Construction Project:

VALVE PREAMP FOR AUDIOPHILES - 1

There's currently a good deal of interest (not to say controversy) among audio enthusiasts, in circuits based on thermionic valves. Following the description of Tean Tan's stereo power amplifier design in the October-November 1992 issues, we've had many requests for a matching line-level preamp design. Here at last is that design, and it's quite a novel one using an interesting gain stage configuration...

by TEAN TAN and JOHN SIOW

Readers of *Electronics Australia* will no doubt be aware that audiophile-quality preamplifiers can be very expensive, with typical retail prices in the thousands of dollars. One of the objectives of this project has been to give readers the opportunity to construct a high quality preamplifier at a much more reasonable price. Additionally, constructors can obtain valuable knowledge from this project such as audio circuit design and its flexibility, and the ways in which various components may affect sound quality.

The design is based on valves, which are currently being used by extensive numbers of audiophile equipment manufacturers and hobbyists throughout the world. The actual circuit configuration used in the gain stage is called a *Mu Follower*, which is by no means new; however its variations and application to audio have been discussed by many audiophiles in magazines such as *Glass Audio*. We believe this circuit is superior to many valve circuits as used in commercial preamplifiers, such as the cathode follower, etc.

The circuit design has been deliberately kept simple to ensure that signal integrity is maintained from input to output. Features such as tone controls, high and low filters are not included. This way the listeners are actually listening to the recordings from the source.

Vinyl recordings are no longer a popular source, and therefore a traditional 'phono' preamp stage is not included in the design. The complete project has a number of features, including four high level (line level) inputs (CD, DAT, Tuner and Tape) and a 'direct' input which bypasses the rotary switch. Outputs include Tape and Main, the latter being for connection to the power amplifier. A mute switch is also included.

A kit is available for the project, and this comes in a number of options to suit the needs of individual constructors. Please refer to the last section of this article for details.

The basic design philosophies embodied in the project encompass three main aspects: circuit design, component selection and circuit layout. These will now be treated in more detail.

Circuit design

Great sounding preamplifiers start with good circuit design; anyone can tell you that. In developing this project the criteria we used for the design were simplicity, low distortion at high output voltage swings, extremely high overload margin, wide frequency bandwidth, minimal phase shift right through the circuit, a high level of linearity and finally low output impedance to drive long interconnecting cables. All of these criteria are measurable and should ultimately determine the sound quality.

Over the past decades the evolution of a circuit topology for valve preamplifiers has ranged from the simple use of a cathode follower (near unity gain) to a two-valve configuration using a common cathode stage direct coupled to a cathode follower. The latter circuit was widely used by Audio Research and Marantz designers in their earlier days.

The basic circuit topology used in this preamplifier has its origin in the 1930's, and has continued until today. An early implementation of the topology is the shunt regulated push-pull (SRPP) stage, which was used extensively in power amplifiers.

In the early eighties it was introduced as a line preamplifier in the Beard preamplifier. This circuit has its limitations, one of which is the high output impedance — in excess of 1k ohms at mid-band frequencies, depending on the tube used. In 1985, Chris Paul's article in *The Audio Amateur* magazine discussed the use of a variation of this circuit, as shown in Fig.1. Paul also introduced an equivalent circuit for this topology.

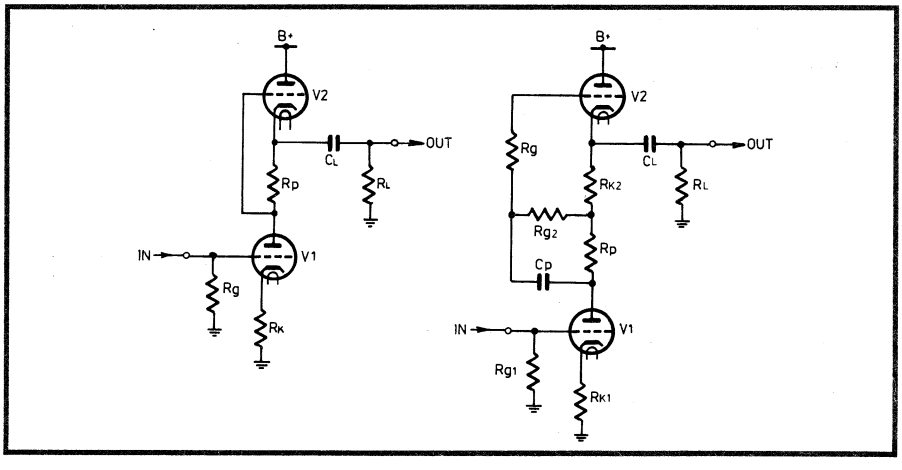


Fig.1: At left is the basic SRPP (shunt regulated push-pull) stage, as used in the original Beard preamplifier, with Chris Paul's adaptation on the right.

Using this topology and by taking advantage of other published research, the end result is the Mu Follower topology using two dissimilar valves. This circuit does in fact satisfy the previously noted design criteria very well, as you can see from the measured performance results.

Valve V1 acts as a common cathode stage, whose gain is determined by the anode impedance; this happens to be largely another valve, V2. The second valve acts as a 'current source' or active load for the first stage, but at the same time also acts as a cathode follower. The effective gain of this two valve topology is close to the mu (amplification factor) of V1. The two valves work in synergy to give a very low distortion even at high output levels.

A complete circuit of the Mu Follower is shown in Fig.2. Careful selection of the components is important to achieve a good technical performance as well as sonic reproduction. The valves chosen are easily obtainable from a variety of sources. The resistors are all of the metal film and metal oxide type, rated at 1W and 2W as appropriate. The non-electrolytic capacitors are metallised polypropylene and polystyrene types to give the best performance.

The valve used for V1 is the common 5814 (12AU7 or ECC82 or CV4003), biased at about 5.3mA. This is within the linear region of this tube. This valve was chosen because its nominal mu-factor is about 17 (24.6dB). This gain is more than sufficient in most line stage preamplifiers.

The top valve V2 must have a high transconductance, and the 6922 (6DJ8 or ECC88) comes to mind. The 5814 and 6922 are upgraded versions of the 12AU7 and 6DJ8 respectively. A high transconductance of the top valve will give a low output impedance. The bias current of V2 is about 7.3mA, which is adequate to achieve a transconductance of about 8mA/V. Again V2 is biased so it operates in the region of linearity.

Note that there is no overall negative feedback to this circuit; only local feedback for each valve as provided by the cathode resistors. Therefore there is no danger of instability and unwanted phase shift. The phase linearity is an important parameter in achieving a sonic coherency in music.

By the way, the authors do not suggest that amplifiers with overall feedback cannot achieve phase linearity; just that careful design is essential to achieve phase linearity.

