are locally manufactured and of high quality.

Sound quality

Now, the question that by now, everyone will be asking: how does it sound? The attractive feature of this valve amplifier is the 'warm' sound, with emphasis on the midrange.

While it may lack the deep bass response of some transistor amplifiers, the latter cannot give the same degree of rich warm sound. Mid-priced transistor amplifiers can also tend to sound 'flat', by comparison.

Without being at all biased about this amplifier (after all, I am its designer!), the following claims are made:

It offers a 'clean' sound, without being too clinical through the use of quality resistors and capacitors.

The midrange is warm and rich, terms synonymous with traditional valve technology.

The bass response is much fuller than many traditional valve amplifiers. Although not as powerful as some transistor amplifiers, it blends in well with the lower midrange.

The treble response is well behaved and can sound a bit bright on some speakers. But after a sufficient warming up period, the brightness tends to disappear.

The overall sound brings out the vocal qualities in many recordings. It is not embarrassed by recordings with wide dynamic range.

In an A-B comparison with a commercial valve amplifier which cost over $4000, it gave very comparable performance. In fact in some areas, it was even judged to sound better. A comment from one reviewer was that it has 'the romantic sound of a Leak, but with better bass response'.

No doubt there is still room for improvements in the circuitry, so as to improve the sonic quality. This could well become a subject for further discussions in future issues of *Electronics Australia*, if there is sufficient reader interest.

(Editor's Note: Mr Tan loaned us a prototype of his amplifier for a couple of weeks, and we were able to both test it with our lab instruments, and conduct listening tests in our homes with suitable speakers and signal sources. The loan unit was also used to take the photographs.

The results of our measurements are shown in the table. As may be seen, it gave a good account of itself even by modern standards, with wide frequency and power response, a good signal to noise ratio and genuine 38W RMS output per channel into 8-ohm loads with both channels driven.

Understandably, for this kind of amplifier, the total harmonic distortion and intermodulation figures were both quite dependent on the quiescent current level chosen for the output valves. Increasing the quiescent current levels to 60mA for class A operation reduced the distortion by a factor of four times, for example.

However this will undoubtedly shorten the life of the valves, as the author points out — even though the dissipation of each valve (30W) is still within the official ratings.

The design therefore seems a good one, in that constructors can decide for themselves how much they are prepared to *'pay' for lower distortion, in terms of reduced valve life.*

In our listening tests, the Stereo Eighty provides some very pleasant and relaxed listening. It can drive reasonably sensitive loudspeaker systems with ease, and provides very smooth and well-balanced sound. With most kinds of programme material there is very little, if any, 'edginess' due to distortion — even with the output valves running at only 30mA quiescent current. No doubt this is due to the relatively 'soft' nautre of the distortion produced by a valve amplifier, with predominantly low-order harmonics being generated.

Only with more complex programme material like that produced by a full orchestra and/or a choir, could we really detect the effects of THD and IMD, at the lower current setting. However our impression is that even this becomes virtually inaudible when the quiescent currents are increased.

In short, we're very happy with Mr Tan's design, and delighted to present it to our readers. We believe he has provided today's audiophiles with an excellent way to build a flexible, high quality stereo valve amplifier, at a reasonable cost and with minimum hassle.)

Obtaining the kit

A complete kit for the Stereo Eighty amplifier can be obtained from Contan Audio, of 37 Wadham Parade, Mt Waverley 3149; telephone (03) 807 1263.

The price for the kit, complete except for the special volume control potentiometer and knob, is $999 plus postage/freight if applicable. If the volume control is required as well, the price is $1035 plus postage. These prices include sales tax.

If required, the amplifier can also be supplied in fully assembled and tested form. In this case it is priced at $1249 without volume control, or $1284 with volume control. These prices again include sales tax, but postage/freight must be added if applicable.

Contan Audio can also supply individual components such as output transformers, power transformers, chassis, valves and so on. Prices for these items are available on request. All parts are guaranteed for one year, except the valves which are only covered for six months and against manufacturing defects only.

In the second of these articles, the assembly and adjustment of the amplifier will be described.

(To be continued) ❖

Construction Project:

HIGH QUALITY STEREO AMPLIFIER USING VALVES - 2

In the first of these articles, the author explained the philosophy behind the project, and described in detail the circuit design and operation. This month he moves on to cover the construction and testing of the amplifier. As he explains, the design is quite straightforward and should not give any problems providing you follow the steps described.

by TEAN Y. TAN, B.E. (Hons.)

To ensure that constructors don't experience any problems getting the parts to build this amplifier (some of them are now rather harder to obtain than they once were!), I have made arrangements to source them myself, and supply them direct to readers as a kit.

