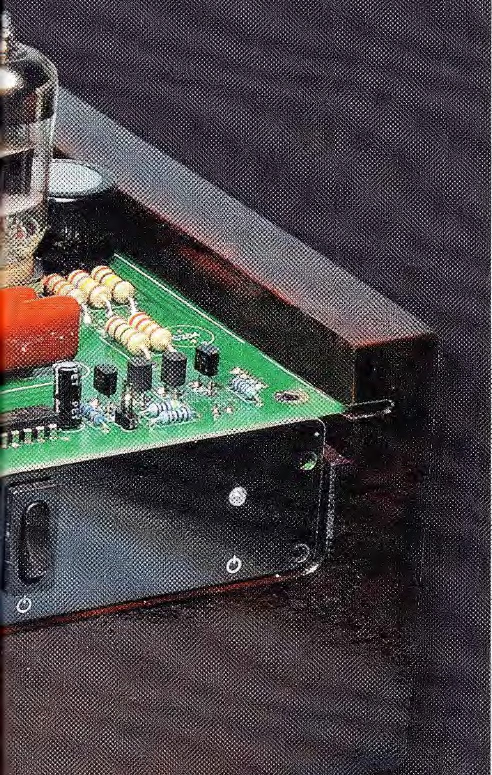
The Curraw

2 x 10W Stereo Valve Ampl

The Currawong amplifier is a tried and tested valve amplifier circuit which has been adapted to components which are readily available in 2014. Each channel uses two 12AX7 twin triodes for the preamp and phase splitter stages and two 6L6 beam power tetrodes in the class-AB ultra-linear output stage. It performs very well, with low distortion and noise.

This progress view of the amplifier shows it sitting in its timber plinth but without the protective Perspex covers in place to protect the PCB and protect the user from high voltages.



By Nicholas Vinen

...ong ...ifier, Pt.1

- **10W per channel**
- **Low distortion**
- **Good performance**
- **Easy to build**

IN DESIGNING this amplifier, we wanted to present a unit which is straightforward to build and which has a good appearance. To satisfy the first requirement, most of the circuitry, with the exception of the power transformers, is mounted on a large double-sided PCB. Hence there is no need for point-to-point wiring from valve sockets, tag-strips, tag-boards or any of that stuff from 60 years ago.

Using the large PCB also means that we have avoided the need for an expensive metal chassis. Instead, the PCB slides into a timber plinth stained as rosewood (although you can have any timber finish you desire). As a nice finishing touch, most of the PCB will be covered and protected by a Perspex cover. This will prevent little fingers from touching any part of the circuit and remove any risk of electric shock which would otherwise be possible. We hope you will like the appearance.

There are two toroidal power transformers used to power the Currawong and these are concealed underneath the PCB, towards the back of the unit.

Control panel

At the front of the timber plinth, there is a small control panel suspended below the main PCB. This carries the volume control, the on/off switch, a bi-colour red/green LED, a blue LED and the headphone socket. And while it might seem like a waste to use the Currawong Stereo Valve Amplifier to drive headphones, we know from long experience that readers will definitely want this feature.

By the way, the red/green LED comes into play when you first turn the amplifier on. There is an initial delay while the valves heat up and during this time, no HT (high tension or high voltage) is applied to the plates of the valves which could otherwise suffer damage in the long term. So during this delay, the LED is red. Then, when the HT is applied, the LED changes colour to green, indicating that normal operation is possible.

The other LED is lit when the headphones are in use. Plugging into the headphone socket enables a relay which disconnects the loudspeakers and connects the headphones via 220Ω resistors.

At the rear of the timber plinth is another panel which accommodates the RCA input sockets, the binding post terminals for the loudspeakers and a fused IEC socket for the mains cord. Both the front and rear panels are made from PCB material to provide a high-quality finish.

The overall performance is summarised in an accompanying panel and three graphs. It gives very good performance for a valve amplifier.

Circuit concept

A major difficulty in the design of the Currawong has involved the output transformers. As valve aficionados will be aware, the output transformer is usually the most expensive component in the circuit, apart from the valves themselves. Similarly, these days the power transformer is also very expensive, simply because there is no locally available off-the-shelf unit which can be pressed into service.

Yes, you can purchase imported power and output transformers but if we had specified these, the total cost of the amplifier would have been a great deal higher. Instead, we have taken a very unusual approach in selecting the output transformer by employing a standard off-the-shelf 15W line transformer (Altronics M1115) which would normally be employed with a professional solid-state PA amplifier to drive 100V lines.

As a line driver, the transformer's primary winding is driven by a solid-state amplifier and it steps up the voltage in its multi-tapped secondary winding. In the Currawong though, we drive the transformers back to front, with the push-pull valve output stages driving the 100V windings and the primary windings becoming the low-impedance drive for the loudspeakers. Conveniently, the 100V winding has a centre-tap, which is necessary for push-pull operation. In addition, we use some of the other taps for the "ultra-linear" connection.

Make no mistake though; while these are low-cost transformers (being made in large quantities), they have grain-oriented steel cores, a wide frequency response and low harmonic distortion. Better still, the taps on the primary winding enable it to be connected for ultra-linear push-pull operation. On the other hand, selection of this transformer is one of the two limiting factors in the maximum output power of the Currawong, at close to 10 watts per channel.

The other factor is the power transformer selection. We would have ide-

Features & Specifications

- **Channels:** 2 (stereo)
- **Valve line-up:** 4 x 12AX7 twin triodes, 4 x 6L6 beam power tetrodes
- **HT supply:** ~310V, actively filtered
- **Tested load impedances:** 4Ω, 6Ω, 8Ω
- **Output power:** 2 x 10W (8Ω, 6Ω), 2 x 9W (4Ω) (see Fig.3)
- **Operating mode:** Class-A (8Ω), Class-A/AB (6Ω, 4Ω)
- **Input sensitivity:** ~1V RMS (8Ω, with feedback enabled)
- **Signal-to-noise ratio:** 77dB
- **Channel separation:** >60dB, 20Hz-20kHz (4Ω, 6Ω & 8Ω)
- **Harmonic distortion:** typically <0.1%, 6Ω & 8Ω (see Figs.3&4)
- **Frequency response:** ±0.6dB, 30Hz-20kHz (see Fig.5)
- **Damping factor:** >20 (8Ω), >10 (4Ω)
- **Mains power draw:** typically 120-130W
- **Other features:** ultra-linear outputs, remote volume control option, delayed HT, HT soft-start
- **Dimensions:** 294 x 304 x 186mm (W x D x H) including protrusions

ally liked to use a transformer with much higher secondary voltages but a specially-designed power transformer would be much larger and more expensive, as already noted. Having said that, there is future potential for this amplifier to be upgraded with better (more expensive) transformers to enable it to deliver substantially more output power.

The valves can be replaced without any disassembly. Their sockets are mechanically mounted to the thick (2mm) PCB to prevent the solder joints from breaking loose during valve removal or insertion. The thick PCB also helps to support the relatively high weight of the output transformers, which are mounted on the board for ease of construction.

Temperature-sensitive components such as electrolytic capacitors have been kept away from the high-dissipation components, primarily the 6L6 valves and associated 5W cathode resistors. However, due to the compact size we have not been 100% successful; one of the large filter capacitors is near the output valves. Checks of its temperature during extended operation show that direct heat transfer is minimal and should not be a problem.

Semiconductors

There are some semiconductor components in this circuit but not in the audio signal path. Mostly, these perform power supply filtering, to get rid of ripple and keep the amplifier quiet. The HT delay and soft-start circuit is also built using solid-state components.

We should acknowledge considerable input to the design of this amplifier from Allan Linton-Smith, the designer of the Majestic loudspeaker system featured in the June and September 2014 issues. Allan built the first hard-wired prototype and the concept was then considerably refined and transferred to the final PCB featured in these pages.

Allan also suggested using the Altronics line transformers, based on a discovery by Grant Wills that they could be used as cheap and effective ultra-linear valve output transformers – see http://home.alphalink.com.au/~cambie/6AN8amp/Grant_Wills_6CM5amp.htm

Circuit description

Fig.1 only shows the circuit for the left channel signal path. The right channel is identical and the corresponding component numbers are provided in blue.

The line-level input signal from RCA socket CON1 has a 1MΩ DC bias resistor to ground, in case the signal source is floating. The signal then passes through an RF-rejecting low-pass filter comprising a 120Ω series resistor and 100pF ceramic capacitor.

The signal is then AC-coupled to (nominally) 20kΩ logarithmic volume-control potentiometer VR1 by a 1.5µF MKT capacitor. This gives a -3dB low-end roll-off at 5Hz. Note that depending on part availability, a motorised potentiometer with a value as low as 5kΩ may be used, in which case the -3dB point rises to 21Hz.

The wiper terminal of VR1 is connected to ground via a 1MΩ resistor so that if it briefly goes open circuit during volume changes, the grid of V1a does not float. The signal is fed to this grid via a 22kΩ RF stopper resistor.

V1a and V1b form the preamplifier, which is very similar to Jim Rowe's design from the February 2004 issue of SILICON CHIP ("Using The Valve Preamp In A HiFi System"). Essentially, this consists of two common cathode amplifier stages in series, with negative feedback around both.

V1's plates are fed from a filtered HT rail of around 224V DC, somewhat less than the 308V DC main HT rail due to voltage drops across the two RC filter resistors (6.8kΩ and 47kΩ). These filters reduce coupling between channels, reduce coupling from the output stage to the preamp stages and minimise supply ripple reaching the preamp. The preamp is the most noise-sensitive section as the signal level is lowest here.

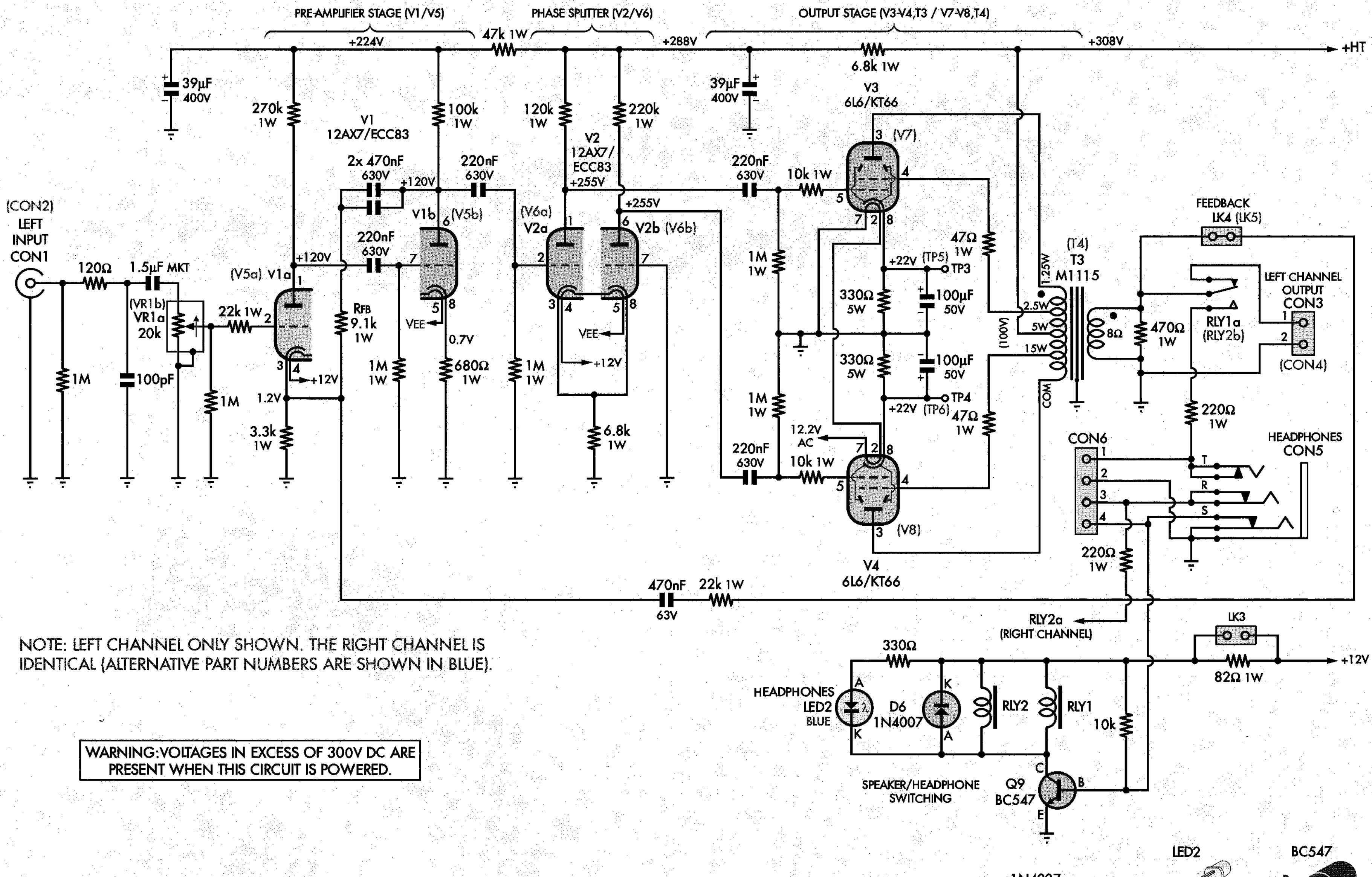
In fact, because hum can be picked up from AC-powered heater filaments, we are running the 12AX7 filaments from regulated 12V DC.

Self biasing

All valves in the circuit are self-biased. V1a's anode runs at around 120V, ie, 224V minus the drop across the 270kΩ resistor. With zero bias, a 12AX7 will conduct around 3mA at this voltage, dropping to near-zero with a grid-cathode bias of around -2.2V. With a 3.3kΩ cathode resistor, V1a's operating point tends to settle at about 0.3mA and thus the cathode is 1.2V above ground.

The output signal from V1a's anode is coupled to V1b's grid by a 220nF capacitor and this grid is DC biased using a 1MΩ resistor to ground. V1b runs at a higher power than V1a, with a 680Ω cathode resistor giving an operating current of around 1mA. Therefore, its anode load resistance is lower at 100kΩ.