The two low frequency poles are determined by the 0.22uF and 3.9uF coupling capacitors. The locations of these poles are spaced far enough so that there is no interaction. The two capacitors are also bypassed with small capacitors to improve transient response. The dominant high frequency pole is determined by the output impedance of V1, the input capacitance of V2 and stray capacitance.

The -3dB points on the preamplifier's frequency response have been measured at below 0.5Hz and around 200kHz.

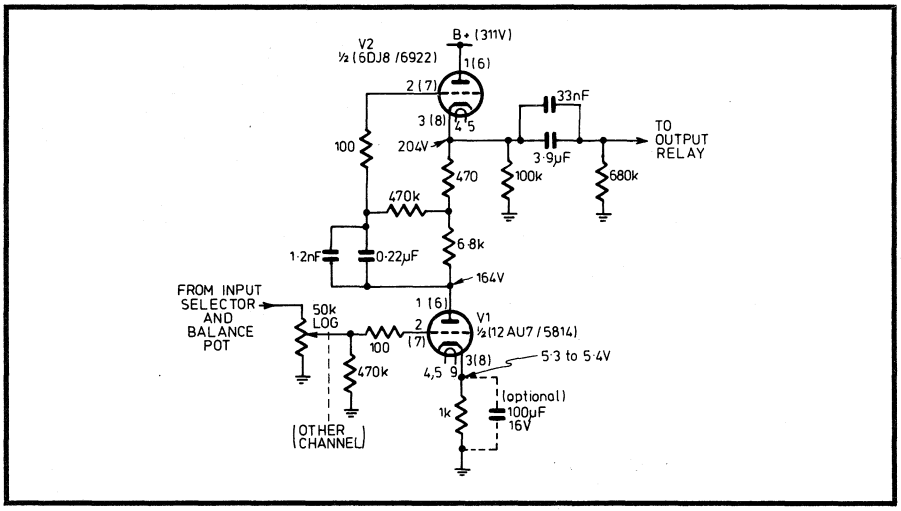


Fig.2: The gain stage configuration used in the authors' preamp, which has been dubbed the 'Mu Follower' topology. The upper valve presents a very high load impedance to the lower one, while also providing a low output impedance.

Power supply

The high tension B+ voltage is not critical; approximately 300V DC is suitable. The supply can be as low as 250V and as high as 320V. The high tension is actually regulated using solid state components, as you can see in Fig.3.

The main highlights of this circuit are the use of a TL783 regulator, which is an adjustable floating regulator whose output voltage is determined by the 390 ohm resistor and the 100k/1.2M parallel resistor combination. The TL783 regulator is preferred over the standard LM317 because of its lower noise output.

The IRF830 power MOSFET has a V_{DS}

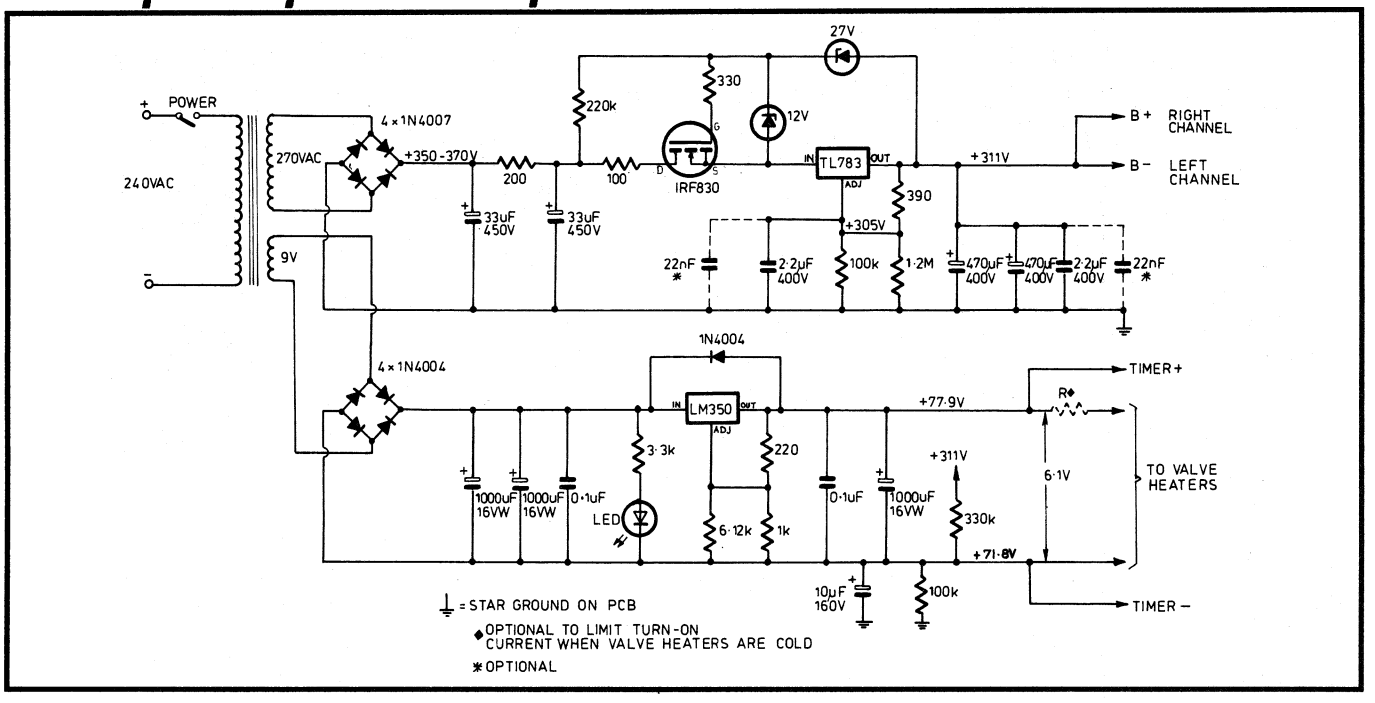


Fig.3: The power supply circuitry for the preamp. As you can see both the HT supply for the valves as well as their low voltage heater supply are electronically regulated, to stabilise the operating conditions and also reduce noise and hum to very low levels. The heater supply floats at about 70V to minimise heater-cathode leakage in the valves.

of 500V DC. This is essential to protect the TL783 from damage due to power-up transients. Sufficient storage capacitors are provided, 470uF per channel, to give the preamplifier the required bass extension.