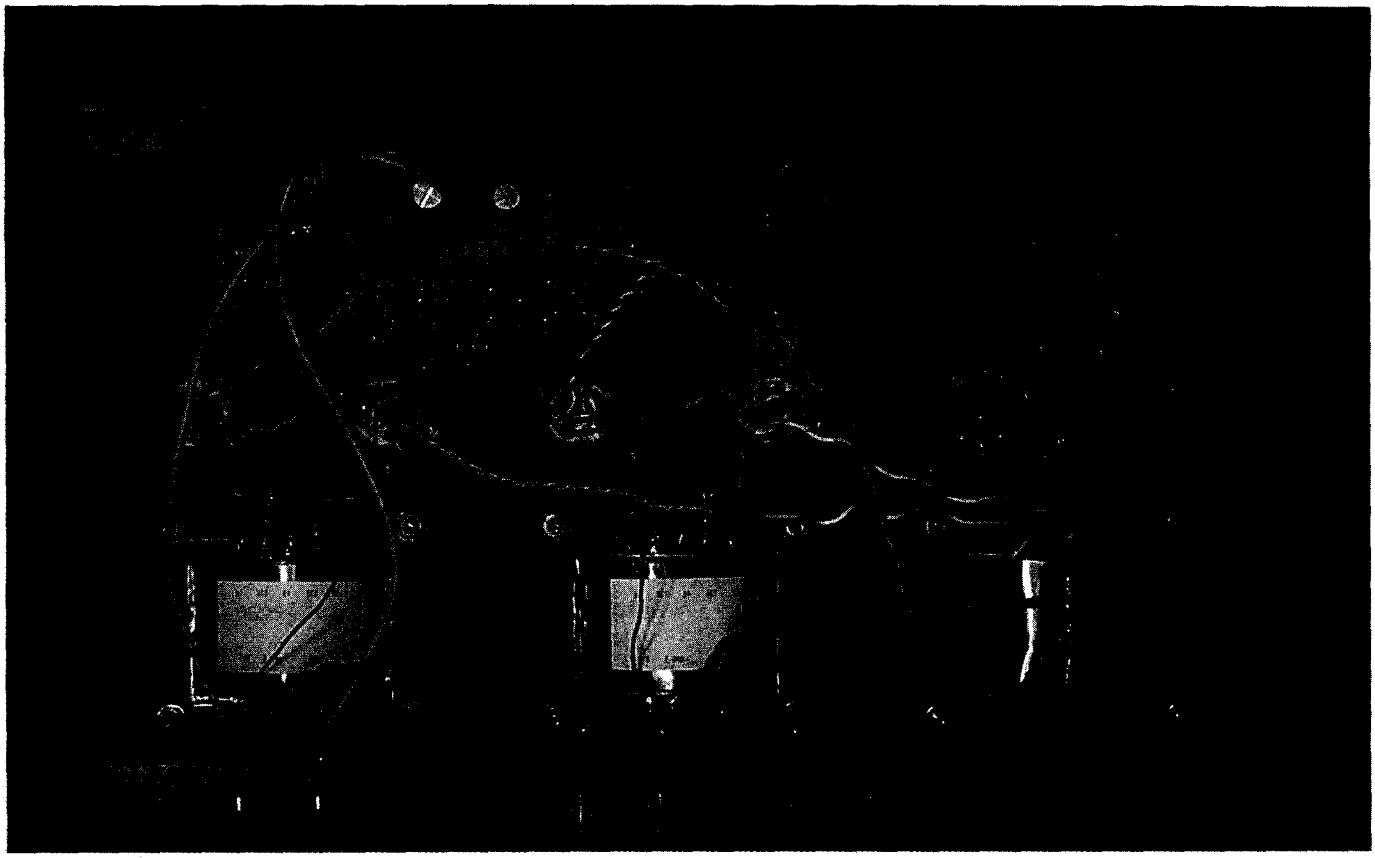
Only the highest quality components and parts are supplied, and the kit is complete as shown in the parts list. It even includes a special chassis, manufactured in Australia.

I estimate that builders with some construction experience should not take more than 10 hours to build the amplifier. The tools required for the construction are a soldering iron, solder, screwdrivers, a small adjustable spanner, a multimeter and a jumper lead with alligator clips at both ends. The use of the last item will become apparent under the section on safety precautions.

The kit can only be obtained directly from Contan Audio; for further details please refer to the end of this article.

Safety precautions

It must be strongly emphasized at this point that builders must take due care when constructing this project. Unlike



Here is a general view looking under the chassis. The output and power transformers are visible at the bottom, near the rear, with the filter choke at upper right. The PC board at upper left supports all of the low level circuitry.

other amplifier projects using solid state components, the present design involves very high voltages — 350V AC on the secondary side of the power transformer and as high as 500V DC for some of the plate and screen wiring and components, quite apart from the usual 240V AC on the primary side of the transformer.

All of these voltages are potentially very dangerous.