The output at V1b's plate is coupled back to V1a's cathode via a pair of parallel 470nF polyester capacitors

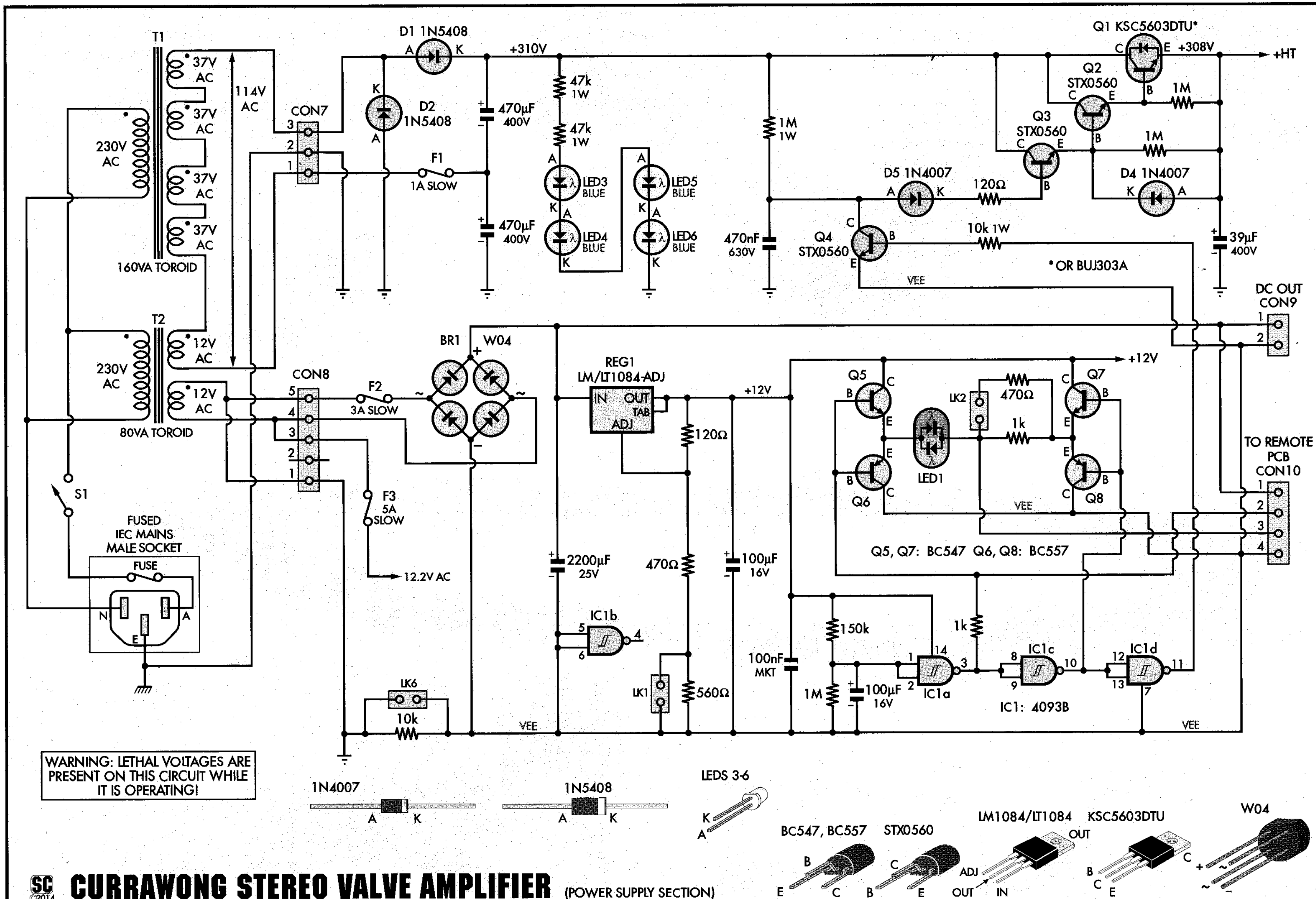


NOTE: LEFT CHANNEL ONLY SHOWN. THE RIGHT CHANNEL IS IDENTICAL (ALTERNATIVE PART NUMBERS ARE SHOWN IN BLUE).

WARNING: VOLTAGES IN EXCESS OF 300V DC ARE PRESENT WHEN THIS CIRCUIT IS POWERED.

SC ©2014 **CURRAWONG STEREO VALVE AMPLIFIER** (AMPLIFIER SECTION)

Fig.1: the left channel circuit of the Currawong Stereo Valve Amplifier (the right channel is identical). The incoming signal passes through a low-pass RC filter and volume pot VR1 and is then fed into V1 (a 12AX7 twin triode) which provides signal preamplification in two stages. Its output is then fed to V2 (another 12AX7 twin triode) which operates as a phase splitter and gain stage to drive push-pull output pair V3 & V4 (both 6L6 or KT66 tetrodes). Output transformer T3 has tapped connections to the output valve screens for ultra-linear operation. The transformer output is switched to either the speaker terminals (via CON3) or to the headphone socket by relay RLY1.



CURRAWONG STEREO VALVE AMPLIFIER (POWER SUPPLY SECTION)

Fig.2: the secondaries of toroidal power transformers T1 and T2 are connected in series and rectified using a voltage doubler to produce a 310V HT rail. Most of the ripple is filtered out by a capacitance multiplier comprising high-voltage transistors Q1-Q3 and a 470nF polyester capacitor. T2's remaining 12VAC secondary drives the 6L6 filaments directly in a series/parallel configuration, while the 12AX7 filaments run from a regulated 12V rail produced by bridge rectifier BR1, a 2200µF filter capacitor and linear regulator REG1. IC1 provides an HT turn-on delay and soft start.

(ie, around 1μF) in series with a 9.1kΩ resistor. This sets the closed-loop gain of the preamp section at around 2.75, so that the following phase splitter receives around 3V RMS at maximum volume. Note, however, that there is also a feedback path from the amplifier's output, which we will cover later.

Phase splitter

The phase splitter is another 12AX7 twin triode, V2. The phase splitter provides some gain but its main job is to produce two similar drive signals with opposite phase for the grids of the push-pull output stage valves Signal is coupled to this phase splitter from V1b's anode via another 220nF polyester capacitor.

V2a operates as an inverter, to generate the out-of-phase drive signal. Like V1a and V1b, it is configured as a common-cathode amplifier. It runs from a higher HT rail of around 288V DC which comes from the first HT RC filter stage (6.8kΩ/39μF). Its grid is tied to ground by a 1MΩ resistor, with the voltage across the shared 6.8kΩ cathode resistor providing the required bias potential.

This resistor is shared with V2b (and both cathode currents flow through it). V2b's grid is connected straight to ground so when its cathode voltage increases, the grid-cathode bias voltage decreases. As such, when V2a's cathode current increases and its anode voltage drops, V2b's bias increases and thus V2b's anode/cathode current decreases, causing the voltage at its anode to rise.

So the signal at V2b's anode has the opposite phase to that at V2a's anode, ie, it is in phase with the signal from the preamp. The 220kΩ anode resistor value has been selected so that the two output signals have a similar swing and so that V2a and V2b both operate with as high an anode voltage as possible, to give maximum drive amplitude for the following stage.

These drive signals are applied to the grids of 6L6 output valves V3 & V4 via 220nF polyester capacitors. These grids are again tied to ground by 1MΩ resistors and there are 10kΩ series stopper resistors to prevent parasitic oscillation.

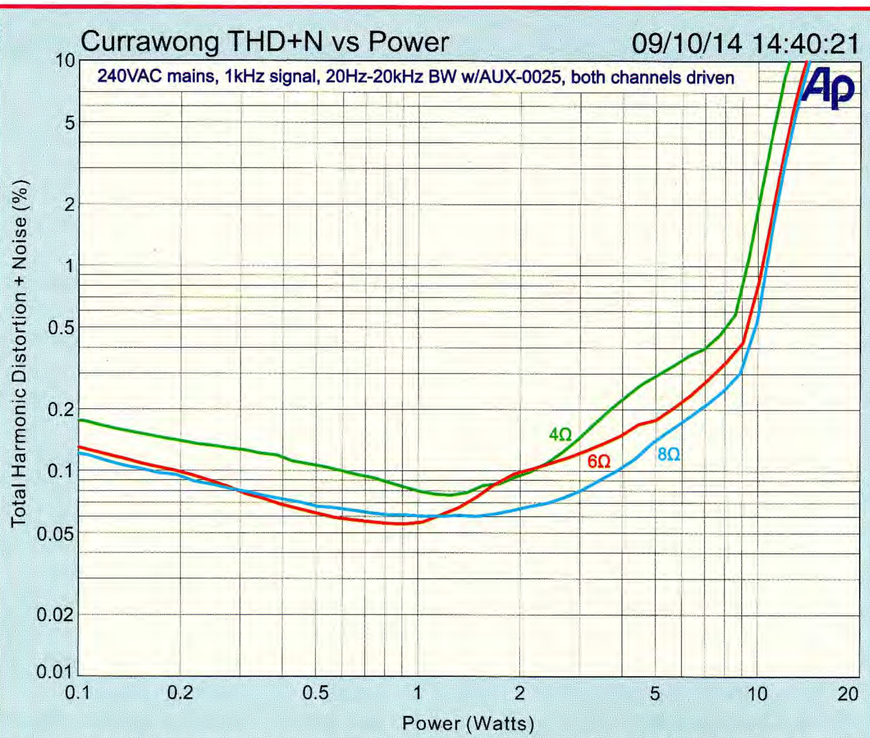


Fig.3: distortion versus power for a 1kHz sinewave into 4Ω, 6Ω and 8Ω load impedances. Again, both channels are driven for a realistic test. As you can see, distortion remains low at under 2W and then rises slowly until the onset of clipping at around 8-10W, depending on load impedance. The best power delivery is actually for 8Ω loads, with 6Ω being virtually identical and 4Ω being a little lower, clipping at around 9.5W/channel. This is partly due to output transformer drive impedance mismatch.

Output stage

V3 & V4 are self-biased using 330Ω 5W cathode resistors, with around 22V across each. This gives an operating current of about 65mA. Each output valve is powered from the main HT rail of around 308V, via the primary windings of T3, for a quiescent power of around 20W each.

Note that DC and AC currents flow in the two halves of the push-pull winding since both plates of the tetrodes are fed from the transformer centre-tap connection. However, the magnetic fields produced by these direct currents are cancelled, as they flow in opposite directions. This is important because otherwise the transformer would be magnetically saturated.

As the current split between V3 & V4 changes in response to the input signal however, an AC magnetic field is induced which is coupled into T3's secondary. The resultant voltage drives the speakers or headphones.

Since the output valve quiescent power of 20W is around twice the amplifier's power output of 10W per channel into 8Ω, this gives Class-A operation. With lower load impedances (for example, 4Ω), V3 or V4 may be fully cut off during signal peaks, giving Class-AB operation.

When the input signal swing is positive, pin 1 of V2a has a negative swing and so the current through V3 drops. At the same time, pin 6 of V2b has a positive swing and thus the current through V4 increases. This causes an increase in current flow from the top (dotted) side of T3's primary to the other, resulting in a positive swing at the dotted side of the secondary. Thus, the output of the amplifier is in phase with the input.

T3 also has taps approximately halfway between each end and the centre (HT) tap. These are connected to the screens of V3 & V4 via 47Ω stopper resistors, providing the ultra-linear connection mentioned earlier. This negative feedback from the transformer to V3 & V4 cancels out some of the transformer distortion. Note that while the feedback signals are high amplitude, the screen gain is much less than for signals applied to the grid, so the feedback doesn't overpower the drive signals.

Because the signal levels in the output stage are much higher and since 6L6 valves require much more filament

Parts List

Chassis/power supply
1 timber plinth with base (details to come)
1 top cover cut from 3mm clear acrylic (details to come)
1 small tube acrylic glue
1 front panel, code 01111142, 249 x 30mm
1 rear panel, code 01111143, 248 x 53mm
1 160VA 37+37+15+15V toroidal transformer (Altronics MC5337)
1 80VA 12+12V toroidal transformer (Altronics M5112)
4 screw-on 30mm equipment feet (Jaycar HP0830, Altronics H0890)
4 M4 x 15mm machine screws and nuts (for feet)
1 15mm anodised aluminium knob to suit VR1
1 snap-in fused IEC mains male socket for 1.6mm panels (Altronics P8325)
2 M205 250VAC 1A slow-blow fuses (one spare)
1 red chassis-mount RCA/RCA socket
1 white chassis-mount RCA/RCA socket
2 red RCA line plugs
2 white RCA line plugs
2 red binding posts (Jaycar PT0453, Altronics P9252)
2 black binding posts (Jaycar PT0461, Altronics P9254)
1 SPST ultra-mini rocker switch, 250VAC rated (Altronics S3202, Jaycar SK0975)
1 1m length 2-core mains flex
1 1m length 3-core mains flex
1 200mm length 3mm diameter black heatshrink tubing
1 200mm length 8mm diameter black heatshrink tubing
1 200mm length 20mm diameter black heatshrink tubing
1 1m length heavy duty red hook-up wire
1 1m length heavy duty black hook-up wire
1 1m length single-core shielded cable
1 1m length medium duty black hook-up wire
1 12-way screw terminal strip (Jaycar HM3194, Altronics P2135A)
6 M3 x 25mm Nylon screws and nuts
1 M4 x 6mm machine screw
2 M4 nuts
2 4mm ID shakeproof washers
1 4mm ID eyelet crimp connector
3 red 6.4mm crimp spade connectors
12 4G x 9mm self-tapping screws
10 small Nylon cable ties

Main board
1 double-sided PCB, code 01111141, 272 x 255mm
2 15W 100V line transformers (T1,T2) (Altronics M1115 – do not substitute)
2 5VDC coil 3A contact SPDT micro relays (RLY1,RLY2) (Altronics S4141B)
6 M205 fuse clips (F1-F3)
1 1A M205 slow-blow fuse (F1)
1 3A M205 slow-blow fuse (F2)
1 6A M205 slow-blow fuse (F3)
1 white vertical RCA socket (Altronics P0131) (CON1)
1 red vertical RCA socket (Altronics P0132) (CON2)
2 2-way vertical pluggable terminal blocks (CON3,CON4) (Jaycar HM3112+HM3122, Altronics P2512+P2532)
1 PCB-mount switched 6.35mm stereo jack socket with long pins (CON5) (Jaycar PS0190)
1 3-way vertical pluggable terminal block (CON7) (Jaycar HM3113+HM3123, Altronics P2513+P2533)
1 5-way vertical pluggable terminal block (CON8) (Altronics P2515+P2535)
4 chassis-mount phenolic 9-pin valve sockets with bracket (V1,V2,V5,V6) (Jaycar PS2082)
4 chassis-mount ceramic 8-pin valve sockets with bracket (V3,V4,V7,V8) (Altronics P8501)
6 2-way pin headers, 2.54mm pitch (LK1-LK6)
2 shorting blocks (LK4-LK5)
1 5-50kΩ 16mm dual gang log pot* (VR1)
2 6073B-type mini flag heatsinks
4 M4 x 10mm machine screws
4 M4 shakeproof washers
4 M4 nuts
8 M3 x 15-16mm machine screws
10 M3 x 10mm machine screws
12 M3 shakeproof washers
12 M3 nuts

current than 12AX7s, we run the filaments of V3 & V4 (and V7/V8) from 6.1V AC, slightly shy of the nominal 6.3V, due to compromises made in power transformer selection. It still works fine; it just takes a little longer for the valves to reach full emission after switch-on.

Speaker connections & feedback

A 470Ω 1W resistor across T3's secondary ensures that there is some load even if there is no speaker connected. This is necessary because operating a push-pull transformer-coupled amplifier with no load can lead to very high AC voltages at the valve plates and subsequent flash-over in the valve sockets.

T3's secondary connects to the speaker terminals via the normally closed contacts of RLY1 and pluggable terminal block CON3.

RLY1 is energised if headphones are plugged into the front panel socket, disconnecting the speaker and redirecting the signal to headphone socket CON5 via a 220Ω resistor.

If LK4 is fitted (and we recommend that it is), feedback is applied from T3's secondary to V1a's cathode via a 470nF capacitor and 22kΩ resistor. Since the output is in phase with the input, by applying some of the output signal to V1a's cathode, we effectively reduce the drive for V1a, giving about 14dB of negative feedback.

There is a limit to how much feedback can be applied in this manner due to the phase shift created by the inductance of T3. We have set the feedback to give as much distortion cancellation as possible, while keeping it stable with capacitive loads.

The circuit as presented is stable with several microfarads across the load, even when driving it with a square wave.

By the way, the 470nF capacitor in the feedback path is important as it damps shifts in valve bias in response to changes in mains voltages and valve temperatures.