To ensure the lowest possible hum level, the valve heaters are fed with DC. This is regulated to 6.1V with very low ripple, using an LM350 device. As the cathode of the V1 valve operates at about 5.5V DC, while that of V2 operates at about 200V, the complete heater supply circuit is arranged to 'float' at about 75V DC with respect to ground, by means of the voltage divider formed from the 330k and 100k resistors (Fig.3). This minimises the risk of heater-cathode leakage or breakdown in either valve.

Because of the relatively long time constant formed by the preamp's 3.9uF output coupling capacitor and 680k bleed resistor, the DC output voltage at the preamp outputs will take some time to settle down after power is applied. To prevent this from causing any audible effects, a simple timer circuit and relay are used to the disconnect output of the preamp at switch-on, and only connect it after about a minute. The timer circuit is based on a readily-available 555 device, and is shown in Fig.4. The 560k resistor and 100uF capacitor determine the delay time.

Component selection

Some of the reasoning behind the choice of component used, such as polypropylene capacitors and resistors, have been explained in the previous section. Other components such as a toroidal power transformer, were chosen for low vibration and lower electromagnetic radiation in comparison to the standard E-core power transformer.

Other important components are the volume and balance potentiometers. The use of standard carbon potentiometers are not recommended. The better quality types are conductive plastic or cermet, and these are far preferable.

The internal wiring is another important component. The kit for this project is supplied with silver and copper alloy wires. This type of wire represents the best value for money in the market, we believe.

The components chosen for this preamplifier are no means the ultimate quality, but an important feature is the careful use components in each and every location. Some components are 'bright' in character while some are less bright and others are neutral. Each type (brand) of component has a character or an imprint of its own.

Therefore careful selection and matching of components is very important. Furthermore a selection of a set of components to give certain sonic qualities may not necessary please all audiophiles.

Further enhancements by the choice of components would be possible. These include a larger power supply, better quality capacitors and resistors, higher quality wiring and a higher quality volume potentiometer. Readers who are interested can contact the authors.

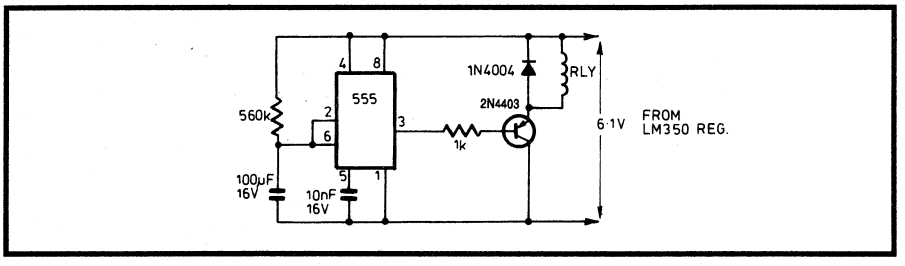


Fig.4: As the preamp output circuitry takes some time to stabilise after switch on, a timer circuit is used to connect the outputs only after a delay (about 1min).

Circuit layout

Circuit layout is the third important parameter in attaining sonic purity. Point-to-point wiring is preferred over a printed circuit board (PCB), although for convenience and minimisation of wiring errors the latter method is chosen. Therefore

MEASURED PERFORMANCE OF THIS PREAMP

The designers of this interesting valve preamp design sent us the prototype unit shown, and invited us to both measure its performance with our instruments and listen to it in a typical domestic environment. This is our report on what we found.

First, the measured performance:

Frequency response	0.5Hz - 200kHz (-3dB)	
Signal to noise ratio	-82dB (ref 1V RMS output)	
Total Harmonic Distortion (1V RMS output)	100Hz	0.038%
	1kHz	0.035%
	10kHz	0.037%
Intermodulation Distortion	0.14% (1V RMS output)	
Crosstalk between channels (ref 1V RMS output)	20Hz	-70dB
	1kHz	-67dB
	10kHz	-50dB
Slew rate	Approx 4V/us	
Output impedance at 1kHz	Approx 450 ohms	
Gain at 1kHz	24dB (Av = 15.8)	

The authors also provided an alternative ECC82 valve for the V1 stage, and we also tried measuring the performance with this in circuit. The only significant difference in measured performance was that the THD increased to 0.045% at 1kHz, while the IMD dropped slightly to 0.13%.

Note, however, that the distortion figures above were all taken with the preamp outputs loaded resistively with a nominal 100k. In the course of our measurements, we found that both the THD and IMD figures *dropped significantly* when the preamp outputs were provided with lower value loads. In fact if the loads were reduced to approximately 7.5k, both types of distortion reached a minimum. In this condition we measured less than 0.010% THD at 1kHz, 0.014% at 100Hz and 0.013% at 10kHz, and 0.02% for IMD, again at 1V RMS output.

We have discussed this with the authors. However they do not recommend reducing the loading to 7.5k, because although this does appear to minimise the distortion, it will also cause the low frequency response to roll off earlier (i.e., at a higher frequency). The -3dB frequency would rise to around 6Hz from the measured 0.5Hz, unless the output coupling capacitors (currently 3.9uF) were increased in value.

However readers contemplating building this preamp may wish to experiment with loading themselves, to find the best compromise between distortion and bass response.

How it sounded...

Our listening tests were actually conducted before these measurements were made. We used the preamp in conjunction with the Playmaster Pro Series One power amplifier, a good CD player and a high-quality speaker system, and were quite impressed with its sonic performance. The overall sound was clean and well balanced, with virtually no hum and very low noise for a valve circuit (only audible right at the speakers).

Playing familiar reference tracks from various CDs, the sound overall was very pleasing to the ear. Our only slight reservations were that we thought we could detect a very slight 'edge' on solo vocalists singing with a fairly complex orchestral background. This was with the preamp channels loaded only with the 33k input impedance of the Playmaster amp, and following our measurements we suspect that we were detecting the preamp's IMD in this condition. It seems likely that with the loading reduced to near 7.5k, this 'edge' would disappear.

In short, then, we found the performance of the preamp quite impressive. Those audio enthusiasts who want to use or experiment with a valve-based preamp design should therefore find it a very good choice.

a high quality PCB is used, with the copper tracks made as wide as possible in areas where this is required. The copper weight is also 'two ounce', twice the normal weight. Boards supplied with the kits will have a layer of lacquer to protect the copper tracks from oxidation and humidity attack.

The layout is such that there is a minimum of interaction between inputs and outputs. The outputs are laid as far away from the inputs as possible to avoid cross-coupling between inputs and outputs. Wherever possible the signal paths are kept to minimum length and only good quality switches are used through- out to reduce sonic colouration.

Earthing is always the main concern among audio constructors. The PCB is laid out such that all the ground connections are taken to a single point — the technique commonly known as 'star wiring'. This is the best method to avoid hum loops and the 50Hz mains hum they can inject into the circuit.