The following precautions should therefore be taken before applying mains voltage to the amplifier, and making subsequent measurements:

1. The mains earth should be connected to the chassis, in a reliable and secure fashion.
2. All of the 0V terminations shown on the schematic as going to chassis ground should be connected to the chassis. This will be elaborated upon in the next section.
3. The correct fuse must be inserted in the IEC socket fuseholder.
4. Use only *one hand* when measuring any voltages — preferably the right hand. The left hand should not be touching any part of the amplifier, or any earthed metal objects. The common terminal of the multimeter is connected to the chassis ground using the alligator jumper lead.
5. Switch off the amplifier before making any adjustments — e.g., changing components, or correcting any faulty soldered joints in the amplifier.
6. Do not plug in any valve when the power is ON.
   Always turn the power OFF before plugging in any tube; if necessary check the B+ voltage before plugging it in.
7. Do not make measurements unless you are wearing suitable footware. This means ideally rubber or plastic soled shoes, although leather-soled shoes are suitable if you are on a perfectly dry floor.

The builder should make sure that he or she takes the above safety precautions. The project is designed so that if constructed as shown, you should be able to measure any voltages on the amplifier without removing or touching any components, parts or the PCB. All the voltages are within easy access.

Construction

You are encouraged to build this amplifier step by step, using the following procedure to reduce the risk of making any mistakes.

By tackling the assembling in stages and testing as you go, any problems which may arise are likely to be isolated and located easily, before they result in any component damage.

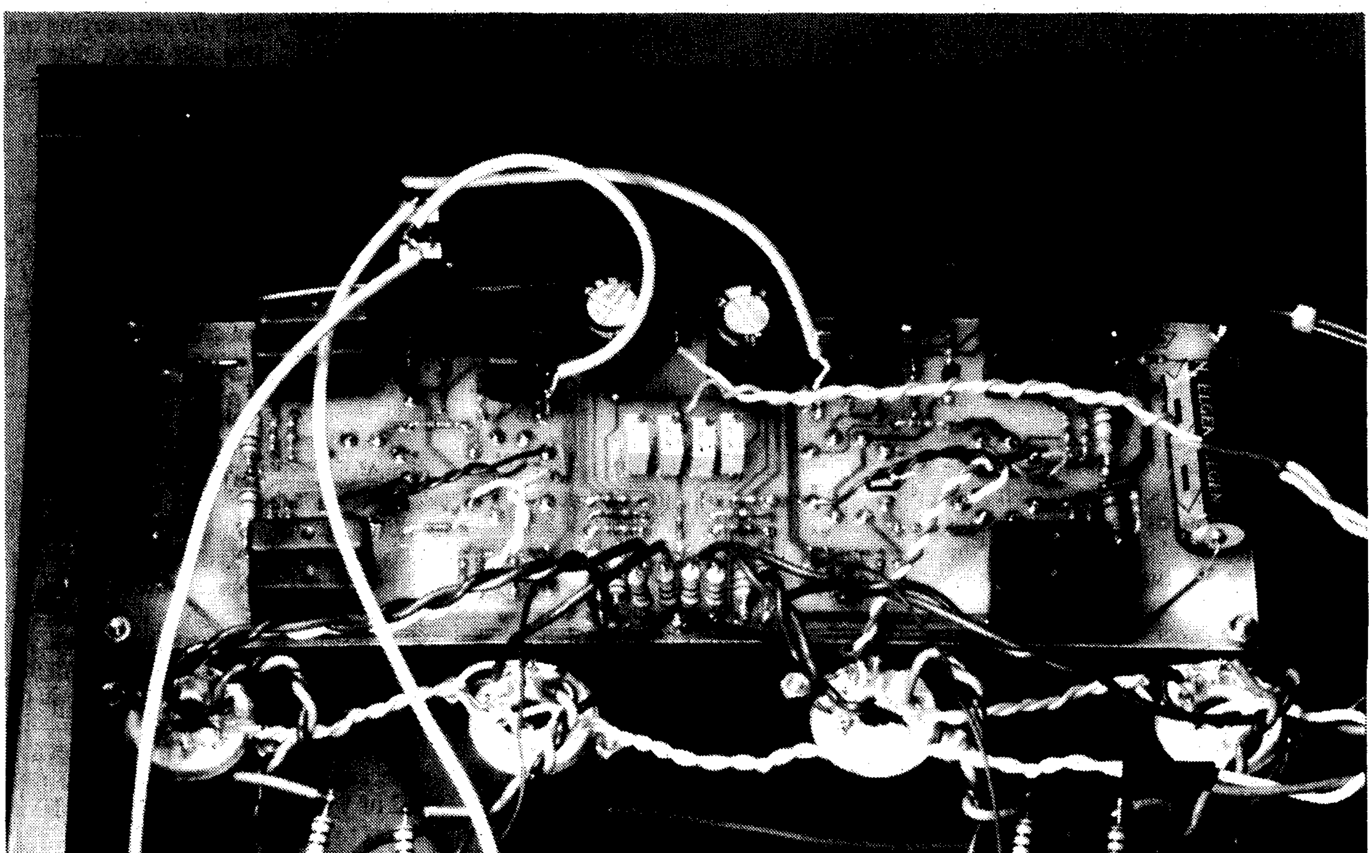
To help you in assembling the amplifier, we are providing a diagram showing the location of all parts mounted on the PCB (Fig.1), plus another showing the wiring between the PCB and all of the components mounted separately (Fig.2). These plus the photographs should make the assembly quite straightforward.