With feedback enabled, input sensitivity is around 1V RMS. Typical CD/DVD/Blu-ray players produce around 2V RMS so this should be plenty in most circumstances. With LK4 re-

14 M3 Nylon nuts
22 3mm inner diameter Nylon flat washers
8 6.3mm M3 Nylon tapped spacers
2 TO-220 insulating washers and bushes
1 1m length medium duty blue hookup wire (250VAC rated)
1 1m length shielded audio cable
1 200mm length 3mm diameter blue heatshrink tubing
6 small green Nylon cable ties (maximum 2mm wide)
2 small blue Nylon cable ties
* *≥ 20kΩ recommended; substitute motorised pot for remote control option (see details in part two next month)*

Valves
4 12AX7 dual triodes (V1,V2, V5, V6)
4 6L6 beam tetrodes – matched pairs if possible (V3,V4, V7,V8)

Semiconductors
1 4093B quad NAND Schmitt trigger IC (IC1)
1 LM/LT1084-ADJ 5A adjustable low-dropout regulator (REG1)
1 KSC5603D 800V 3A high-gain NPN transistor (Q1)
3 STX0560 600V 1A NPN high-gain transistors (Q2-Q4)
3 BC547 100mA NPN transistors (Q5,Q7,Q9)
2 BC557 100mA PNP transistors (Q6,Q8)
1 red/green 2-lead bi-colour 3mm LED with diffused lens (LED1)
5 blue diffused lens 3mm LEDs (LED2-LED6)
1 W04 1.5A bridge rectifier (BR1)
2 1N5408 3A 1000V diodes (D1,D2)
3 1N4007 1A 1000V diodes (D4-D6)

Capacitors
1 2200µF 25V electrolytic
2 470µF 400V snap-in electrolytic
4 100µF 50V electrolytic
2 100µF 16V electrolytic
5 39µF 400V low-profile snap-in electrolytic (Nichicon LGJ2G390MELZ15) (Mouser)
2 1.5µF 63V MKT
5 470nF 630V polyester
2 470nF 63V MKT
8 220µF 630V polyester
1 100nF 63V MKT or 50V multi-layer ceramic
2 100pF ceramic disc

Resistors (1W, 5%)

9 1MΩ	2 9.1kΩ
2 270kΩ	4 6.8kΩ
2 220kΩ	2 3.3kΩ
2 120kΩ	2 680Ω
2 100kΩ	2 470Ω
6 47kΩ	2 220Ω
2 22kΩ	1 82Ω
5 10kΩ	4 47Ω
4 330Ω (5W, 10%)	

Resistors (0.25W, 1%)

7 1MΩ	1 560Ω
1 150kΩ	2 470Ω
2 10kΩ	1 330Ω
2 1kΩ	4 120Ω

moved, the overall gain is much higher and the input sensitivity is around 350mV RMS for full power. However, distortion rises to around 0.5% at 1kHz and >1% at lower frequencies.

Note that the 470nF series capacitors in the feedback network are important. These form high-pass filters in combination with the feedback resistors, with a -3dB point of around 15Hz. If DC feedback is used, the bias time constants in the circuit form a type of relaxation oscillator and the bias voltages never quite settle down, leading to asymmetric clipping and other undesirable behaviour.

Power supply

The separate power supply circuit is shown in Fig.2. All components, except the two power transformers T1 & T2, power switch S1 and the fused IEC mains socket, are on the main board.

There are three main power requirements for this circuit: the 310V HT rail, the ~12V DC filament supply for the 12AX7s (at around 1A) and ~6VAC for the 6L6 filaments, at around 4A. We also use the 12V DC rail to power various ancillary circuits, as described below.

All of T1's secondaries are connected in series, along with one of T2's secondaries, to produce 114VAC. T2's other secondary provides a little over 12VAC, to run the 6L6 filaments at around 6.1VAC each, in series pairs. The 12VAC is also rectified, filtered

Most of the parts except mainly the power transformers are mounted on a single large PCB to make the assembly easy. The optional remote volume control is built on a separate PCB.

and regulated to provide the 12V DC rail (actually about 12.3V DC), for the 12AX7 filaments and DC-powered circuitry.

The 114VAC from CON7 is rectified in a half-wave voltage doubler consisting of 1000V 3A diodes D1 & D2 and two 470μF 400V capacitors, giving about 310V across both capacitors with several volts of ripple. Fuse F1 provides some protection against faults.

There are two 47kΩ series-connected bleeder resistors to discharge the 470μF capacitors when power is removed. Four blue LEDs are connected in series with the two 47kΩ 1W resistors. The blue LEDs indicate the presence of HT and also illuminate output transformers T3 and T4 (very effective in a room with subdued lighting).

The output stage has no HT low-pass filter, unlike the preamplifier and phase splitters. So to prevent HT ripple in the output stage from affecting the signal, we are using an active ripple filter. This is a capacitance multiplier filter built around high-voltage, high-current transistor Q1, configured as an emitter-follower.

The traditional HT filter is a large iron-cored choke but these are heavy and expensive, not to mention hard to find these days. Our transistor-based method is more effective and cheaper.

Q1 is driven by Q2 and Q3 which are high-voltage high-gain signal transistors, in a "Triplington" configuration; it's like a Darlington but with an extra stage. The higher the gain in this buffer, the more effective the filter is. Base bias comes from an RC low-pass filter across the incoming HT rail, consisting of a 1MΩ resistor and 470nF polyester capacitor.

Q2 and Q3 have a gain of around 70-100 each while Q1 has a gain of around 30. So the overall gain is about 70 x 70 x 30 = 147,000 which multiplies the effect of the 470nF capacitor to act as if it is 69,000μF! In practice, it isn't quite as good as this as the 470nF capacitor discharges slightly through the three base-emitter junctions at the trough of each ripple cycle but despite this, the ripple at Q1's emitter is just a few hundred millivolts.

Q1 has an integral emitter-collector diode so that when the unit is switched off, the output filter capacitors can safely discharge back into the input filter capacitors without doing any damage. D4 protects Q2 while D5 provides similar protection for Q3 but also has a role in the start-up delay, which we'll explain later.

Note that this arrangement also results in HT "soft-start" as it takes a few hundred milliseconds for the 470nF capacitor to charge and the HT rail tracks this voltage.

Turn-on delay

We have also incorporated a 20-second (or so) turn-on delay, to allow the valve filaments to heat up before HT is applied. Part of the rationale for this is to prevent "cathode stripping" which can occur with cold cathodes, although the existence of this phenomenon is somewhat controversial. But since the valves aren't "ready" to operate immediately anyway, it certainly doesn't hurt to delay the application of HT.

IC1 is a quad Schmitt-input NAND gate which runs from the 12V rail and provides the turn-on delay. Note that ground for the 12V rail is labelled V_{EE} and will be close to, but not necessarily at, GND (0V).

IC1a is connected as an inverter with a 100µF capacitor from its input to ground. A 150kΩ resistor charges this capacitor from the 12V rail while a 1MΩ capacitor discharges it when power is switched off. It takes about 20 seconds for this capacitor to charge to a sufficient voltage for the output of IC1a to go low.

During this time, IC1a's output is high. This is inverted by IC1c and then again by IC1d, so Q4 (another 600V transistor) is switched on initially. This keeps the 470nF capacitor in the HT filter from charging until the delay has ended. Diode D5 in the HT filter prevents the base of Q3 from being pulled below GND when V_{EE} is (slightly) negative.

IC1a and IC1c also drive LED1 via two pairs of complementary emitter-followers (Q5-Q8). LED1 is a bi-colour device and consists of a red LED and green LED on the same die, connected in inverse parallel. Since inverter IC1c is between them, one inverter is always driving one end of LED1 high and the other is driving it low. Thus LED1 is red initially at turn-on and switches to green once the time-out period has expired and the HT rail is powered up.

A 1kΩ resistor sets the LED current to about 10mA while another 1kΩ resistor partially isolates the bases of Q5 & Q6 from IC1a's output. This allows the optional remote control board to independently drive LED1, in order to flash it to acknowledge infrared command reception. The remote control board connects via CON10 and will be described next month.

Low-voltage supplies

5-pin pluggable terminal block CON8 provides separate low-voltage AC connections for the 6L6 filaments (pins 1 & 3) and the regulated supply (pins 4 & 5). Each is fused on the board.

The PCB is slid into a slot that runs around the top inside edge of the timber plinth. Perspex covers will be used to protect the PCB and speaker transformers.

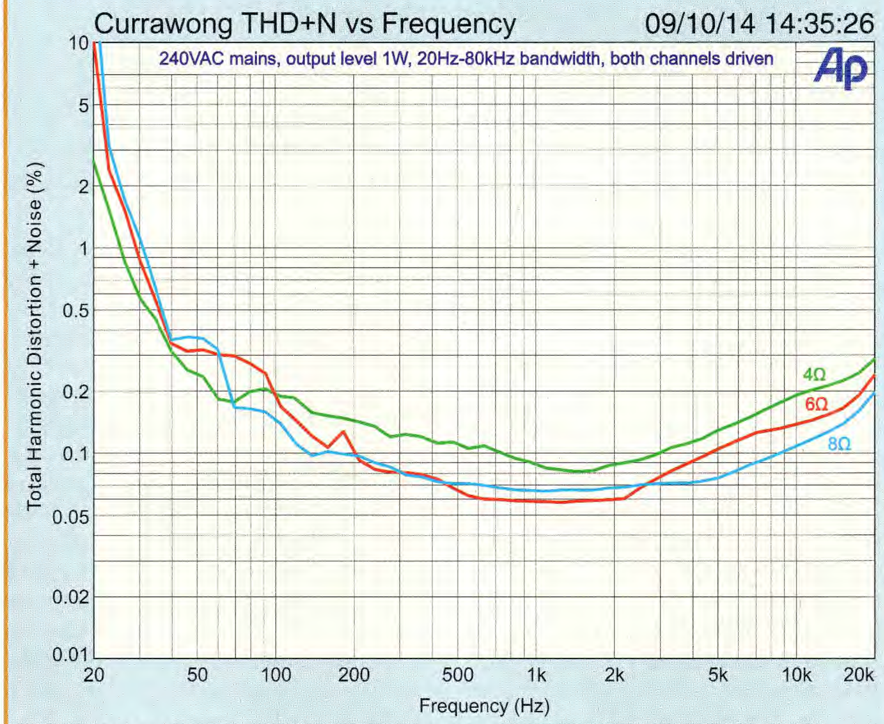


Fig.4: distortion versus frequency, with both channels driven at 1W into three different resistive loads. As you can see, the distortion is pretty low for a valve amplifier, especially between 100Hz and 10kHz. Below 100Hz, distortion rises steeply due primarily to the output transformer's non-linear response. Distortion into lower impedances is only slightly worse than that for 8Ω. Note the 80kHz bandwidth used, to ensure that higher frequency harmonics are included in the measurements.

However, we ultimately decided to use one transformer winding to power both, hence they are wired in parallel despite the separate connections.

The 12VAC from pins 4 & 5 of CON8 is rectified by 1.5A bridge rectifier BR1 and filtered with a 2200µF capacitor to produce around 15-16V DC with

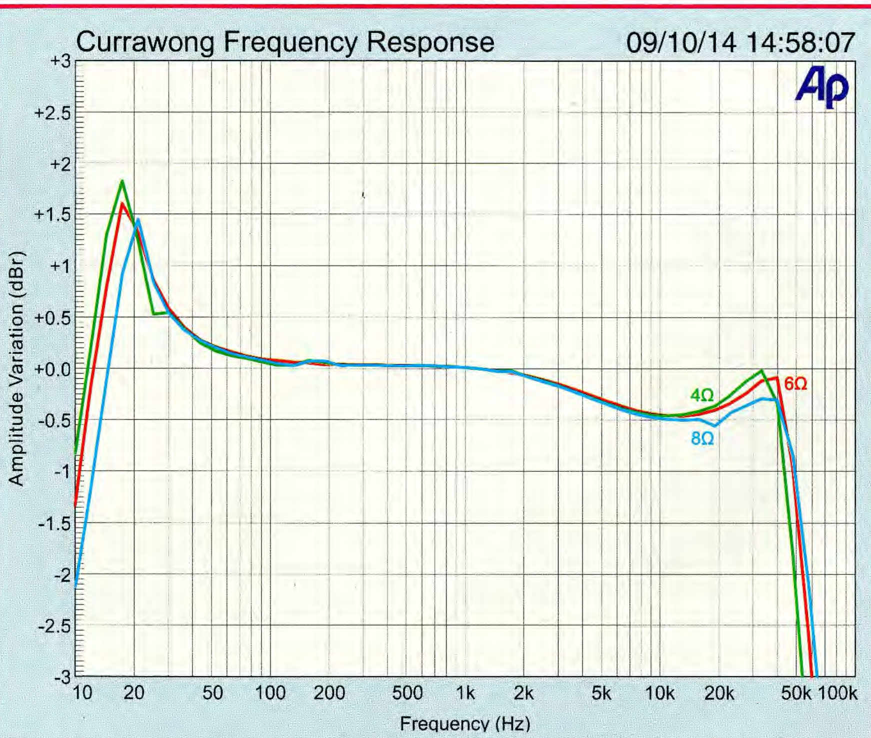


Fig.5: the frequency response is pretty flat in the audible range (note: the vertical scale is only ±3dB for the entire diagram). Roll-off at the high frequency end is -3dB at around 50kHz while the low-end -3dB point is below 10Hz. The peak at around 20Hz is partly due to the AC-coupled global feedback and partly due to greatly increased waveform distortion below about 30Hz due to the output transformers. However, the peak amplitude is only around +1.5dB and 20Hz signals are barely audible.

about 1V ripple. This is regulated to provide a nice smooth rail by REG1, a low-dropout, high-current equivalent to the LM317.

Pins 1 & 3 of CON8 connect straight to the series/parallel-connected 6L6 filaments and as a result, they get about 6.1VAC each. One end of this AC supply is grounded for noise immunity.

Now because of this ground connection and the fact that the same transformer secondary is used to feed BR1, the negative end of BR1 actually floats between about +0.7V and -15V. Hence, the need to disconnect V_{EE} from GND. If two separate 12V transformers or windings were used, LK6 could be fitted and thus V_{EE} would be at the same potential as GND. **LK6 must not be fitted with the supply arrangement shown here!**

The circuit will work the same regardless as to whether V_{EE} is connected to GND, as Q4 is the only connection between the two supply "domains".

The DC supply is also used to power relays RLY1 and RLY2 when headphones are plugged in. These are 5V relays, so an 82Ω series resistor drops the 12V DC to an appropriate voltage. LED2 is also connected across the relay coils, in series with a 330Ω current-limiting resistor, to indicate when the speakers are disconnected.

Unused linking options

Note that the supply was also designed to operate with the regulated rail at 6V DC rather than 12V. This would require a different transformer (ie, 6VAC rather than 12VAC) and the option was provided as there are some 12AX7-compatible valves with 6.3V-only filaments (rather than the typical arrangement with a 12.6V centre-tapped filament).

However, given the relative rarity of these valves, we aren't going to go into details as to how to reconfigure the supply except to say that LK1-LK3 are fitted for this purpose. Normally, they are left out.

PCB layout

We wanted to put as many parts on the PCB as possible to make this amplifier easy to build. Soldering parts to a PCB is certainly a lot easier than point-to-point wiring! It minimises the chances of mistakes and also means that performance will be consistent between amplifiers.

The PCB layout was a bit tricky though, due to the voltages involved. We have kept tracks with voltages that may differ by over 60V apart by 2.54mm to prevent arcing, while in other areas low-voltage tracks need to be closer together so they can fit. We also used "star" earthing as much as possible to avoid hum and ripple injection into the preamp stages. Most of the grounds on the board converge on the main power supply filter capacitor negative pin.

The board has been designed with plated slots for the valve socket pins so that they fit snugly and neatly.

All connectors have been placed along the back of the board, on the underside, to keep the chassis wiring neat. The input signals run from the back of the board to the front (where the volume pot is mounted) through shielded cables that are strapped to the underside of the board, to prevent the low-level input signals from picking up ripple, hum and buzz.

We have also used low-profile components where possible, so that a clear perspex shield can be fitted over the top, to prevent prying fingers from getting a shock, as mentioned earlier. The valves, main filter capacitors and output transformers will pass through cut-outs in this shield, with perspex boxes around the transformers. The rest of the components will be safely underneath.

Warning!

Note: parts of this circuit operate at over 300V DC. Do not touch any components or any part of the PCB while the unit is operating or immediately after switch off. The blue LEDs in the circuit indicate when dangerous voltages are present.