Possible enhancements

The design is flexible enough to allow constructors to perform various modifications, if they wish, to alter and enhance the sonic balance. These include:

1. The use of better quality components, such as MIT capacitors, Holco resistors, etc.
2. Experimenting with different brands and types of valves — e.g., 6CG7, 5965 etc.
3. Possible improvements in the circuit, such as bypassing the 1k cathode resistor of each V1 input stage with 100uF, to reduce the output impedance and distortion.

It is the authors' experience that these three factors affect the sonic balance of the music output. So constructors can experiment with these factors as desired, to obtain the particular sonic balance they prefer — e.g., better bass, smoother treble etc.

Sound quality

The authors set out with a specific sound in mind for this preamplifier. It should have high definition, including good clarity, good bass extension, smooth treble, tuneful mid-band and good tonality. These are the sonic qualities which typify a valve preamplifier. It must also have a 'big sound stage' with depth and extension. It must also be capable of handling fast transients from CD and DAT sources, without sounding sluggish or compressed. There must be a good balance between all of these sonic attributes to achieve musical coherence.

We believe we have achieved what we set out to do, and invite constructors to verify this for themselves.

In the second of these articles, we will present the construction details for the preamplifier. In the meantime, for those readers interested in obtaining the kit, it is available from Contan Audio, of 37 Wadham Parade, Mount Waverley, Vic 3149; phone/fax (03) 807 1263.

The kit comes in a number of options:

A. PCB only $45.00
B. PCB and all components ... $289.00
C. Toroidal transformer $85.00
D. Alps volume, balance pots ...$49.00
E. Case & all components except items B, C and D $269.00
F. Complete Preamplifier kit (B+C+D+E) $649.00
G. Fully assembled kit, tested and guaranteed $849.00

The components supplied in this kit are of very good quality. For example the pots are from Alps, the capacitors from Wonder and Solen, the resistors from Beyschlag and Philips, and the electrolytic capacitors from Panasonic and Nippon ChemiCon. The valves supplied are military grade 5814 (12AU7 equivalent) and 6922 (6DJ8 equivalent) types. The toroidal transformer is 'over designed' to run with very low temperature rise, while as mentioned earlier military grade hookup wire, silver contact switches, a high quality IEC socket and power cord are supplied. The case is of high quality aluminium, fully screen printed and professionly finished.

Incidentally individual components can also be obtained from Contan Audio; send a self-addressed envelope with $1.00 stamp for a catalog.

(*To be continued.*) ❖

Construction Project:

VALVE PREAMP FOR AUDIOPHILES - 2

In this second article describing an interesting new design for a high-quality stereo preamplifier using valves, the author covers its construction and setup. All parts necessary to make the preamp are available as a kit from Contan Audio, with various options to suit individual needs. As explained later, Contan can also supply individual components if required.

by TEAN TAN

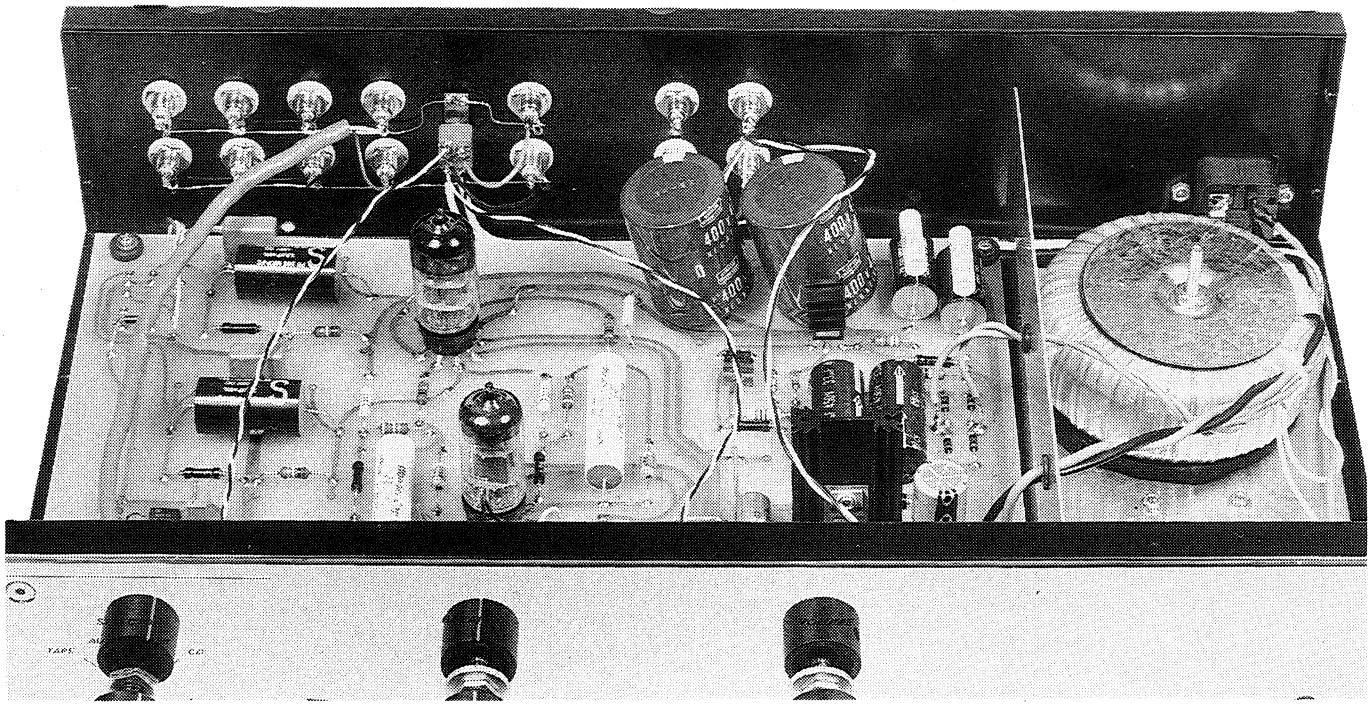
This preamplifier is easier to build than our power amplifier, the Stereo Eighty, which was based on EL34 valves (*EA*, October-November 1992). However like most valve preamps based on the common cathode/cathode follower configuration, it's still not entirely straightforward. For example this design has the B+ (high tension) supply regulated, and the amplifier outputs have a timer circuit to protect the speaker.

As a result, it's important that constructors take the necessary precautions to ensure that constructing this project is successful. There are two areas that should be mentioned, one involving your own safety and the other the soldering and wiring techniques used to make the project itself.