STEP 1: Mechanical assembly

First of all, mount the two pairs of octal sockets for the output valves (V3 and V4) underneath the chassis, with the socket rings and screws provided. Note the correct orientation (Fig.2).

Then mount and tighten the following components to the chassis:

A. The front panel.
B. The RCA input terminals.
C. The earth screw terminal.
D. The speaker terminals.
E. The IEC captive power plug and fuseholder.
F. The power switch.



Here's a close up of the PC board assembly, with the four output valve sockets just below it. Note the way that the valve heater wiring is twisted together, to minimise any external field and prevent hum injection into the signal circuitry.

Valve Amplifier - 2

G. The volume control pot, if you are fitting one.
H. The output transformers, together with their protective covers (provided). Refer to Fig.2 for the correct transformer orientation.
J. The power transformer, again with its protective cover. Fig.2 gives the correct orientation.
K. The 8-way terminal strip, for supporting C8 and C9, etc. Make sure that you scrape a small amount of the lacquer away from the inside of the chassis, around each mounting hole, and use a 'star' lockwasher between each foot of the tagstrip and the chassis, so that when the mounting screws are tightened, there is a really good metal-to-metal contact via the lockwashers and bared metal.
L. The filter choke L1. This mounts on the end of the chassis; ensure that the terminal connections are located underneath and not exposed.
M. The main reservoir electrolytic capacitors C10 and C11, with the rings and screws provided. Mount the rings underneath the chassis.
N. The main rectifier bridge B1. This mounts under the chassis between C10 and C11.
Before mounting, bend each lead carefully about 8-10mm from the body, into a small loop (say 2mm ID), to allow easy soldering of the connection leads. Then cut off any excess lead length. The bridge attaches to the chassis using a single machine screw, nut and lock washer.

This completes the assembly of the main items, apart from the PC board.

STEP 2: PCB assembly

A single PCB measuring 255 x 85mm is used to mount the majority of the smaller components, along with the sockets for the input and driver valves (V1, V2) for each channel. Note that the components are mounted on the same side as the tinned copper tracks, except for the valve sockets which are mounted on the reverse (top) side.

With reference to the circuit diagram and Fig.1, fit and solder the components in the following sequence:

A. All of the resistors, diodes and zener diodes. Note that the power dissipation for R1 and R2 exceeds 0.3 watts, under quiescent conditions, so for adequate ventilation, bend the leads of these resistors so that they mount about 3mm up from the surface of the PCB.
B. The valve sockets. These mount on the reverse side, orientated as shown in Fig.1 so that the pins pass through the holes in the PCB and solder to the pads on the copper side.
C. The BC546 transistors (one per channel — Q1).
D. The bias trimpots P2 - P5. Fit the centre two, P3 and P4 first, then the outer P2 and P5. Each trimpot should be mounted with its adjustment screw towards the front panel and C12/C13.
E. All of the electrolytic, coupling and bypass capacitors. Take care with the polarity of electrolytics C5 (x2), C12 and C13 — this is shown clearly in Fig.1.

With everything thus fitted to the PCB, you should now make a final check that everything is in its correct place and orientated correctly.

Then you are ready to mount the complete PCB assembly under the chassis, with the components facing inwards and the valve sockets passing through the clearance holes in the chassis.

Use the sticky tape provided as spacing, and fasten the PCB to the chassis firmly with the machine screws and nuts provided.

STEP 3: Hard wiring

You should now be ready for the 'hard' wiring — that which connects between the major items, and between the PCB assembly and the rest of the components.

The suggested sequence of wiring is as follows. Note that pairs of wires should be twisted together where appropriate, and that although the description below describes the wiring for one channel, both need to be wired up. Fig.2 should be used as a guide, along with the photographs.