Next month

That's all we have room for this month. Over the next couple of months we will present the main PCB layout diagram, describe the assembly procedure, explain how to build the plinth and finish the wiring. We'll also go through the testing and troubleshooting procedure and describe the optional infrared remote control which uses a motorised potentiometer. SC

By Nicholas Vinen

The Currawong Stereo 10W Valve Amplifier, Pt.2

In Pt.1 last month, we described the circuit and presentation of our new Currawong stereo valve amplifier. We now describe the PCB assembly and detail the timber plinth and chassis wiring along with detailed instructions on putting it all together.

MOST OF THE parts for the Currawong are mounted on a single large PCB. This then slides into a slot near the top of a timber plinth, with the remaining components – primarily the two large power transformers – underneath the PCB and attached to the plywood or MDF base.

The front panel carries the headphone socket, volume control, power switch and status LEDs. The input connectors, loudspeaker terminals and power socket are mounted on the rear panel which is recessed into a cut-out in the rear of the plinth.

So let's start putting the main PCB together, which is a significant part of the work involved in building the Currawong.

PCB assembly

Start the PCB assembly with reference to overlay diagram Fig.6. The board is coded 01111141 and measures 272 x 255mm. It's 2mm thick, which makes it more rigid and stronger than typical 1.6mm laminate.

Start by fitting the smaller resistors. The colour-coded stripes on small resistors aren't always distinct so it's best to check each value with a DMM. Use the lead off-cuts to make the two wire links (next to LK4 and LK5).

Follow with the three 1N4007 diodes (D4-D6), in the top corners of the board, with the striped cathode ends towards the right or bottom of the PCB as shown. IC1 can go in next – there's no need for a socket. Check that its pin 1 notch/dot is towards the left side of the board before soldering it.

Then fit all the 1W resistors. Their colour codes are usually clear however it doesn't hurt to measure them to be sure. None of these run hot so they

This view shows the completed PCB assembly for the prototype amplifier, with the front-panel fitted. It's housed in a timber plinth and fitted with Perspex covers to protect the user from high voltages.

can be mounted in contact with the PCB. You may find it difficult to get the specified 9.1kΩ 1W resistors, so 8.2kΩ resistors can be used instead with only a minor impact on performance (don't use 10kΩ as this may prejudice overall stability).

The two large 1N5408 power diodes are next, with both cathode stripes facing the bottom of the board. These will get a little warm so we recommend spacing them about 5mm off the board (eg, using a 5mm-wide strip of cardboard as a temporary spacer). The W04 bridge rectifier can also go in now; again it's a good idea to space it off the board a little.

Next, fit blue LEDs3-6. These have a dual purpose: to indicate the presence of HT and to illuminate the transformers. They also form part of the HT bleeder circuit so must not be left out (if you must omit them, use wire links in their place). Angle each one back so that it will shine on either T3 (LED5, LED6) or T4 (LED3, LED4) and make sure the longer anode leads go through the holes closer to the righthand side of the board.

Now you can mount all the TO-92 package small signal transistors, ie, Q2-Q9. Don't get the three different types mixed up. Follow with the six fuse clips. Check that the fuse retention lugs are on the outside before soldering the clip in place, otherwise you will not be able to fit the fuses. Also make sure that they are pushed all the way down onto the PCB before soldering them in place.

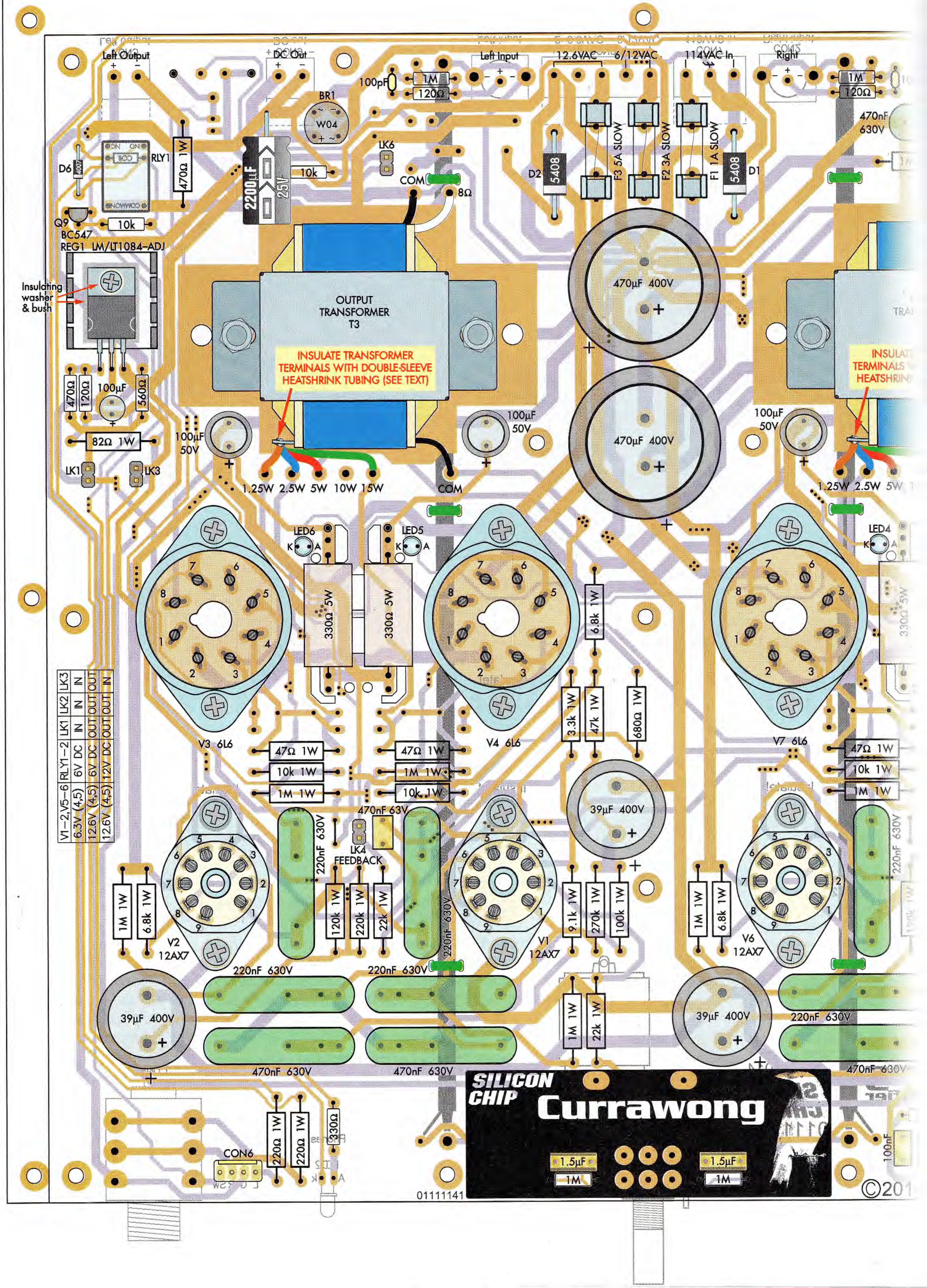
Next on the list are transistor Q1 and linear regulator REG1. These are both fitted with small heatsinks and it's important that the heatsinks are isolated from the device tabs using

WARNING! HIGH VOLTAGES

High AC and DC voltages are present in this circuit. In particular, mains voltages (230VAC) are present on the IEC socket and the primary side of the mains transformers (including the wiring to the power switch). In addition, the transformer secondaries together provide a 114VAC output and the power supply produces an HT voltage in excess of 300V DC which is present on various parts of the amplifier circuit (including the output transformers).

Do not touch any part of the amplifier or power supply circuitry when power is applied otherwise you could get a severe or even fatal electric shock.

The blue LEDs in the circuit indicate when high voltages are present. If they are lit, the power supply and various parts on amplifier board are potentially dangerous. **The completed amplifier must be fitted with Perspex covers as described in Pt.3 next month to ensure safety.**



Left Output
DC Out
Left Input
12.6VAC
6/12VAC
114VAC In
Right
100pF
1M
120Ω
BR1
W04
LK6
10k
2200µF 25V
COM
8Ω
D6
4007
RLY1
470Ω 1W
Q9
BC547
REG1 LM/LT1084-ADJ
Insulating washer & bush
OUTPUT TRANSFORMER T3
INSULATE TRANSFORMER TERMINALS WITH DOUBLE-SLEEVE HEATSHRINK TUBING (SEE TEXT)
D2
5408
F3 5A SLOW
F2 3A SLOW
F1 1A SLOW
D1
470nF 630V
470µF 400V
470Ω
120Ω
100µF
560Ω
82Ω 1W
100µF 50V
LK1
LK3
1.25W 2.5W 5W 10W 15W
LED6
LED5
LED4
330Ω 5W
6.8k 1W
3.3k 1W
47k 1W
680Ω 1W
V3 6L6
V4 6L6
V7 6L6
47Ω 1W
10k 1W
1M 1W
470nF 63V
LK4 FEEDBACK
39µF 400V
220nF 630V
120k 1W
220k 1W
22k 1W
9.1k 1W
270k 1W
100k 1W
V2 12AX7
V1 12AX7
V6 12AX7
CON6
220Ω 1W
330Ω
SILICON CHIP
Currawong
1.5µF
100nF
01111141
©201
V1–2,V5–6 | RLY1–2 | LK1 | LK2 | LK3
6.3V (4,5) | 6V DC | IN | IN | IN
12.6V (4,5) | 6V DC | OUT | OUT | OUT
12.6V (4,5) | 12V DC | OUT | OUT | IN

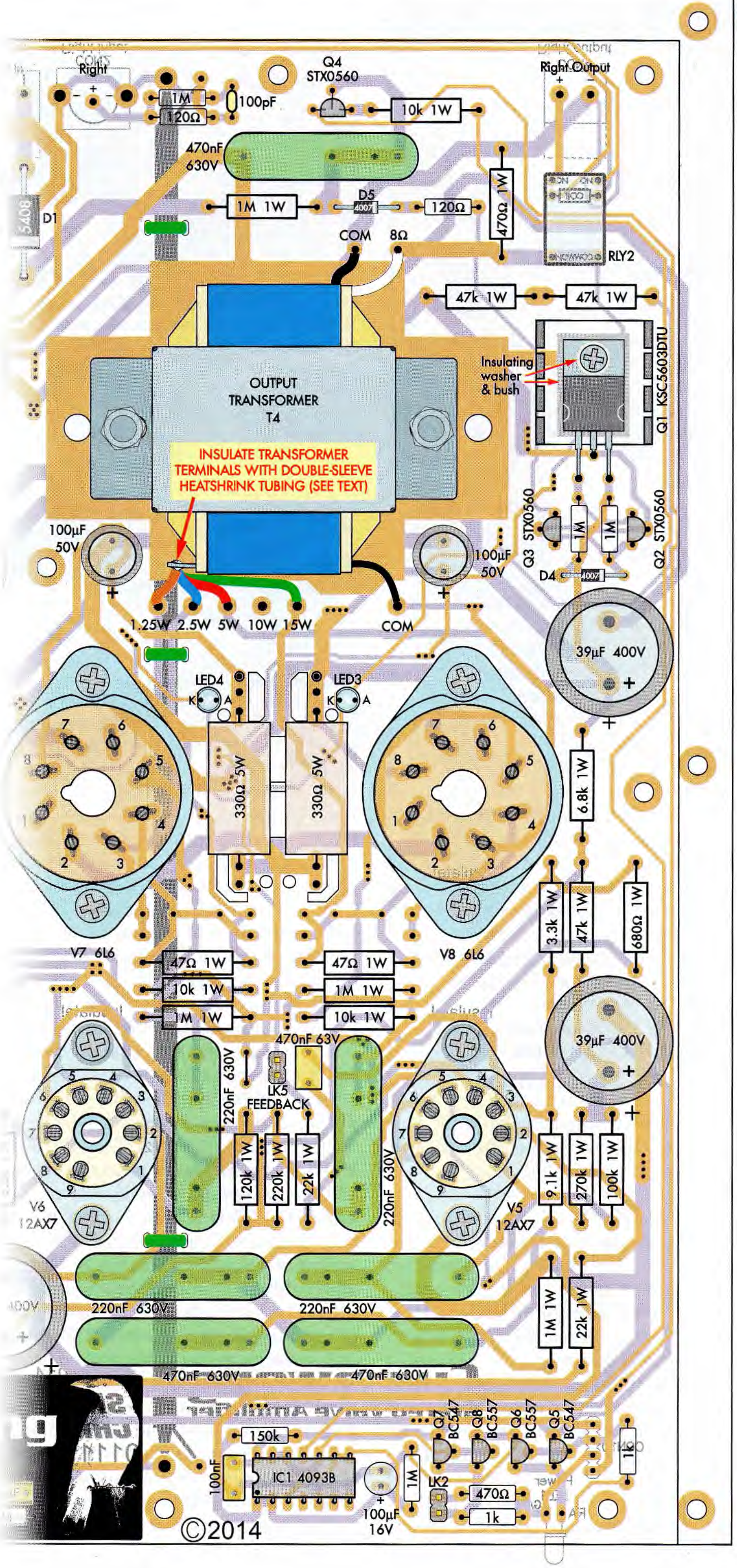


Fig.6: the parts layout on the top of the PCB. This diagram has been split and the righthand side partly duplicated where it meets the magazine gutter, for clarity. The text describes how the valve sockets are mounted; they must be mechanically secured before the pins are soldered. Note that D1, D2 and the 5W resistors should be stood off the board to allow air to circulate around them and don't forget to insulate Q1 & REG1 from their heatsinks.

insulating washers and bushes – see Fig.7. In each case, start by bending the leads of the TO-220 device so they fit through the pads on the board, with the tab hole lined up with the PCB mounting hole.

Note that Q1's centre lead is bent closer to the package than the other two (due to the high voltage between the pins) but this is not the case for REG1.

To mount each device, place an insulating bush in the tab hole, then feed an M3 x 10mm machine screw through from the top. Slip an insulating washer under the device, over the screw thread, then slide the heatsink on from underneath. Drop this assembly onto the PCB, ensuring all pins go through their respective holes, then use a shakeproof washer and M3 nut to hold it in place.

In each case, ensure the heatsink and insulating washer are straight before tightening the nut fully, then solder the leads. That done, fit the two relays, making sure they are nice and flat on the PCB before soldering more than two pins.

Now it is time to install the ceramic capacitors, followed by the MKT (metallised polyester) capacitors, in increasing order of height. Follow with the six pin headers for LK1-LK6. Try to solder these flat on the board and neatly aligned with the edges of the board for best appearance.

You can then bend the leads of the

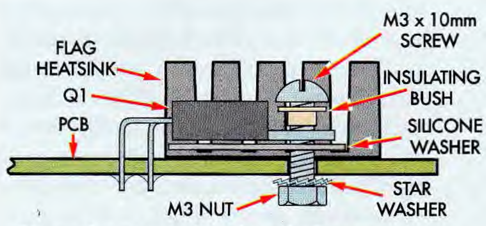


Fig.7: the mounting details for transistor Q1 and regulator REG1. In each case, the device tab must be isolated from the heatsink using a silicone insulating washer and insulating bush.