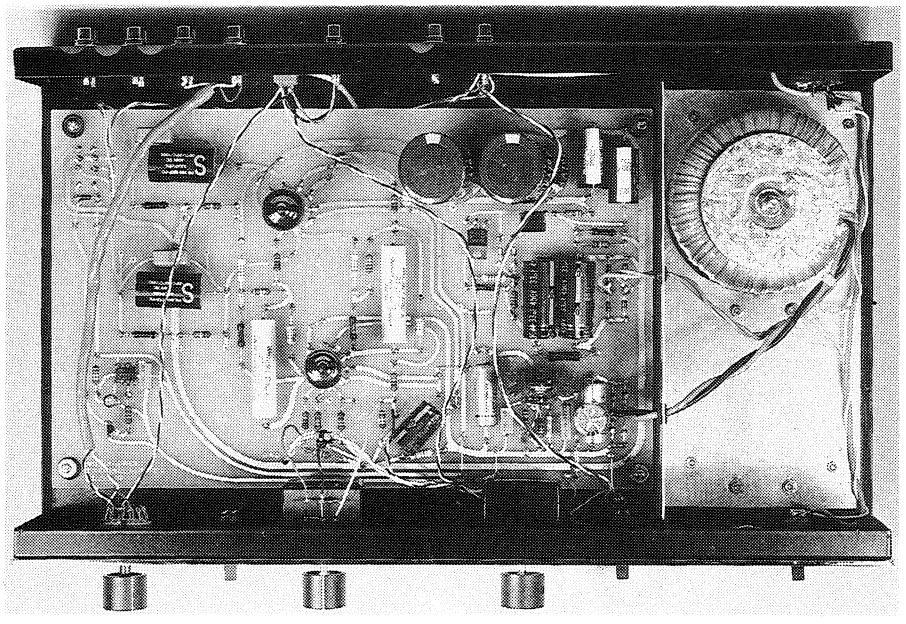
Safety precautions

We can't emphasise too much that because of the high voltages present in a valve project of this type (300V DC as well as 240V AC from the mains), constructors should take the necessary safety precautions. Accidental contact with these high voltages will cause a nasty shock, and could even by fatal — so please be **very careful**. Recommended precautions to take include the following:

1. The mains earth should be connected to the chassis in a reliable and secure fashion, as described later. Make sure that you produce a secure earth connection by scraping off the paint from the metal under the solder lug, so there's a good metal-to-metal contact. The chassis ground is connected to the 0V line on the PCB. Refer to the wiring diagram for details.
2. A correct fuse (500mA slow blow) must be used, inserted in the IEC socket fuse holder.
3. Use only one hand when measuring any voltages — preferably the right hand. The left hand should not be touching any part of the PCB, or metalwork. The common terminal of the multimeter should be connected to the chassis ground using an alligator clip jumper lead.
4. Switch off the amplifier before



This view inside the preamp case gives a good idea of the internal layout, and also the way the components are fitted to the copper side of the main PCB. Not all of the input connector wiring was in place when this photo was taken.



An overall view of the preamp internals. The toroidal power transformer at upper right is mounted on an L-shaped shield plate, as explained in the text.

making any adjustment — e.g., when changing components or resoldering.

5. Do not plug in any valve while the power is on. Always turn the power off first, and preferably allow the capacitors to discharge by waiting say 30 seconds before plugging in the valve.
6. Do not make any measurements of voltages, etc., inside the preamp without wearing suitable footwear, such as rubber or dry leather shoes.

Here are some other suggestions we'd like to make, regarding the steps to take when you're building the preamp, in order to minimise problems and ensure success:

A. The kit is supplied with a large PCB which accommodates all of the electronic components. Prior to soldering, perform a stocktake and make sure you have all of the parts needed.

B. Note that the components should be soldered on the same side as the copper tracks. The preamp has been designed this way so that the components can be installed or removed easily without turning over the PCB. This enables the constructor to experiment with the different components — e.g., resistors, capacitors and valves. The only component mounted under the board, on the non-copper side, is the muting relay.

C. Ensure that polarised parts such as diodes and electrolytic capacitors are orientated correctly before you solder them in.

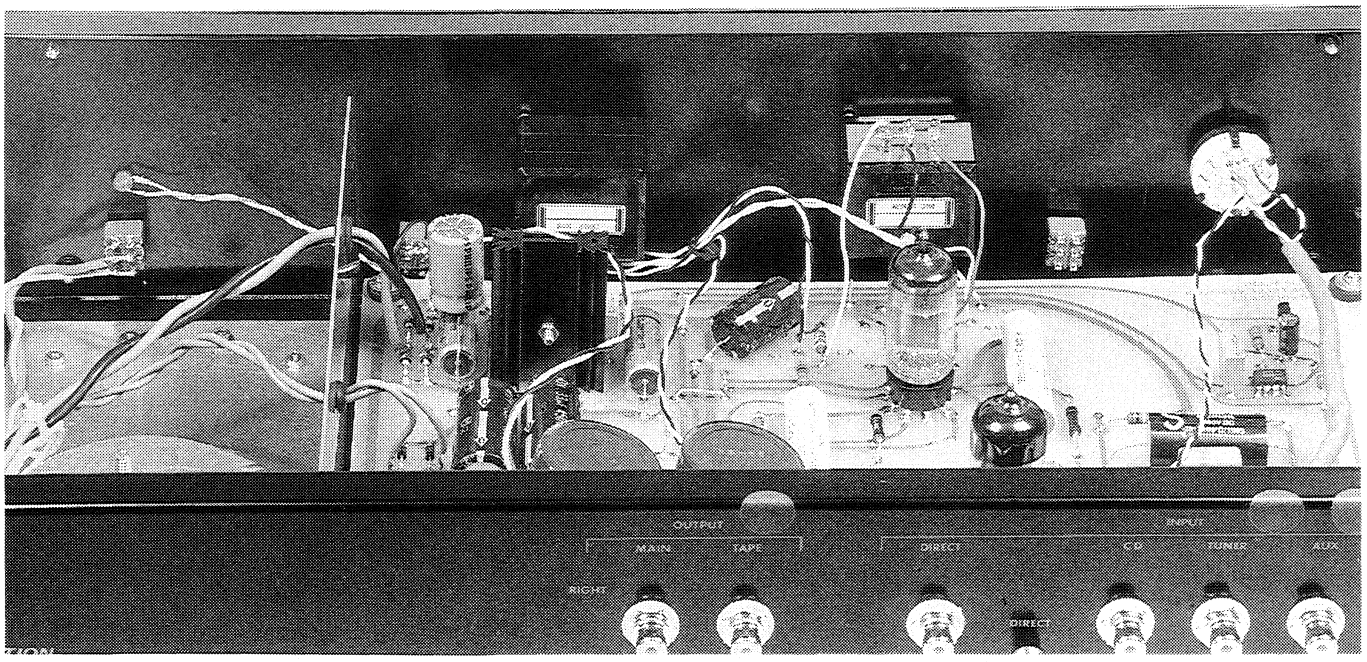
D. Bend the component leads to the required shape (to reach the appropriate PCB pads) carefully using long nose pliers, so as not to strain the component. Do not bend them using your fingers.