A. First fit the 240V AC wiring between the IEC plug/fuseholder, the On-Off illuminated power switch and the primary connection lugs of the power transformer. Make sure that this wiring is all in suitable cable, with mains-rated insulation. Also fit the earth lead (green or yellow/green insulation) between the IEC plug's 'E' lug and the earth lug at the L1 end of the terminal strip, so that it makes a reliable connection to the chassis.
2. Connect the high voltage (350V AC) secondary winding of the power transformer to the bridge rectifier B1, as shown in Fig.2, and then complete the HT supply wiring involving C8, C9, C10 and C11, L1, R29 and R30.
Double check your wiring, to make sure you have not made any errors. Do NOT connect the output of this supply to the PCB, as yet.

The following step is advisable, but not compulsory; it involves powering up the amplifier at this stage, to check that the correct HT voltage is being produced. If you do this, first connect your multimeter carefully between the chassis (earth lug of the tagstrip) and the '+' side of C10, with the multimeter set to its 1000V DC range.

Then connect the mains cord, and apply the power. The meter should read approximately 500V, if all is well with your wiring. If the voltage is correct, remove the power and allow the capacitors at least 20 minutes to discharge before proceeding further.

The only way to avoid this wait is to fit an additional temporary discharge resistor from the '+' terminal of C10 to chassis, BEFORE applying the power for the test.

A 100k, 1 watt resistor used in this way will reduce the capacitor discharge time down to about two minutes. Don't forget to remove this resistor, though, after it has done its job.

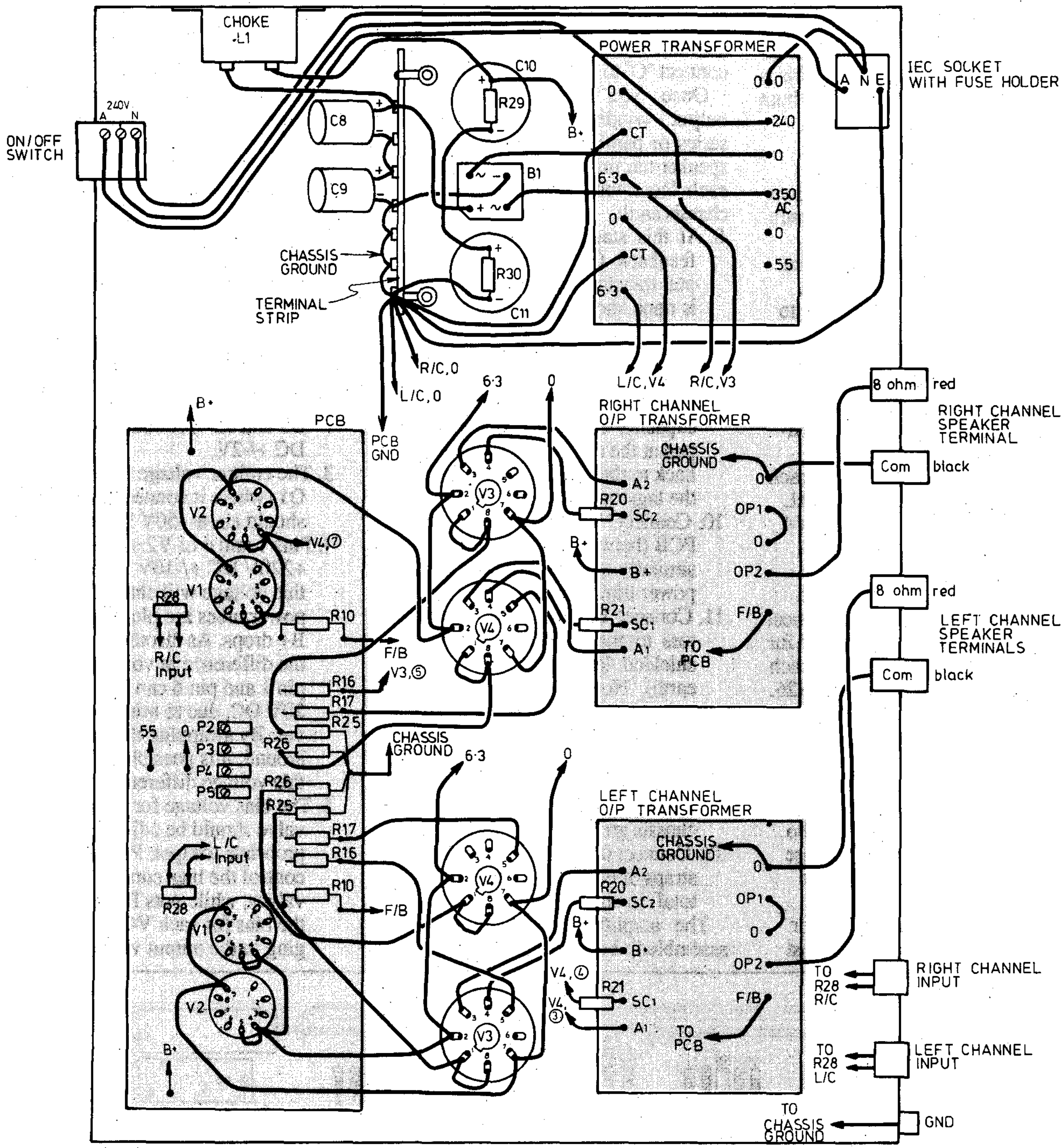
By the way, while you are carrying out the above test, you can check that the On-Off switch is illuminated when power is applied.