Parts List

Since publishing Pt.1 last month, we've made a few small changes to the chassis arrangement and this affects the list of parts required. Please note the following changes:

Main board

(1) Delete vertical RCA sockets for CON1 & CON2; add short stereo RCA-RCA lead

(2) 2 x 8.2kΩ 1W resistors can be used instead of the 2 x 9.1kΩ 1W resistors listed

Revised chassis parts

1 timber plinth with base (see text)
1 top cover cut from 3mm clear acrylic (details to come)
1 small tube acrylic glue
1 front panel, code 01111142, 249 x 30mm
1 rear panel, code 01111143, 248 x 53mm
1 160VA 37+37+15+15V toroidal transformer (Altronics MC5337)
1 80VA 12+12V toroidal transformer (Altronics M5112)
4 screw-on 50mm equipment feet (Jaycar HP0832)
1 15mm anodised aluminium knob to suit VR1
1 snap-in fused IEC mains male socket for 1.6mm panels (Altronics P8325)
2 M205 250VAC 1A slow-blow fuses (one spare)
1 red chassis-mount RCA/RCA socket
1 white chassis-mount RCA/RCA socket
2 red binding posts (Jaycar PT0453, Altronics P9252)
2 black binding posts (Jaycar PT0461, Altronics P9254)
1 SPST ultra-mini rocker switch, 250VAC rated (Altronics S3202, Jaycar SK0975)
1 1m length 2-core mains flex
1 1m length 3-core mains flex
1 200mm length 3mm diameter black heatshrink tubing
1 1m length 5mm diameter clear heatshrink tubing
1 200mm length 20mm diameter black heatshrink tubing
1 50mm length 50mm diameter black heatshrink tubing or large insulating boot (Jaycar PM4016)
1 1m length heavy duty red hook-up wire
1 1m length heavy duty black hook-up wire
1 500mm length figure-8 speaker wire
1 12-way screw terminal strip (Jaycar HM3194, Altronics P2135A)
1 M4 x 10mm machine screw
2 M4 nuts and shakeproof washers
2 yellow 5.3mm ID eyelet crimp connectors
2 red 8.4mm ID eyelet crimp connectors
5 red 6.4mm insulated spade crimp connectors
4 solder lugs
1 5mm cable clamp (P-clamp)
12 black 4G x 12mm self-tapping screws
12 4G x 9mm self-tapping screws
1 4G x 6mm self-tapping screw
1 3mm ID flat washer
7 3mm ID spring washers
10 small Nylon cable ties

four 5W resistors to fit through their mounting holes. There are two pairs of holes for each; we used the inner pair but it isn't mandatory. As with the 1N5408 diodes, use a 5mm spacer to stand each resistor off the board. Keep them level and straight for a tidy result.

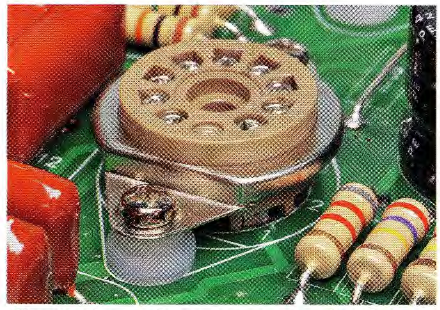
The 630V polyester capacitors can then be fitted. The PCB is designed with multiple pads for each capacitor, to suit different lead spacings. If you have an odd one, you may need to bend its leads out however most should drop straight in. Refer to Fig.6 to see which type goes where.

Now solder the smaller electrolytic capacitors in place, ie, the six 100µF types. In each case, ensure that the longer (positive) lead goes in the pad closer to the front edge of the board, as shown on Fig.6.

Valve sockets

The valve sockets are secured to the board before soldering, so the solder joints aren't under stress. The specified sockets have solder lugs and the board has been designed with slots to accommodate them.

Start with the smaller 9-pin sockets. Feed M3 x 10mm machine screws through the top mounting holes and tighten Nylon nuts on the underside. Slip two Nylon washers over each screw thread, then pass the screws down through the mounting holes on the board, guiding the solder lugs through the slots. If it won't go in, check that you have the right orientation as it will only fit one way.



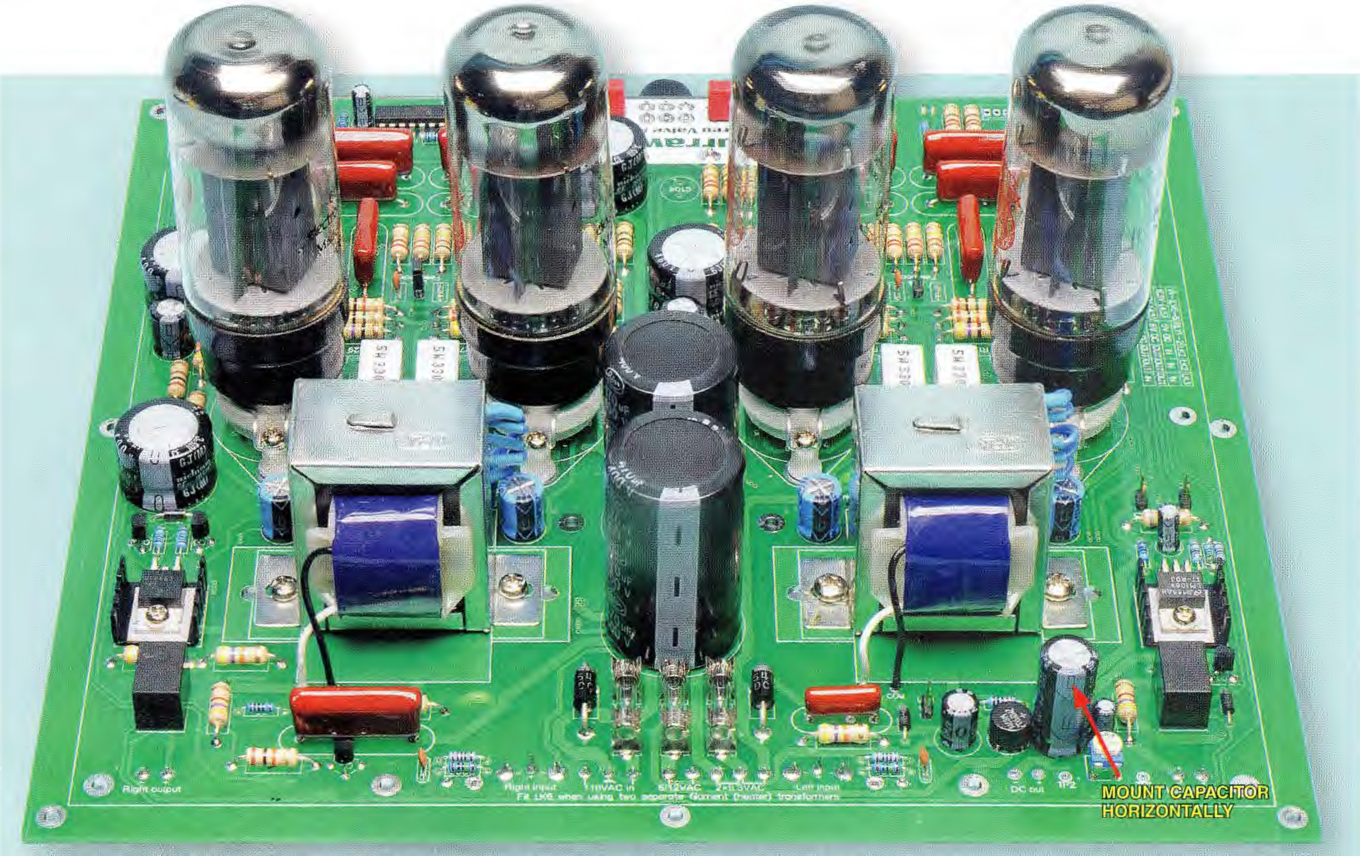
The 9-pin sockets are secured using M3 x 10mm machine screws, with a Nylon nut & two Nylon washers used as spacers at each mounting point.

This mock-up shows the final mounting arrangement used for the 8-pin sockets (it differs slightly from that used on the prototype). These sockets are secured using M3 x 15mm screws and M3 x 6.3mm tapped Nylon spacers.

You may need to put the solder lugs under a small amount of tension to get them to go through the slots, due to the way they are angled. But once they all line up it should slip into place and you can push the socket right down so it's sitting on the Nylon washers.

Use a shakeproof washer and M3 nut to secure the screw closest to the front (bottom) edge of the board. **Fit a Nylon washer and nut to the other (this is necessary to avoid shorts to adjacent PCB tracks) – see Fig.8.** Do both nuts up tightly, check that the socket is sitting level on the PCB and then solder the pins and repeat for the other three sockets. It isn't necessary to trim the solder lugs after soldering.

For the larger 8-pin sockets, the arrangement is similar but their mounting brackets are supplied separately. Take a bracket and feed M3 x 15mm machine screws through the top of the mounting yokes (see photos), then loosely screw M3 x 6.3mm Nylon tapped spacers on, just tightly enough



Another view of the completed PCB assembly, this time taken from the rear. Check the board carefully after assembly to ensure that all polarised parts are correctly orientated. Note that the 2200µF capacitor indicated by the red arrow must be mounted horizontally (ie, on its side) as shown in Fig.6, not vertically as shown here.

so that the screws stay in place.

Now position this assembly over the PCB and adjust the spacing so that the two screws are equally far from the centre of the mounting bracket and they pass through the appropriate holes on the PCB. You can then remove the bracket and drop the socket in place. Some "jockeying" may be required but it should fit easily once you get all the pins lined up.

These sockets can be installed with eight different orientations but only one is correct. The notch in the central hole must face towards the lefthand side of the PCB. If you solder one incorrectly, it will be difficult, if not impossible to remove (see Fig.6).

With the socket pushed down onto the PCB and orientated correctly, slip the bracket on top and secure it in position with shakeproof washers and M3 nuts. **Note though that for valves V4 and V8, the mounting screw closest to the front (bottom) edge of the board must be secured with a Nylon washer and Nylon nut instead.**

Do both mounting nuts and screws up tightly, then re-check the socket orientation before soldering the eight lugs. Repeat for the other three sockets.

With all the sockets in place, fit the five low-profile 39µF 400V snap-in capacitors, again with their positive terminals towards the front (bottom) of the board. These should be pushed all the way down before soldering.

The 2200µF capacitor can now go in however it must be laid over towards transformer T3 or else the top cover will not fit later. There should be sufficient room for it to sit flat on its side on the PCB. Like the others, it is polarised and the negative stripe should face up.

You can then fit the two large 400V capacitors between T3 and T4. Double-check their orientation before soldering the leads and they too should sit right down on the board; if they aren't perfectly vertical, they may not later fit through their corresponding holes in the top cover.

Output transformers

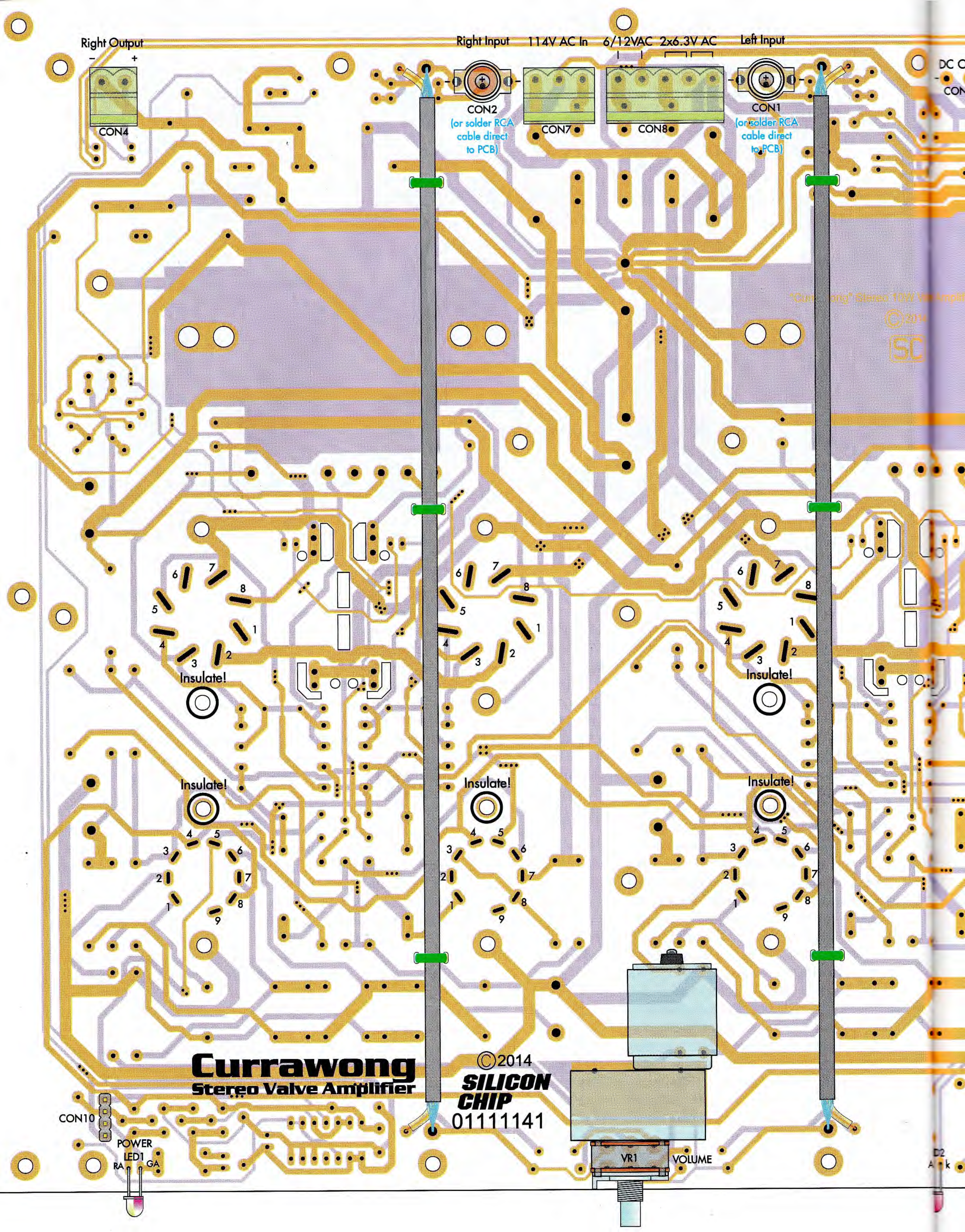
The 15W 100V line transformers (T3 & T4) come fitted with a terminal block on top and stickers indicating the taps. We removed these as we felt it improved the appearance. The stickers can be peeled off and the glue residue gently cleaned off using an appropriate solvent. Methylated spirits or isopropyl alcohol are good choices are they are unlikely to damage the transformer but try not to soak it.

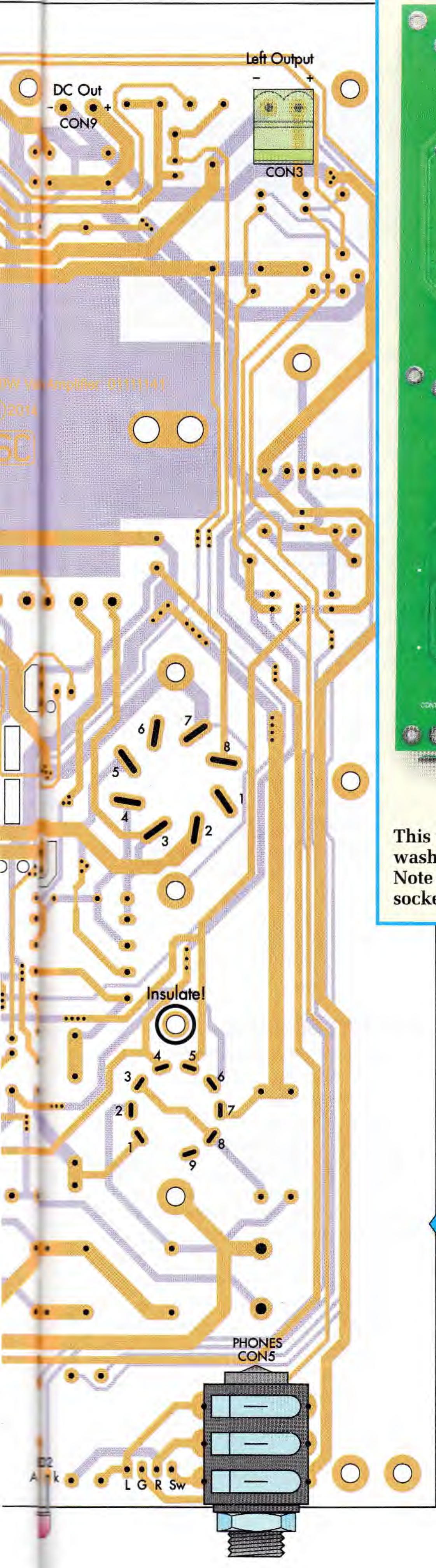
The terminal blocks can be simply pulled off although they're a tight fit and you may need to use pliers. The metal tab used to hold it in place is then bent down.