E. When soldering a wire to a binding post, ensure that you apply solder to 'tin' both first. This will ensure a good joint.

F. Use only good quality resin core solder, to ensure a solid joint. Ersin 60/40 resin core is suitable, although the author prefers Wonder solder because this has low melting point. A good solder joint should be smooth and shiny.

Do not move the component or wire while the solder is cooling, or you may get a 'dry' joint.

G. Prior to switching on the power, check over the entire amplifier and make sure that all wires and components are in their places and all of the connections are soldered. 99% of the problems that occur with any project are because of unsoldered joints and improperly placed wires.



Another view inside the case, looking towards the front panel controls. Again, when this photo was taken, the unit concerned did not have the wiring to the normal/direct switch fitted — or all of the wiring to the input selector switch.

Valve Preamp for Audiophiles - 2

Mechanical assembly

The first step in building the preamp is the mechanical assembly. First install the IEC power input connector and the RCA sockets (seven pairs total) in their right locations on the rear panel. Make sure that the mounting nuts on the RCA sockets are well tightened, so that they won't become loose, and also that the ground tags are readily accessible.

Note that all of the ground tags will be connected together, except those for the 'main' preamp outputs.

Now install the selector switch, balance pot and volume pot on the front panel, ensuring that the pot tags are facing upwards to allow easy access for soldering. Also install the toggle switches for defeat/record, mute/operate, direct/normal and power on/off.

The toroidal power transformer can now be mounted as shown in the wiring diagram and internal photo. The mounting bolt is introduced from under the chassis, and has the large neoprene rubber washer fitted first, followed by the transformer itself and then the small neoprene washer and the dished metal washer, and finally a solder lug, lock washer and nut. Don't over-tighten the nut as yet; for those of you who have access to an oscilloscope, it is possible to minimise flux interference with the preamp circuitry (i.e., minimise hum) by rotating the transformer later. This will be explained in the testing section.

PCB assembly

Follow the PCB wiring diagram closely when soldering the components onto the board. The PCB is single sided, with '2oz' copper (twice the normal weight), and as you can see from the photo it's mounted in the chassis with the copper track side — which is also the component side, in this case — uppermost. Note that some pads on the board are left blank for future use or experimentation.

The PCB assembly procedure is as follows. First, mount all of the low profile components, such as the resistors, diodes, 555 timer chip, transistors and capacitors. Solder all of them in, making sure your joints are firm as they hold the components in position as well as make the connections.

Now solder in the jumper links, as indicated on the PCB layout. Use offcuts from the resistor leads, or short lengths of tinned copper wire. The links can either be fitted under the board, or on the copper side if you wish — but in this case, make sure you loop them away from the board so they don't touch any of the other tracks.

Then mount the heatsink for the LM350 regulator IC, and solder in both this regulator, the TL783 and the IRF830 power MOSFET. At this stage you can also fit the valves sockets and the relay, which is mounted from the underside of the board.

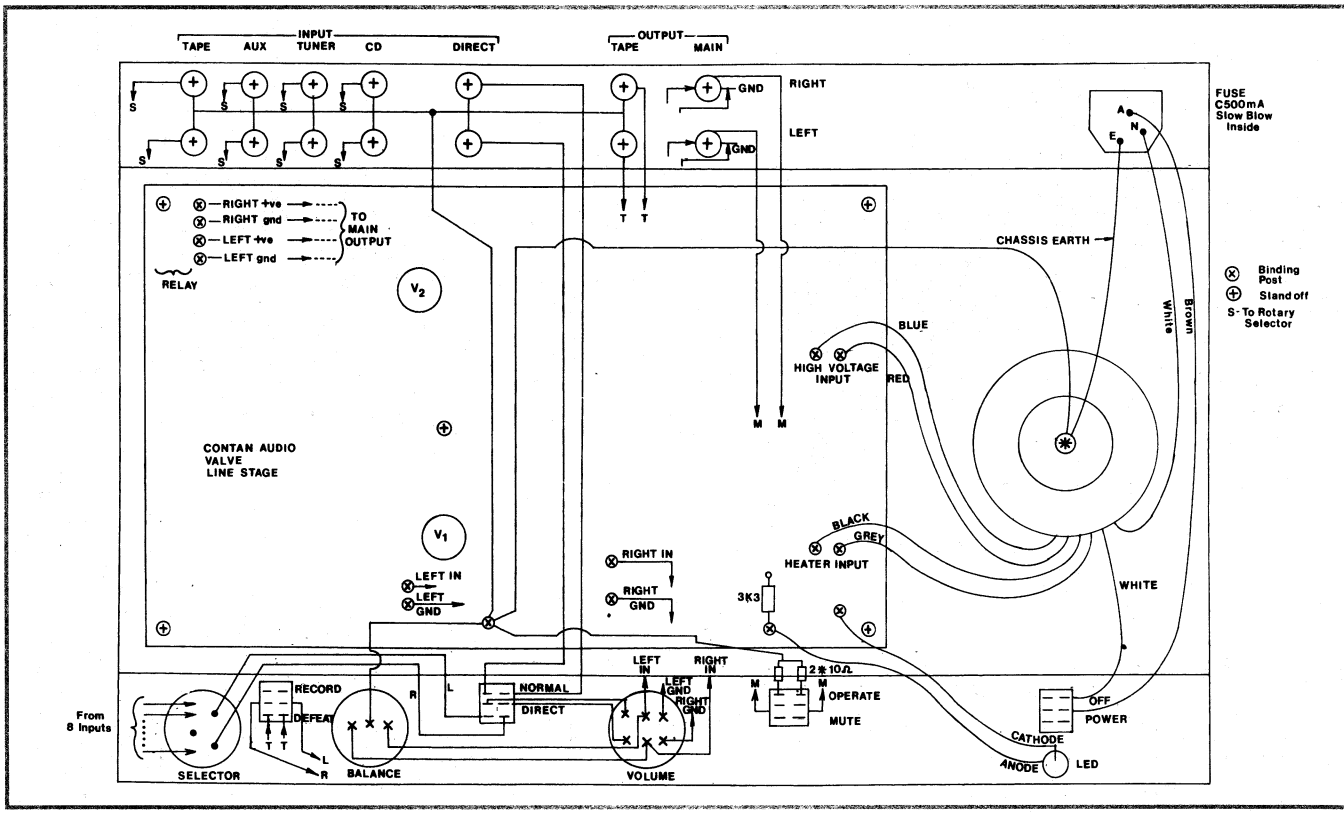
The final step in PCB assembly is fitting and soldering the PCB terminal pins, to take the interconnection wires.