3. Wire up the output valve heaters, for V3 and V4 in both channels. Connect lugs 2 and 7 of each V3 socket to the same lugs on the V4 socket in the same channel, and then connect pins 2 and 7 of the socket nearer the power transformer, for each pair, to the outer lugs of one of the 6.3V heater windings (i.e., the '0' and '6.3V' lugs). In other words, the heaters for the output valves of the right channel go to one winding, and those of the left channel to the other winding.

Note that the centre-tap (CT) of each heater winding on the transformer must be connected via a short insulated wire, to the 'chassis ground' lug of the main tagstrip. The heaters for V1 and V2 of each channel are then connected to the output valve heaters for the same channel.

Lugs 4 and 5 of each V1/V2 socket are connected together, and connect to say lug 2 of V3 or V4, while lug 9 of V1/V2 connect to lug 7 of V3 or V4.

All of the heater wiring is shown in basic form in Fig.2. However it is very important to *twist together* each pair of



Use this overall wiring diagram as a guide in making the connections between all of the main items, and also between the PC board and the rest of the circuit. Note that for clarity, the heater wiring is not shown here twisted together. Note too, that the wiring for the optional volume control is not shown — but is clearly visible in the photographs.

Valve Amplifier - 2

(insulated) wires used to make the various heater connections, from the power transformer to the output valve sockets, between the output valve sockets and to the V1 and V2 sockets. This is necessary to prevent induction of hum into the signal circuitry.

4. Connect lug 3 (plate) on each V3 socket to the 'A2' lug on its corresponding output transformer; then connect lugs 4 (screen grid) on each V3 valve socket to the matching 'SC2' lugs of the transformers, via resistors R20. When this is done, connect lugs 3 of the V4 sockets to the 'A1' lugs of the matching output transformers, and finally connect lugs 4 of each V4 socket to the remaining 'SC1' lugs respectively, via resistors R21. Again these connections are shown in Fig.2.
5. Connect lugs 5 (control grid) of each V3 socket to R16 of each channel, on the PCB, and lugs 5 of each V4 socket to the corresponding R17. Then connect lugs 1 (suppressor grid) and 8 (cathode) together on each V3 and V4 socket, and connect each V3 socket's lugs to the R25 for that channel (on the PCB), and each V4's lugs to the corresponding R26.
6. Connect the 'B+' lug of each output (O/P) transformer to the positive terminal of C10.
7. The output transformers are optimized for either eight ohms or two ohm loads. (For those who require four or 16 ohms, please ask for a different transformer type.) It is believed that the transformers supplied will cater for over 90% of users, as most modern speakers are nominally of eight ohms.

For eight ohm operation, connect the two secondary windings of each output transformer in series, as shown in Fig.2. For two ohm speakers, the connections should be connected to parallel — that is, connect 'O' to 'O' and 'OP1' to 'OP2'.

Once you've connected the two output windings together in either series or parallel, then wire them to the speaker terminals as shown, and connect each 'common' speaker terminal to the chassis earth.

8. At this stage, DO NOT wire the feedback (F/B) lugs of each output transformer to the PCB. This is done later, after troubleshooting the circuit.
9. Connect the 'B+' pad at each end of the PCB (next to R22) back to the positive terminal of reservoir capacitor C10. Also connect the '0' pad at the centre rear of the PCB back to the chassis ground lug of the tagstrip.
10. Connect '55V' and '0' pads on the PCB (between C12 and C13) to the similarly marked terminals on the power transformer.
11. Connect the RCA input connectors to the PCB inputs, using shielded leads (outer braid to earth). Note that when the volume control pot is not fitted, resistors R28 are connected across the PCB input lugs along with the leads from the input connectors.
12. Connect the earth terminal to the chassis ground.
13. Connect the copper flux reduction straps of each transformer (three total) to chassis ground, also.