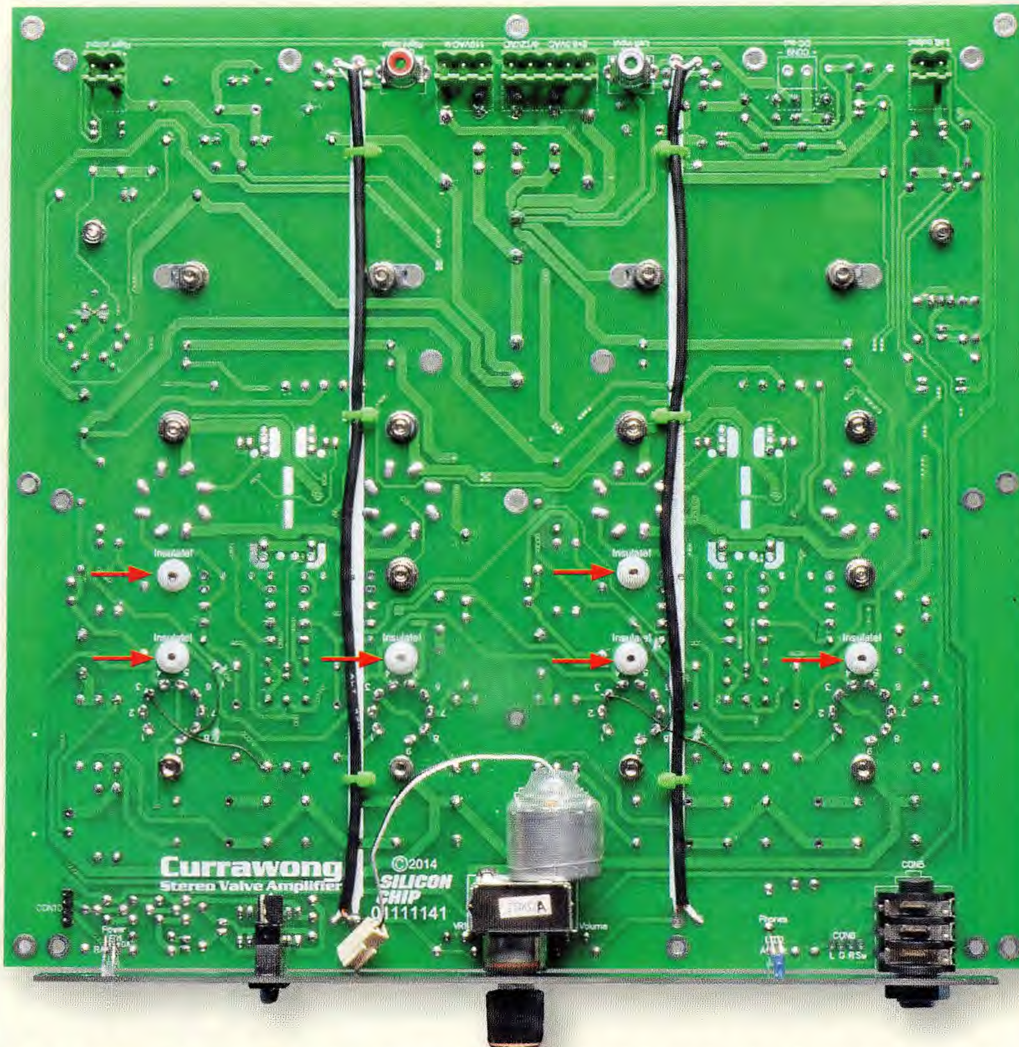
The next job is to cut, solder and insulate four or five wires to the winding tap lugs. The 10W winding is not connected on the PCB so you don't have to wire it up but we did anyway, because we thought it would look better. We used blue wire, to match the blue transformer insulation although different colours are shown on Fig.6 for clarity.

Cut each wire to a length of about 70mm, then strip about 3mm of insulation from one end and 6mm from the other. Feed the longer section of exposed wire through one of the solder lugs and double it over, then solder it in place. Try not to heat the joint more than necessary or add too much solder.

The output transformer terminals all operate at 308V DC and they must all be fully insulated with two layers of heatshrink sleeving to ensure safety. It's just a matter of slipping a 15mm-length of 3mm-diameter blue heatshrink tubing over each terminal


Right Output
CON4
Right Input
CON2
(or solder RCA cable direct to PCB)
114V AC In
CON7
6/12VAC
2x6.3V AC
CON8
Left Input
CON1
(or solder RCA cable direct to PCB)
Insulate!
Insulate!
Insulate!
Insulate!
Insulate!
Currawong
Stereo Valve Amplifier
©2014
SILICON CHIP
01111141
CON10
POWER
LED1
RA
GA
VR1
VOLUME





This view shows the parts in position on the underside of the PCB. Note the Nylon nuts and washers used to secure the valve sockets at various locations, as indicated by the red arrows. Note also that this is a prototype PCB and the short wire links on two of the 12AX7 valve sockets have been eliminated from the final version shown in Fig.8

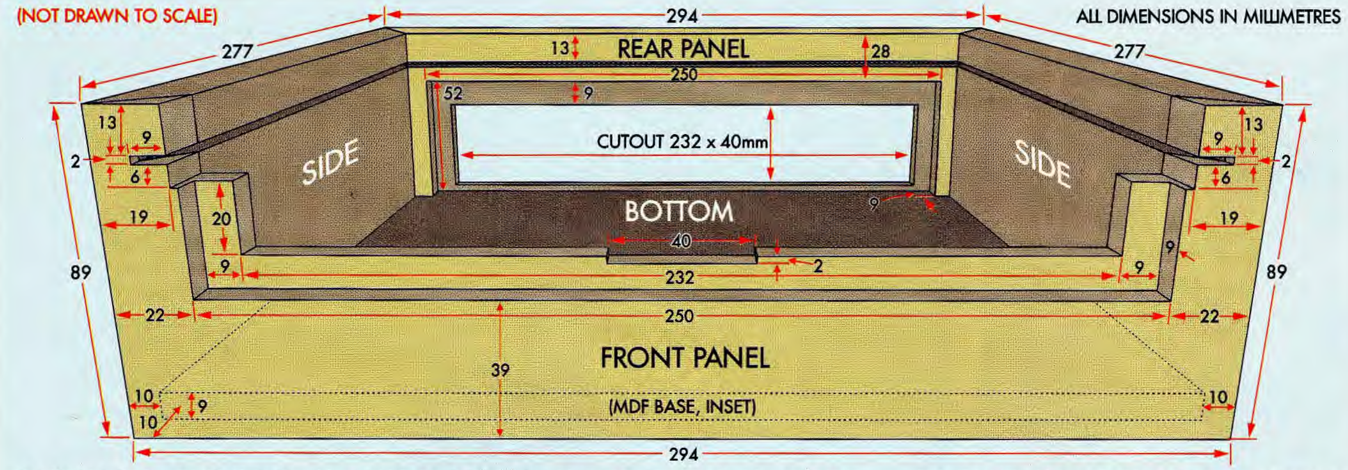
and shrinking it down, then adding a second layer. **Make sure each terminal is fully insulated, including the 10W tap, even if you aren't soldering a wire to it. If necessary, use neutral cure silicone to ensure that there is no gap in the insulation where each terminal goes into the transformer.**

Twist the bare strands together at the other end of each wire and tin them in preparation for mounting. Do the same with the three pre-existing wires, after trimming them so that they will reach their PCB pads with a little slack. You can place the transformer temporarily on the board to check this. Don't cut the leads too short.

Once all the wires have been prepared, fit the transformers to the board using M4 x 10mm machine screws, shakeproof washers and nuts. The front side (facing the bottom of the board) should have five or six connections, while the rear of the transformer has two. Make sure they are nice and square with the rear edge of the board, centred on their mounting positions and firmly secured.

It's then just a matter of soldering the eight wires to the PCB. The topmost of the five front wires goes to the leftmost pad, the next one down to the second-from-left and so on.

Fig.8: the parts layout on the underside of the PCB. A motorised pot is shown here for VR1 but a regular 16mm dual-gang log pot can be used instead if you don't want remote volume control. The RA/GA markings for LED1 indicate the position of the red LED anode and green LED anode respectively. Note the orientation of CON3, CON4, CON7 & CON8 and be sure to use Nylon nuts and washers at the indicated "insulate" positions when securing the valve sockets.



SIDE PANELS: 277mm LENGTHS OF 89 x 19mm DAR PINE WITH 45° INWARD CHAMFER AT EACH END, 2mm SLOT 9mm DEEP ALONG INSIDE, 13mm FROM TOP EDGE. ALSO 10mm DEEP x 9mm WIDE REBATE ALONG INSIDE LOWER EDGE

REAR PANEL: 294mm LENGTH OF 89 x 19mm DAR PINE WITH 45° INWARD CHAMFER AT EACH END, 2mm SLOT 9mm DEEP ALONG INSIDE, 13mm FROM TOP EDGE. ALSO 10mm DEEP x9mm WIDE REBATE ALONG INSIDE LOWER EDGE, OTHER REBATE & CUTOUT AS SHOWN

FRONT PANEL: 294mm LENGTH OF 89 x 19mm DAR PINE WITH 45° INWARD CHAMFER AT EACH END, 10mm DEEP x9mm WIDE REBATE ALONG INSIDE LOWER EDGE, SLOTS, REBATES & CUTOUTS AS SHOWN

BOTTOM: 276 x 259 x 9mm MDF RECESSED INTO BASE

Fig.9: the Currawong plinth details. It's made from four lengths of 89 x 19mm DAR pine arranged in a rectangle with a 9mm MDF or plywood base. The slot cut into the sides and rear accommodates the 2mm-thick PCB while the cut-outs and rebates at the front and rear are for the two panels which the controls and connectors pass through.

Skip the pad labelled "10W" if you only soldered four wires. These can be tack-soldered initially from the top (without melting the wire insulation), then pushed through the board and soldered from the bottom afterwards.

Connect the three remaining wires as shown on Fig.6, then tie the bundles of four or five blue wires together using blue cable ties.

Underside components

The remaining parts are fitted to the other side of the board, as shown on Fig.8. Start with the two shielded cables which run down the middle.

First, cut them to length and remove about 15mm of the outer insulation from either end, then twist the exposed shield braid wires together and strip about 5mm of the inner insulation away. Now twist together and tin these inner conductors and also tin the twisted end of the shield.

Solder the shield wires into the larger of the two holes at either end of the board and the inner wires into the smaller pads – see Fig.8. Make sure there's sufficient solder on the shield braid so that it's rigid and can't move and short to any adjacent pads. Also try to keep the wire reasonably taut along the bottom of the board. Once they've been soldered at each end, fit the six cable ties (three per wire) using the slots provided.

Next, fit the four pluggable terminal blocks. Make sure these go in the right way around, with the curved sections towards the back edge of the board (ie, towards the nearest edge).

The headphone socket can be mounted next and must be pushed all the way down onto the PCB. This can be followed by dual potentiometer VR1, after cutting its shaft to 15mm long. You can cut the potentiometer shaft using a hacksaw and then file off any burrs. If you've opted to have remote volume control, solder the two mounting lugs for the motor in addition to the six for the pot itself.

Now for the two remaining LEDs: blue LED2 goes on the left (with the board right-side up) near the headphone socket while bi-colour LED goes on the right. Use a DMM set on diode test mode to figure out which of the bi-colour LED leads is the red anode – the LED will light red when the red lead from the multimeter is connected to this pin (in our case, the longer of the two leads). This lead goes towards the righthand edge of the board.

Bend the LED's leads at right angles 7mm from its lens and fit the LED so that the lens is centred 10mm below the top of the PCB (ie, 8mm from the bottom). The other LED is fitted in the same manner, with its longer (anode) lead also towards the righthand edge of the PCB.

Input wiring

Note that what the board is designed to accept vertical RCA sockets for the input signals, we decided it was easier to solder a stereo RCA cable directly to the board, which plugs straight into the RCA/RCA sockets on the rear panel. This provides more clearance on the underside of the board for the transformers. So we suggest you get a short stereo RCA lead, chop off a ~500mm length, strip it back and solder it to the left and right input pads, with the shield braid to the terminals marked "-" and the inner conductor to "+".

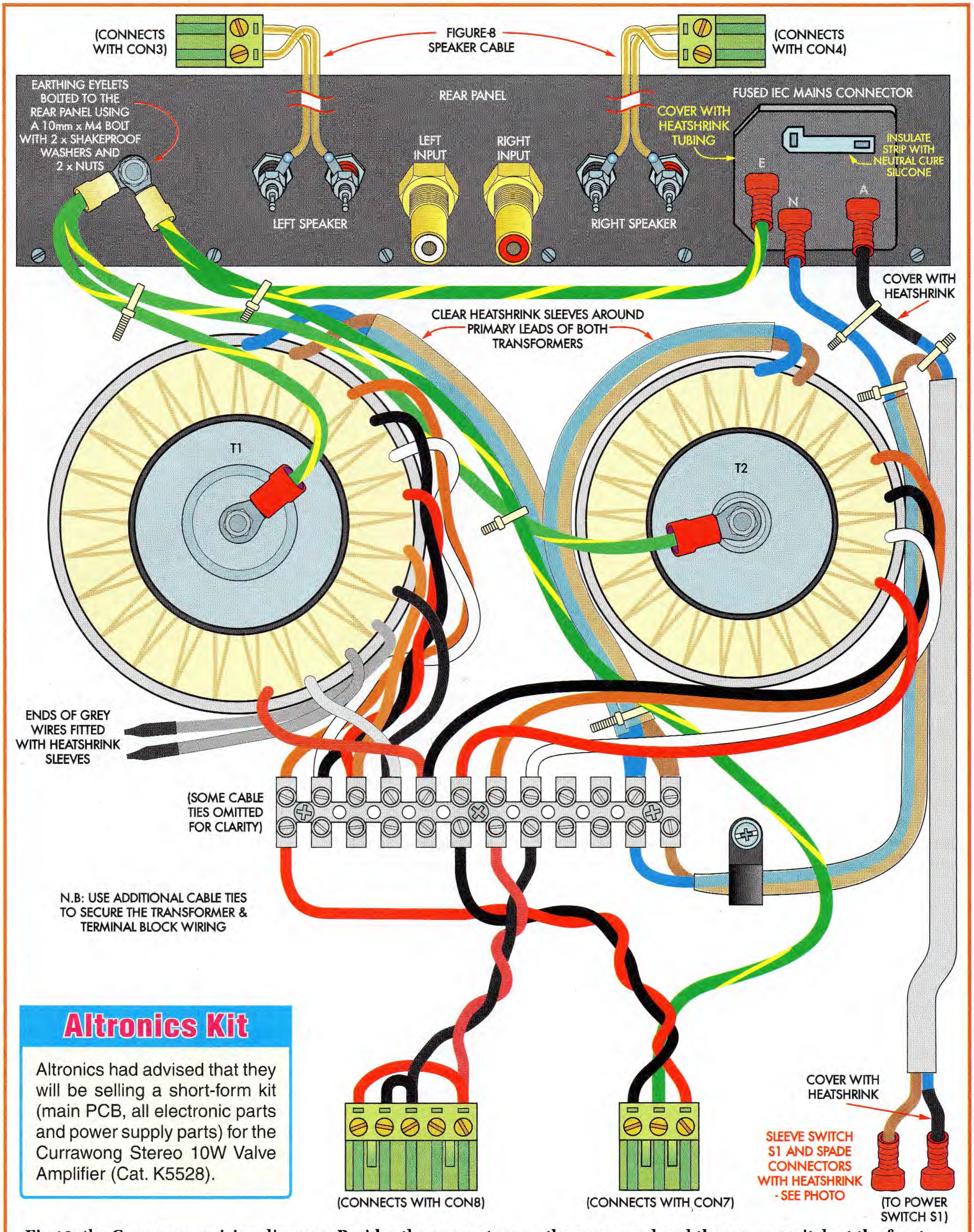
Now fit the three fuses; 1A for F1, 3A for F2 and 5A for F3 (all slow-blow). The main board assembly is now complete.