Once you have completed soldering, just make a final check that all of the components are in the correct position. Now is the time to solder in any left over components, rather than later!

At this stage you can mount the completed PCB assembly in the chassis, using the mounting hardware provided. You should then be ready for the 'hard wiring' — that is, the wiring that interconnects the major components, made using conventional insulated wires rather than PCB tracks.

Hard wiring

Actually the kit is supplied with silver-plated copper wires, and these should be used for all of the signal path interwiring — particularly the inputs and outputs to/from the PCB. Use the wiring diagram



Use this wiring diagram as a guide when you are making all the interconnections between the preamp PCB and the other main components. Note the central earth point at the front centre of the PCB.

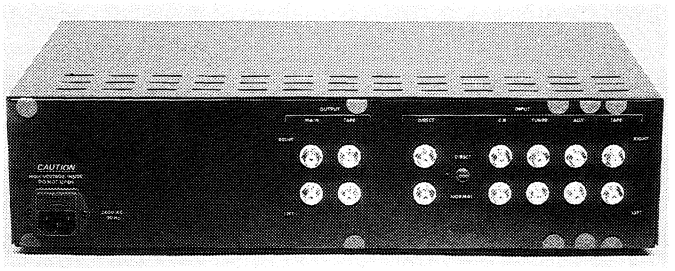
as a guide for this and the rest of the hard wiring.

The first step is to connect all of the ground lugs on the RCA sockets (apart from the two 'Main' outputs) together, using a long copper wire, and then run a wire between this input socket earth line and the main PCB signal earth pin (front centre of the PCB). Another short wire connects the centre lug of the balance pot to this PCB signal earth pin, as well.

Then connect the signal lugs of the 'Direct' RCA inputs to the direct/normal switch as shown, and also connect the other terminals on the switch to the volume control pot and the input selector switch.

Now connect the centre lugs (L&R) of the volume pot to the Left and Right inputs on the PCB, and also to the outer lugs of the balance pot. The preamp outputs from the PCB (near the relay) should also be connected to the 'Main' RCA output sockets.

You can now solder the AC leads from the heater winding on the power transformer (grey and black wires) to the 'heater input' pins on the PCB, bringing them first through the grommetted feedthrough hole in the shield plate, nearest the front panel. Similarly the leads from the transformer's HT secondary winding (blue and red) can be brought through the other grommetted hole, and soldered to the 'high voltage' input pins on the PCB.



A rear view of the preamp. This prototype unit had the direct/normal switch mounted on the rear panel; it is now fitted to the front panel.

Probably it's best to do the transformer primary/AC wiring at this stage. Solder one of the transformer's white wires to the 'neutral' (N) lug of the IEC mains connector, and the other white wire to one lug of the the power switch. The other lug of the power switch is then connected to the 'active' (A) lug of the IEC connector, using a length of mains-insulated wire (preferably colour coded brown or red).

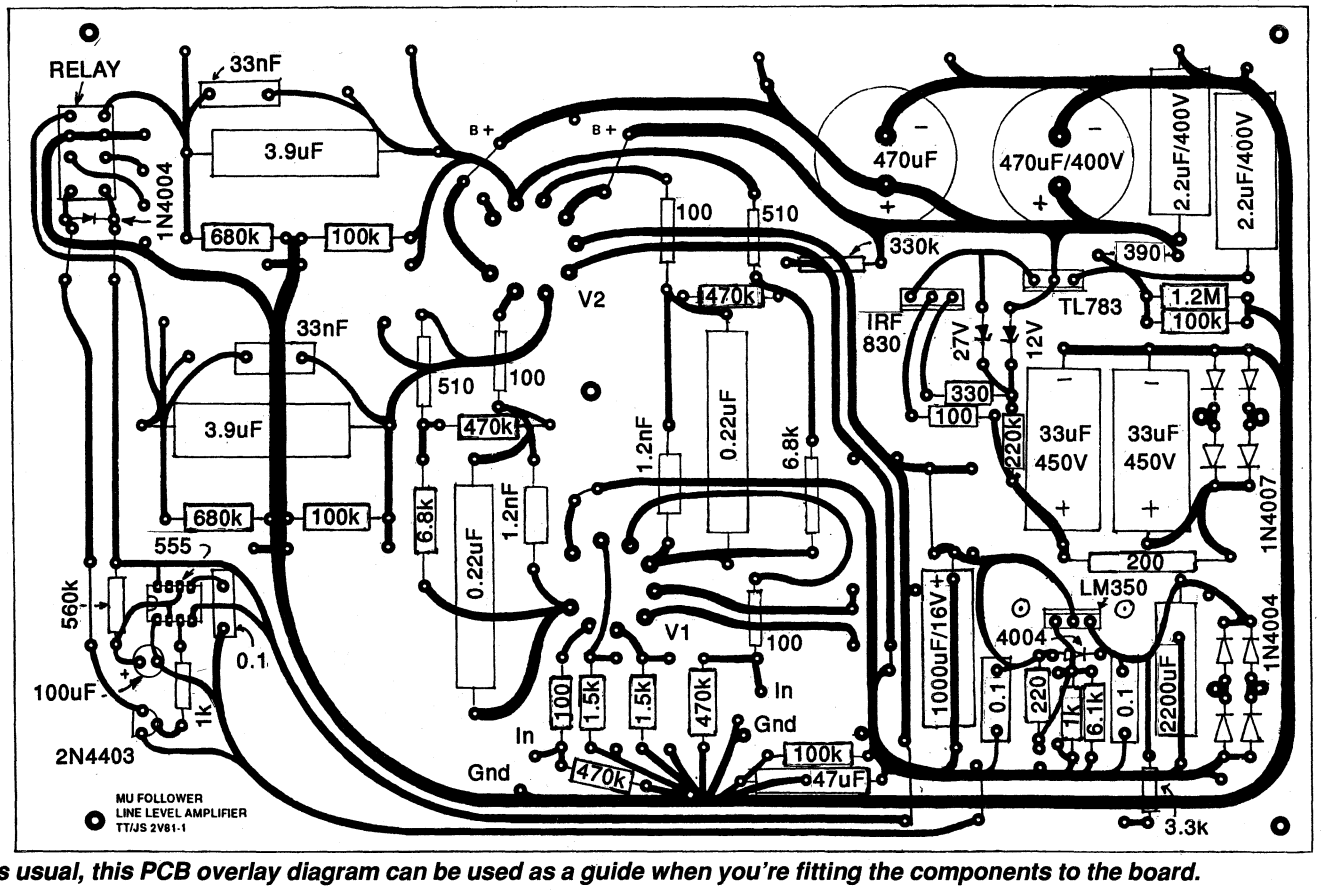
Now run a wire (coded green or yellow/green) from the IEC connector's earth (E) lug to the solder lug mounted under the transformer mounting nut, as described earlier. Also run a similar wire from the same transformer earthing lug to the main earth pin on the PCB (near its front centre), taking the wire through the rear feed-through hole. At this stage you can jump forward to the next section, for testing the PCB, before you complete the rest of the PCB interconnections.