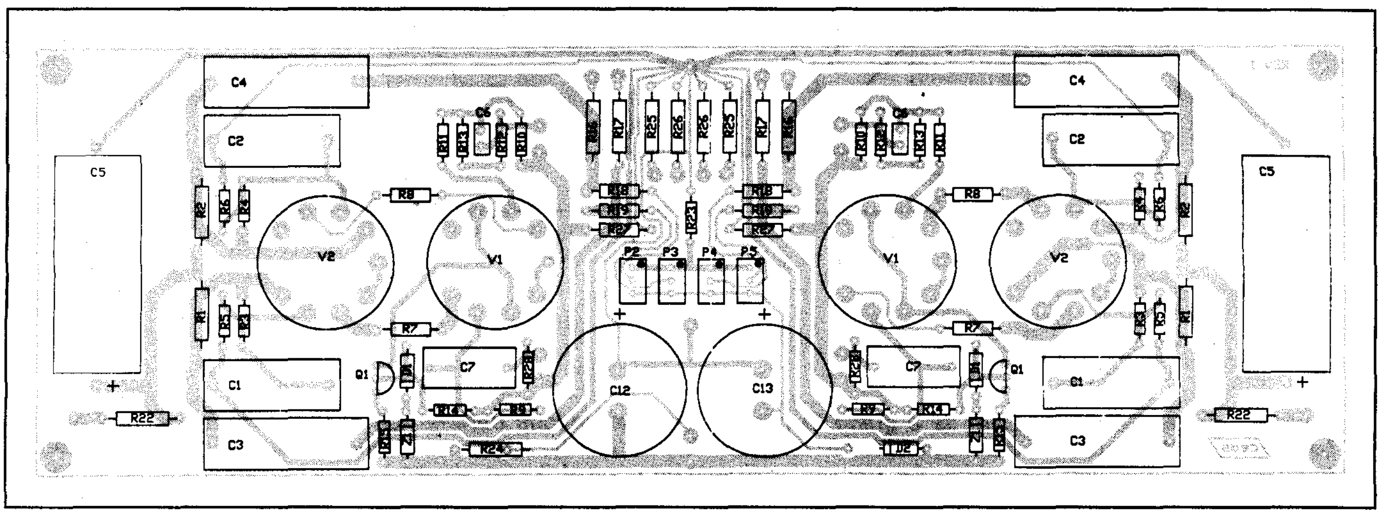
The amplifier should now be fully assembled, but before going any further I suggest that you check the above steps again to ensure that nothing has been missed.

Testing time!

Now it is time for you to test whether everything has been wired correctly. As discussed earlier, the safe method to perform any measurements is to have the common terminal of the multimeter connected to chassis ground, via the aligator jumper lead.

First, plug in the valves V1 and V2 for both channels. DO NOT plug in the power tubes just yet. Then apply power to the amplifier, and the following voltages should be checked with the help of the circuit diagram:

1. The B+ (at say the + terminal of C10) should be about +495V DC +/-10V.
2. The B- (at the junction of C13, D2 and R24) should be about -77V DC +/-2V.
3. The emitter voltage at each transistor Q1 (where it connects to R15) should about -50V DC +/-2V.
4. Pins 1 and 6 of V2 should about +220V DC +/-10V DC. Note that this voltage will change when the power tubes are plugged in, as the B+ drops. As discussed in part one, the difference in voltage between pin 1 and pin 6 can be as high as 20V DC, due to mismatch of the valves. By swapping the valves around, it is possible to minimise this voltage difference.
5. The bias voltage for each output valve should be adjusted via the appropriate trimpot. Pots P3 and P5 control the bias current for the V3 valves, while pots P2 and P4 control the bias for each V4. Before plugging in the output valves, the pots



Placement of all of the parts in their correct places on the PCB should be a straightforward job using this overlay diagram as a guide. Note that all components except the valve sockets are mounted on the copper side.

should be adjusted such that the voltage at lug 5 of each output valve socket measures approximately -44V DC. This is to set the bias current for each output valve to not more than 40mA when they are plugged in.

When you have performed all of the above tests and adjustments, you are ready to turn off the power and plug in the output valves. Then you can turn on the power again, and after waiting for them to warm up (allow say one minute), re-check the main voltages.

With the output valves plugged in the B+ at C10 will normally have dropped to about +475V DC, while the voltage at pins 1 and 6 of each V2 should be between about +180V and +200V DC.

Trimpots P2, P3, P4 and P5 should now be adjusted so that the quiescent cathode current for each output valve is set initially to about 30mA. The builder can experiment with other current levels later, once the amplifier is operational (although I suggest that you do not use currents higher than 60mA, as this would considerably shorten valve life).

The easiest way to monitor the cathode currents is by measuring the voltage at each valve cathode (lug 8 on each V3/V4 socket) — this reflects the voltage drop across the 10 ohm cathode resistors R25/R26.

For 30mA, each trimpot should be adjusted to produce +300mV at the appropriate cathode lug. Make sure you check and if necessary adjust the voltage at each of the four cathodes.

If all is well so far, you are now ready to connect the negative feedback to each amplifier channel. Turn off the power, wait 30 seconds or so and then connect the 'F/B' lug on each output transformer to resistor R13 for that channel, on the PCB.

Use insulated hookup wire, of course. Then turn the power back on. If there are no funny noises from the output transformers, then the polarity is correct. Otherwise there is a 180% phase shift between the output and input, resulting in positive feedback.