Building the plinth

The base of the plinth is a sheet of 5-ply or 9mm MDF cut to 276 x 259mm while the rest is made from a single length of 89 x 19mm dressed all-round (DAR) pine, cut to two lengths of 277mm for the sides and two lengths of 294mm for the front and back.

Fig.9 shows the plinth details. A plunge router is required to cut the rebates while a mitre or drop saw is used to make 45° cuts so that the four pieces of DAR pine can be assembled in a similar manner to a picture frame. A drop saw is used to cut the 2mm-wide slots but make sure that all the slots will later line up correctly.

We used wood glue to hold it all together, along with 6G x 20mm wood screws to additionally secure the base.



Altronics Kit

Altronics had advised that they will be selling a short-form kit (main PCB, all electronic parts and power supply parts) for the Currawong Stereo 10W Valve Amplifier (Cat. K5528).

Fig.10: the Currawong wiring diagram. Besides the connectors on the rear panel and the power switch at the front, the only additional components in the case are the two toroidal power transformers (T1 & T2) and the terminal strip which is used to connect their secondaries to the main board. Be sure to pay close attention to the insulation and anchoring of all mains wiring and note that the IEC socket must be covered with heatshrink tubing (see photo).

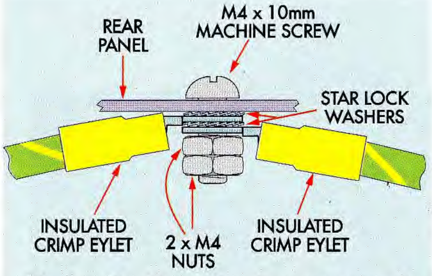


Fig.11: the Earth leads are secured to the rear panel via insulated crimp eyelets as shown here. The second nut serves as a lock-nut, so that the assembly cannot come loose. Make sure that the leads are securely crimped.

Once assembly is complete, check that the PCB will slide all the way back so that the front is flush with the front panel rebate.

After assembly, we smoothed the plinth using sandpaper, stained it with "Jarrah" oil-based stain and finished it with a clear polyurethane lacquer.

Putting it all together

Start by fitting feet to the plinth. These should be placed just inside each corner and attached using 9mm 4GA self-tapping screws. Drill a ~5mm deep 2mm diameter pilot hole for each foot before putting the screw in.

Next, fit the rear panel. This is held in place with a self-tapping screw in each corner and a few extras along the edge, primarily next to the mains input socket. You don't need to put screws through every single mounting hole provided. Again, drill 2mm pilot holes for each screw; due to the limited amount of space, you may need to use a pin vice.

Now fit the connectors to the rear panel. Fig.10 shows how the connectors are fitted. The IEC socket goes in with fuse towards the edge. It will snap into place and should not be able to move much once it's in.

The RCA connectors are supplied with two insulating washers; we kept the one on the inside but didn't bother with the one on the outside as the solder mask on the panel acts as an insulator anyway. Do them up nice and tight; the profile of the mounting holes will stop them from rotating.

Similarly, the binding post mounting holes prevent them from rotating and should result in the wire hole through the metal shaft being aligned vertically. These should also be mounted securely, taking advantage of the supplied spring washers.

It's possible that some binding posts may have their wire hole misaligned even though the shafts are keyed, so check before fitting them. If any are misaligned, you may be able to disassemble the binding post and reassemble it correctly.

By the way, the wire holes on the specified binding posts are quite small. You don't need to use especially thick speaker wire with this amplifier due to the limited output power and low damping factor, but it would be possible to enlarge the mounting holes and fit bigger binding posts if necessary. Alternatively, use banana plugs, which plug into the end of the specified posts.

With the posts in place, prepare the two internal speaker leads. Cut some figure-8 cable to ~200mm lengths, strip about 6mm of insulation from both ends and split the two halves apart slightly at either end. Solder the wires at one end to the smaller eyelets of some solder lugs. Put these wires aside so they can be fitted later.

Power transformers

The transformers should be located as shown in the wiring diagram (Fig.10). Leave enough room between the transformers and rear panel so that you can later reach behind the main PCB as it's being slid in and plug the various connectors into the underside (this requires more clearance than is available above the transformers).

Note that T1 at left is the larger of the two (160VA). We suggest a gap of no less than 50mm between T1 and the rear of the case. In practice, this means positioning the transformer mounting bolts so that they are approximately 115mm from the back edge of the plinth (ie, about 96mm from the inside rear edge).

Mount the transformers using the supplied plastic mounting washers, metal plates and washers via 6mm holes drilled in the bottom of the plinth but do the nuts up loosely at this stage. Note that these mounting holes are the only ones drilled right through the base; all other screws used are self-tappers which don't penetrate fully.

Now position the terminal block, as shown in Fig.10. Use three 12mm self-tapping screws to hold it in place, one in the middle and one at each end. Again, it's a good idea to drill 2mm pilot holes first.

For each pair of transformer primary wires (ie, blue and brown), cut a length of 5mm diameter clear heatshrink tubing to cover the entire length except for about 10mm at the end. Adjust the wires so that they run parallel and so that they end side-by-side, then shrink the tubing down. Bend the wires so they run as shown on the wiring diagram and terminate them in the terminal block. Once they're firmly screwed in placed, fit a cable tie around the lot.

The two grey wires from T1 aren't needed, so bend the bare ends over in a U-shape and then insulate with some 5mm diameter heatshrink tubing. Now, twist the six sets of transformer secondary wires together (red/black and white/orange). This will help to minimise the hum and buzz fields radiated by keeping the magnetic loops small. You can twist the grey wires in with their associated secondaries as we did, or leave them separate.

Now it's just a matter of bending the bundles of secondary wires down to reach the terminal block and screwing them in as shown in Fig.10. Be careful when doing the terminals up, since the solid copper wires are quite thin and are loose within their insulating sleeves. This makes it easy to think you've secured it in the terminal block when you haven't so tug gently on each one to make sure it won't come loose.

Now make up two pairs of twisted red/black heavy-duty wires around 200mm in length and attach them to the near side of the terminal block, as shown in the wiring diagram. Screw the other ends into the plug portions of the pluggable terminal blocks as shown. Note the two extra short wires required for the 5-way plug; fit these now too.

Once all the wires are in place, measure the resistance between the red/black pairs in the two terminal block plugs (for CON7 & CON8). You should get a low reading (<10Ω). Any higher than that suggests at least one wire is not making good contact in the terminal block, so go over them again.

Earth wiring

Before making any connections to the IEC socket, it's a good idea to cover the exposed metal strip as this operates at 230VAC. We also shrunk a length of 50mm-diameter heatshrink tubing around the rear of the connector (Jaycar Cat. WH5582) – see photo.

Two Earth wires are required. Start

This is the view inside the plinth with all the wiring completed. Be sure to cover the IEC socket with heatshrink tubing as shown.

by stripping the yellow/green striped wire out of a length of mains flex, then remove the insulation from one end and crimp securely into a 6.4mm insulated female spade connector. Plug this into the IEC mains input socket and route the wire to the rear panel Earth lug hole at the lefthand side.

Note that if you are using a plastic boot to insulate the mains socket, you will have to feed the Earth wire through that before plugging it in.

Cut the wire so that it reaches 150-200mm beyond this Earth lug hole, then mark the point where it passes that hole. Using sharp side-cutters, carefully remove about 25mm of insulation at the marked point without damaging the copper conductors. This can be done by making a series of nicks around the wire at either end of the 25mm section, to separate that piece of insulation from the rest, then slitting down the isolated section and peeling it away.

Double over the exposed copper wire, squeeze it together using pliers and then crimp it into one of the yellow 5mm inside diameter eyelet connectors. Bare the copper at the far end of the wire; this goes into the centre terminal of the 3-way pluggable terminal block.

Now for the second Earth wire. This needs to reach from the top of one transformer mounting bolt, to the rear panel Earth point and then to the other transformer mounting bolt. Cut it to length, mark the location of the rear Earth panel point, strip the insulation at each end and crimp an 8mm inside diameter red eyelet connector at either end. Strip away the insulation in the middle as before and crimp it into the other yellow eyelet.

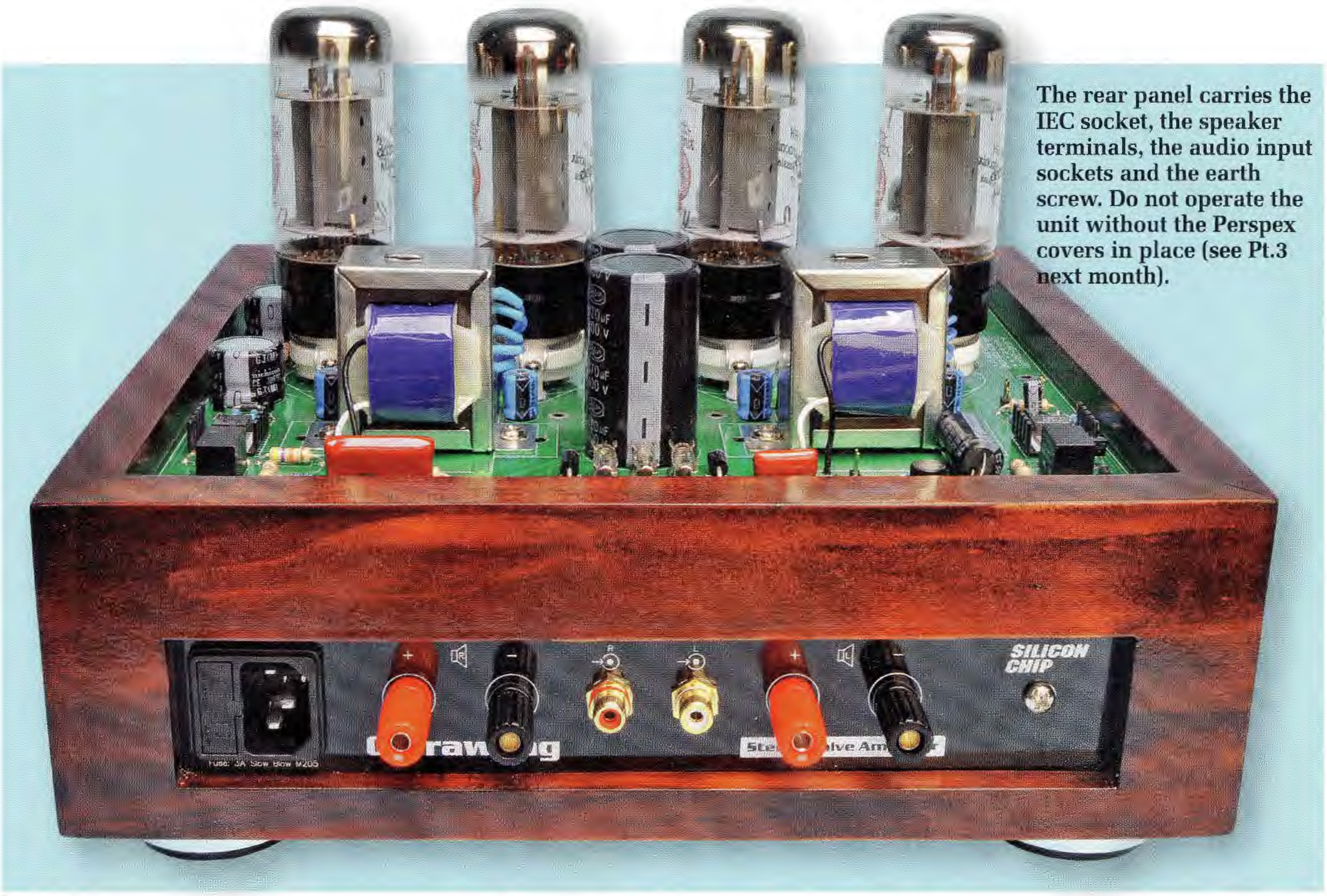
Now attach both yellow eyelets to the rear panel Earth point as shown in Fig.11. To do this, feed an M4 x 10mm machine screw in from the rear and place a shakeproof washer over the thread, followed by the eyelet connector from the IEC socket, then another shakeproof washer, then the second eyelet and an M4 nut. Do this nut up tight, then do up another nut on top, so it can't possibly shake loose.

You can now remove the transformer mounting bolt nuts one at a time and fit the red eyelet connectors under the flat washers. When refitting the nuts, do them up firmly but not so tight as to risk crushing the transformer windings.

Switch wiring

Prepare the power switch by cutting a length of 2-core figure-8 mains flex to around 500mm, then strip away the outer insulation for about 200mm, exposing the blue and brown wires. Cut the blue wire short, to 40mm, then strip the end and cover it with 3mm-diameter black heatshrink tubing back to the sheath. Crimp on a 6.4mm red insulated spade connector.

Cut the brown wire to the required length as shown in Fig.10 and strip the



The rear panel carries the IEC socket, the speaker terminals, the audio input sockets and the earth screw. Do not operate the unit without the Perspex covers in place (see Pt.3 next month).

insulation at the end. Run this though a section of clear heatshrink along with the blue wire you cut off earlier and crimp a 6.4mm insulated red spade lug on the IEC socket end of the blue wire, as shown in the wiring diagram.

Now plug the two spade connectors into the rear of the IEC socket (blue wire to Neutral, heatshrink-covered wire to Active). If using a boot, feed them through first. Lay the cable along the bottom of the case and screw it into the terminal strip as shown. Fit the P-clamp in the position indicated using a 6mm self-tapping screw and washer after drilling a small pilot hole.

Preparing the front panel

If you're going to fit the optional remote volume control, you will need to drill a hole in the front panel for the IR receiver. This should be vertically aligned with the power indicator LED (at right) and 28mm to the left. Drill the hole to at least 5mm.

Note that if using a SILICON CHIP front panel, there may be a hole position indicated on the rear but this may not be correct as we changed it while building our prototype.

The mains switch can now be fitted. It should click into place but make sure it has the correct orientation, so that it's switched down to connect the two terminals. If you switch doesn't have an "on" marking on the front, use a multimeter to check which way around it should go.

Now strip the sheath at the loose end of the mains twin flex back by about 30mm, strip the insulation from the two inner wires and crimp the two remaining 6.4mm insulated spade connectors onto these.

Slip a couple of lengths of 20mm diameter black heatshrink tubing over this cable and then plug the two spade connectors onto the power switch lugs securely. That done, slide one length of the heatshrink tubing right over the rear of the switch body and shrink it down, then slip the other length on top and shrink that too.

The rear of this switch must be thoroughly insulated (as explained above) since it is connected to mains Active and is near the front panel controls and other circuitry.

Now fit the two speaker wires prepared earlier to the binding posts. This is simply done by securing the solder lugs between the two supplied nuts on each binding post shaft. Do this with the correct polarity as shown in Fig.10.

You can finish all the wiring by fitting some cable ties. In addition to the one fitted to the transformer secondary wires earlier, use several others to tie the transformer secondary wires in bundles close to the terminal block so that none of them can come adrift. Also fit some cable ties to the mains and Earth wiring to hold it in place.

Checking the wiring

Removing the board after it's fitted is a bit fiddly so it's best to do as much checking as we can now. First, use a DMM set in Ohms mode to measure the resistance between the Earth pin on the IEC socket and each of the Active and Neutral pins. There should be no continuity at all (the meter should show "OL" or similar).

Check also that there is no connection between any of the secondary winding connection points on the terminal block and any of the Earth, Neutral or Active pins on the IEC socket. Then take a quick look over the wiring and make sure nothing is touching or shorting to anything it shouldn't be.