When this has been done, you can complete the assembly by adding the wiring to the LED, the rest of the toggle switches, between all of the RCA input socket signal lugs and the selector switch, and the tape output sockets. Then you should be ready for a final check of all the connections, before fitting the lid.

Testing time

Now is the time to test whether the preamplifier is working properly. As discussed earlier, the safe method to perform any measurements is to have the common terminal of the multimeter connected to the chassis ground, via an alligator jumper lead.

First, plug in the two valves, the 12AU7/5814 (V1) and the ECC88/6922 (V2). Before connecting the power cord



As usual, this PCB overlay diagram can be used as a guide when you're fitting the components to the board.

Valve Preamp for Audiophiles - 2

to the IEC connector, check that the power switch is off. Then turn on the power, and with the help of the circuit diagram and the PCB layout check the following voltages:

1. The B+ should be about +311V (+/-5V). It is regulated, so it should be stable and with no ripple. Reducing the 1.2M resistor connected to the 'Adj' pin of the TL783 regulator will reduce the B+ to about 300V, if you wish.
2. The common side of the heater wiring should be at about +72V above earth (measure at pin1 of the 555 timer chip). The heater line is designed to 'float' at this voltage so that the heater to cathode voltage rating of the top valve (V2) is not exceeded.
3. The voltage on the other side of the heater line should be 6.1V higher than the common voltage (measure at pins 4 or 8 of the 555). The heater supply is purposely designed to be around 6.1V, rather than the traditional 6.3V. (Many audiophiles believe that 6.03V is the ideal heater voltage!)
4. Now check the cathode voltages (pins 3,8) of V1 measure between about +5.3V and +5.4V. The anodes (pins 1,6) should measure around +164V.
5. The circuit should be working properly. Check the timer is working — there should be a 'click' from the relay about one minute after power is applied, as the timer energises it to connect the outputs.
6. With the multimeter on the AC volts setting, the output after the relay should read negligible AC volts — less than 0.003V.
7. If an oscilloscope is available, observe the Main L and R outputs. Only a tiny amount of valve noise should be visible, and possibly some mains hum from the toroidal transformer. The latter can be reduced by rotating the transformer.
8. Now that you are confident that the circuit is working properly, you can return to complete the hardwiring. Or if you're impatient, you may wish to carry out an initial listening test first, as described below.

PARTS LIST (Basic design)

Resistors
(All 0.25W 1% metal film unless stated)
2 10 ohms 0.6W
5 100 ohms 1W
1 200 ohms 1W
1 220 ohms
1 330 ohms
1 390 ohms
4 470 ohms
4 1k
1 3.3k
1 6.1k
2 6.8k
4 100k
1 220k
1 330k
4 470k
1 560k
2 680k
1 1.2M
1 Dual 50k volume pot, Alps audio taper
1 Cemet balance pot

Capacitors
(All polypropylene unless specified)
2 1.2nF
1 10nF
2 33nF
2 0.1uF
2 0.22uF
2 2.2uF 600VW electrolytic
2 3.9uF
1 47uF 160VW electro (replaces 10uF)
2 33uF 450VW electrolytic
1 100uF 16VW electrolytic
2 470uF 400VW electrolytic
1 1000uF 16VW electrolytic
1 2200uF 16VW electro (replaces 2 x 1000uF)

Semiconductors
6 1N4004 rectifier diode
4 1N4007 rectifier diode
1 1N4742 12V zener diode
1 1N4750 27V zener diode
1 2N4403 PNP transistor
1 IRF830 power MOSFET
1 TL783 adjustable regulator
1 LM350 adjustable regulator
1 555 timer IC

Valves
1 12AU7 or 5814 (V1)
1 ECC88 or 6922 (V2)

Miscellaneous
Toroidal power transformer, 270V and 9V secondaries, with mounting hardware; 6V relay, Omron; TO-220 heatsink for LM350 regulator, PCB mounting; LED (red or green) with panel- mounting holder; 2 x valve sockets, polycarbonate; 4 x toggle switches; 2-pole 4-position rotary switch; 14 x RCA sockets, gold plated contacts; 3 x control knoibs, screw type; case and front panel; IEC mains connector, panel mounting with inbuilt fuse; PCB mounting hardware; rubber grommets; hookup wire, silver-plated; solder lugs, solder etc.

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.

By the way, the output of the preamplifier is phase inverted, i.e., 180° shifted in phase compared with the inputs. Because of this, those of you who are purists may wish to reverse the connections to your speakers (both channels), to obtain correct absolute phasing...

There should be no hum at the output of the preamp, and the noise level should be very low as measured by *Electronics Australia* and shown in the box on page 63 of the October 1993 article.

The circuit is flexible enough to allow experimentation, in order to obtain the kind of 'sound' you wish for your system. As described, it should give a smooth 'open' sound without being aggressive. Those of you who want a slightly more 'forward and faster' sound can try changing the 'top' valve V2 to a 12AT7/ECC81.

If you do this, you'll have to change some resistors to get the biasing right for the new valve. Constructors who need further information can contact me for the correct values.

Obtaining a kit

As mentioned in the first of these articles, a kit for this preamp can be obtained directly from Contan Audio, of 37 Wadham Parade, Mount Waverley, Victoria 3149; phone or fax (03) 807 1263. Here are the options available:

PV1: PCB only	$45.00
PV2: PCB and components	$289.00
PV3: Toriodal transformer	$85.00
PV4: Alps volume, balance pots	$49.00
PV5: Complete Preamplifier Kit	$649.00
PV6: Preamp fully assembled, tested and guaranteed*	$849.00
PV7: EA Preamp articles, parts 1&2	$10.00

Enhanced components can be added, please call for prices as there are many options. (* Parts and labour are guaranteed for two years.)

Note that some parts used in the preamp may be subject to change; if alternatives must be used, constructors will be notified. ❖