Troubleshooting

If the above voltages are not right, check the following:

1. If the B+ line measures zero volts, check the mains fuse. If the fuse is there but has blown, you may have a short circuit somewhere or have made a mistake in your connections. If the fuse blows again, when you replace it, there is almost certainly a short somewhere. Check your wiring around the rectifier bridge, the polarity of all electrolytics (especially C8, C9, C10 and C11), and the heater wiring.

PARTS LIST

Resistors	
R1,R2	220k 1W 5% carbon
R3,R4,R5,R6,R9	1M 0.25W 1% metal film
R7,R8	100 ohms 0.25W 1% metal film
R10	510 ohms 0.25W 1% metal film
R11,R27	10 ohms 0.25W 1% metal film
R12	1k 0.25W 1% metal film
R13	22k 0.25W 1% metal film
R14	56k 0.25W 1% metal film
R15	12k 0.25W 1% metal film
R16,R17	2.2k 1W 5% carbon
R18,R19	470k 0.25W 1% metal film
R20,R21	1k 1W 5% carbon
R22,R23,R24	10k 0.25W 1% metal film
R25,R26	10 ohms 1W 5% carbon
R28	100k 0.25W 1% metal film
R29,R30	470k 1W 5% carbon
Capacitors	
C1,C2	1uF 250V polycarbonate
C3,C4	0.47uF 400V polypropylene
C5,C8,C9	47uF 450V electrolytic
C6	39pF ceramic
C7	0.68uF polypropylene
C10,C11	680uF 250VW electrolytic (chassis mtg)
C12,C13	100uF 160V electrolytic
Semiconductors	
D1	1N914/1N4148 signal diode
D2	1N4004 1A/400V rectifier
B1	BR1010 10A/1000V bridge
Z1	1N971B 27V/400mW zener
Q1	BC546 NPN transistor
Valves	
V1	12AX7/ECC83 dual triode
V2	12AT7/ECC81 dual triode
V3,V4	6CA7/EL34 power pentode
Miscellaneous	
T1	Power transformer, with cover
T2	Output transformer, with cover
L1	Filter choke, 1.5H
P1	Dual ganged 100k log pot, matched
P2-P5	50k 0.25W multi-turn trimpot
F1	IEC captive mains plug with 1A fuse
SW1	SPST 250V mains switch with neon

Four octal valve sockets; four miniature 9-pin valve sockets; four insulated screw terminals (two red, two black); two RCA audio sockets; one screw terminal for earthing; mains cord with 3-pin plug and IEC socket; one 8-lug tagstrip for mounting C8, C9 etc; hookup wire, shielded wire, mounting clips for large electrolytics, nuts, bolts, lock washers, solder etc.

If the B- line measures a positive voltage instead of the correct negative voltage, you have probably wired D2 the wrong way around. This may have caused damage to either D2 or C13.

2. If the voltages at pins 1 and 6 of V2 are too high, check that your heater wiring is correct — there should be 6.3V AC between pins 4 and 5 and pin 9, for each of valves V1 and V2 in each channel. Also check that the bias current is correct, by checking the correct orientation of zener diodes Z1 and signal diodes D1, and each transistor Q1. The voltage across each resistor R15 should be about 27V DC +/-0.5V.
3. If positive feedback occurs when you connect the feedback loops, then change over the wiring at the O/P transformer. That is, swap the wires connecting to the A1 and A2 lugs, and also those connecting to the SC1 and SC2 lugs. Normally this should not be necessary.

Listening tests

Now that you have finished the construction and testing of your amplifier, it is time to reap the reward and listen to it.

At normal listening levels, the sound should as described in part One. Otherwise, there is something wrong with your construction.

The slight brightness reported in part one of these articles is mainly due to the output valves. After replacing them the brightness should disappear altogether. The sound is now more balanced and as a result there is better imaging.

For those builders who like to experiment, there are a number of options worth exploring. Examples include setting the output valves for Class A operation and connecting them for triode operation. These options were discussed in part one. Free advice will be given to those who purchase the kit.

I hope you will enjoy building and listening to this amplifier, as much as I have enjoyed designing, testing and manufacturing it.

Obtaining a kit

As noted in the first article, kits for the Stereo 80 valve amplifier are only available from Contan Audio, of 37 Wadham Parade, Mount Waverley, Victoria 3149; phone (03) 807 1263.

The price of the kit, including all parts and valves, is $999 plus postage without volume control, or $1035 with the special matched dual-gang volume control. These prices include sales tax.

If required, the amplifier can alternatively be supplied fully assembled and tested for $1249 without volume control, or $1284 including volume control.

Individual parts for the design are also available, such as the output and power transformers, chassis, valves etc. Please ring for prices. All parts are guaranteed for one year, except for the valves which are only covered for six months. ❖