Move all the loose wiring (terminal plugs, etc) out of the way, then plug in an IEC mains lead. Check that the power switch insulation is intact, then plug in and switch on. Check the AC voltage across each pair of red and

You Must Use A Ratchet-Driven Crimping Tool

One essential item that's required to build this amplifier is a ratchet-driven crimping tool, necessary for crimping the fully-insulated quick-connect terminals to the leads.

Suitable crimping tools include the Altronics Cat. T1552, and the Jaycar TH1829. These all feature double-jaws so that the bared wire end and the lead insulation are crimped in a single action.

Don't even think of using one of the cheap (non-ratchet) crimpers that are typically supplied in automotive crimp kits. They are not up to the job for a project like this, as the amount of pressure that's applied to the crimp connectors will vary all over the place. This will result in unreliable and unsafe connections, especially at the mains switch and IEC socket terminals.

By contrast, a ratchet-driven crimping tool applies a preset amount of pressure to ensure consistent, reliable connections.

black wires connected to the terminal block plugs.

Use caution when doing this as the transformer secondaries can put out over 120VAC – don't touch the plugs while the power is on! It's easier to probe the terminal block where the red and black wires are terminated.

You should get close to 13VAC across the right-most output pair (going to the 5-way plug). Now, if the transformer phasing is correct, the other pair (going to the 3-way terminal) will read over 110VAC; possibly over 120VAC with no load. If you get a reading closer to 90VAC then you will need to switch off and swap around the black and red wires from the 80VA toroid. Power it back up and check that the voltage is now correct.

If either reading is much lower than specified, there is probably a bad connection to the terminal block, so you will have to switch off and re-check all the connections. But assuming the voltages are OK, remove the IEC mains cord and proceed to final assembly.

Mounting the board

If you're fitting the remote volume control add-on (to be described next month), make sure that the remote board is attached to the main board and that the motor is plugged in. Then slide the board into the case carefully and slowly, checking that the connectors on the underside don't catch on any wires. Push it back about two-thirds of the way, with the attached RCA leads folded over the top, then plug them into the internal RCA sockets on the rear panel and push them all the way home.

It's a good idea now to check that there is good continuity between the inner and outer contacts of the rear panel RCA sockets and the input wire solder termination points on the top of the PCB. They should all read low resistance.

Now for the tricky bit. It's necessary to plug the four terminal blocks into the underside of the board but you have to slide it almost all the way back for there to be enough clearance underneath to do so. Thus, you need to reach around the back edge of the board and push them up into place. And watch out because unfortunately, these pluggable connectors are open on the sides so it's possible to plug them in offset from the correct position!

Start with the 3-way and 5-way connectors in the middle of the board as these will have the best clearance and you won't have to push the board back as far to plug them in. Note that the screw housing projection of each plug faces the front of the case.

Once they're in, you can check that the 3-way connector is fitted correctly by confirming good continuity between one of the valve socket mounting screws and the IEC socket Earth pin. Similarly, the 5-way connector is plugged in correctly when there is a very low resistance between the pins at either end, which you can probe on the top of the board.

The procedure for the two speaker terminal plugs is the same but you will probably have to push the board back even further to make room for them to fit. Check for good continuity between each "+" speaker output pin on the top of the board and the red binding post.

Assuming that's all OK, push the PCB all the way back. You may find it hesitates when it reaches the rear panel but you should be able to "finagle" it in. Recheck the isolation between the Earth and Active/Neutral pins on the mains socket, and the Active/Neutral pins and the eight supply pads on the main board (ie, immediately behind the fuses), just to make sure that pushing the board in hasn't disturbed any of the wiring.

This metal strip on the IEC socket operates at 230VAC and should be insulated using silicone sealant.

Now place the front panel over the pot shaft and gently push it back, guiding the two LEDs through their respective holes. Loosely fit the pot and headphone socket nuts, then you can drill 2mm pilot holes for the two lower mounting holes in the corners of the panel and attach it using two black self-tapping screws. Finish off by tightening the two nuts and attaching the knob.

That's all we have space for in this article. **Next month we'll go over powering it up and checking it out. Then we'll fit the clear top cover, to make the whole thing safe to operate.** We'll also describe the optional remote control add-on board. **SC**

By Nicholas Vinen

The Currawong Stereo 10W Valve Amplifier, Pt.3

In the last two instalments, we introduced the Currawong valve amplifier, described its circuit and gave the PCB assembly and wiring details. This final article describes the optional remote volume control, the acrylic cover and the setting-up procedure.

YOU DON'T HAVE to build the remote volume control board but we think most constructors will want to. It's just so convenient when it comes to setting the volume and is far easier than having to wander over to to wind the volume control up or down.

If you intend building the remote control into the Currawong, you should have already fitted the motorised pot to the main board. The 50 x 50mm remote board hangs from the front-right corner of the main PCB via a tapped spacer and is connected via a 4-pin header. There is also a connection from the remote control board to the pot motor.

If you aren't fitting the remote control option to your Currawong amplifier, skip down to the "Initial power up & testing" cross-heading below.

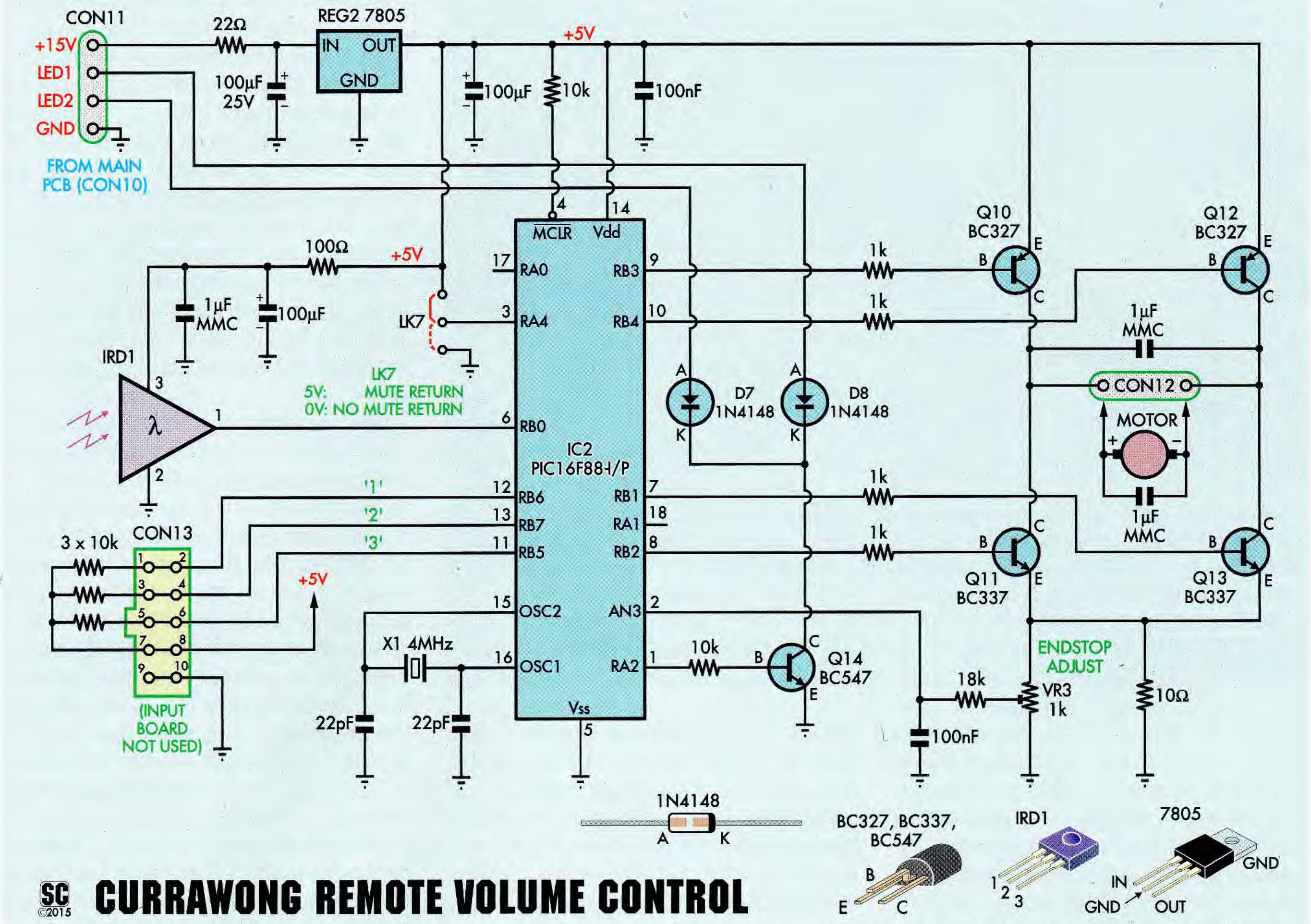
IR remote control circuit

The remote control circuit is shown in Fig.12. It's based on the low-noise remote-controlled preamplifier used in the Ultra-LD Mk.3 Stereo Amplifier described in the November 2011 issue.

Basically, we took the remote control parts used in that project and put them on a separate PCB, without the preamplifier circuitry (which is already present on the Currawong's main board).

It works as follows. The remote control is set to generate Philips RC5 protocol codes which are picked up by infrared receiver module IRD1. Its output goes to pin RB0/INT on PIC16F88 microcontroller IC2. IC2 decodes the remote commands and if it detects a relevant code (volume up/down/mute), it then uses its RB1-RB4 output pins to drive transistors Q10-Q13 which are arranged in an H-bridge configuration, to drive the pot motor in the appropriate direction.

A 1μF capacitor is connected across the motor terminals on the PCB to reduce hash from the motor brushes



CURRAWONG REMOTE VOLUME CONTROL

SC ©2015

Fig.12: the circuit for the add-on remote volume control is based on the one used in the Ultra-LD Mk.3 Stereo Amplifier (November 2011). The infrared signal is received by infrared receiver IRD1 and passes to microcontroller IC2 which decodes it and uses Q10-Q13 to drive the pot motor in the required direction. Power comes from the main board.

while there is also a capacitor soldered directly across the motor terminals, at the other end of the figure-8 wire from CON12.

IC2 monitors the motor current across a 10Ω shunt resistor. The feedback voltage is adjusted using pot VR3 and goes through a low-pass RC filter (18kΩ/100nF) before being fed to analog input AN3 on IC2. IC2 can thus detect the increase in current when the pot hits one of its end-stops.

This feedback is used for the mute function. When mute is pressed, the motor is driven anti-clockwise until the pot hits its minimum end-stop. IC2 detects the increase in current and shuts the motor off once minimum volume has been reached. If mute is then pressed again and LK7 is in the high position, the motor is driven clockwise for the same time as it took to reach the end-stop, thus returning the pot to the original volume level.

For this to work, VR3 must be adjusted correctly. If it's set too high, the motor may stop prematurely while if set too low, the motor may not stop once minimum volume has been reached.

In the November 2011 design, IC2 flashed an acknowledge LED to indicate when a valid remote control command was received. We have used the same output (RA2) to drive NPN transistor Q14 which pulls the cathodes of small signal diodes D7 & D8 low in acknowledgement. These go to either end of red/green LED1 on the main board via pin header CON11. As a result, when a command is received, LED1 is shorted out and so it flashes off briefly. This avoids the need for an extra LED to be fitted for the remote control function.

The only change in the microcontroller software compared to the Ultra-LD Mk.3 remote preamp is to increase the time that pin RA2 is driven high upon receipt of a valid remote command. That's done in order to make the LED flashing more visible.

PIC microcontroller IC2 uses 4MHz crystal X1 for time-keeping. This is required as the remote control commands are sent at a particular frequency and the micro needs to be able to "lock on" to these commands to properly decode them.

Multiple input option

We've kept the original design's

> **Transformer Bolt Earthing – Warning!**
>
> Note that the mounting bolts for mains transformers T1 & T2 **must not** be separately earthed (ie, via earth leads) if the amplifier is mounted in a metal chassis. That's because running earth leads to them would result in a shorted turn on each transformer and this would immediately blow the fuse in the IEC socket.

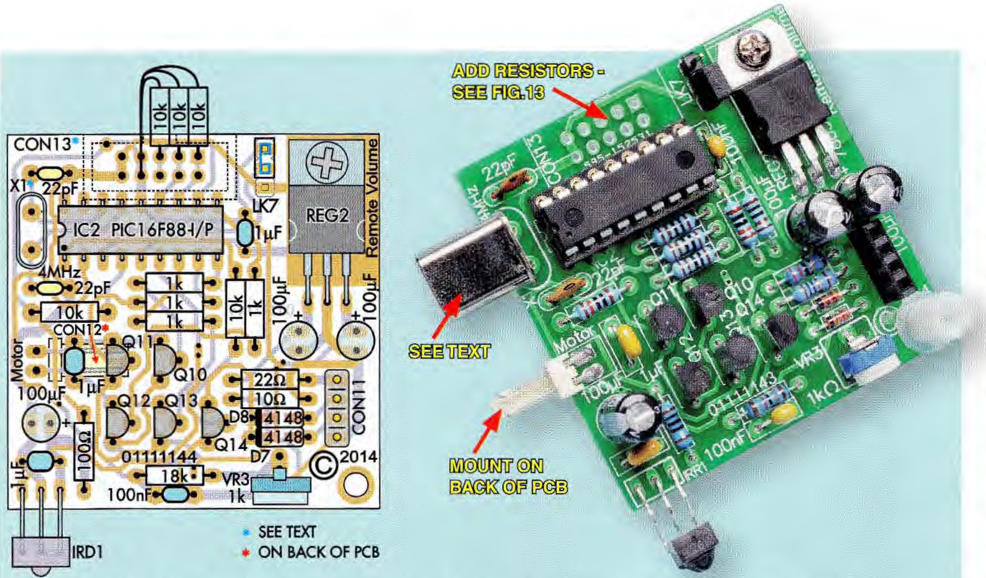


Fig.13: follow this parts layout diagram to build the remote volume control PCB. This sits just below the main board, so the available component height is limited. As a result, motor header CON12 and crystal X1 (if full height) must be fitted at right angles on the underside of the PCB (not on top as shown in the photo). In addition, the electrolytic capacitors should be pushed all the way down to the board before soldering or else bent over so that they will later clear the main board assembly.

10-pin header CON13, which was used to connect to two other PCBs for input switching. This enables the possibility of fitting multiple inputs to the Currawong and having remote-controlled switching. This would require the main Currawong board to be built into a larger case with enough room for the extra inputs and the relay board required.

In the standard Currawong design, (ie, no input switching), we just connect 10kΩ pull-up resistors from pins 7 & 8 (+5V) to pin pairs 1/2, 3/4 and 5/6 as shown so that the unit will function without the input switching board connected.

Power for the remote control unit is derived from the Currawong's unfiltered low-voltage DC rail of around 15V via pins 1 & 4 of CON11. This supply goes through a low-pass RC filter (22Ω/100µF) before being fed to a standard 5V regulator, REG2.

The 5V output from REG2 is used to power the micro and the motor but is further filtered using a 100Ω resistor and 100µF capacitor for infrared receiver IRD1 (plus an extra 1µF ceramic bypass capacitor) in order to prevent motor hash from interfering with infrared command reception.

Remote PCB assembly

The remote control PCB is coded 01111144 and the parts layout is shown in Fig.13. Start by fitting the two diodes, cathode stripe to the left, then follow with the resistors. You can check their striped bands against the resistor colour code table (Table 3) however it's also a good idea to measure them with a DMM as the colours can be hard to read clearly.

Note that while most of the resistors are laid flat in the traditional manner, the three 10kΩ resistors soldered to the pads for CON13 will need to be fitted vertically, with two leads sharing one of the holes. We used mini 0.25W resistors here, since they fit more easily.

Solder the IC socket in place next, with its notched end to the left, followed by REG2. Prepare the regulator by first bending its leads down through 90° about 6mm from the tab, then attach the tab to the PCB using an M3 x 6mm machine screw and nut. Make sure the screw is done up tightly before soldering and trimming the leads.

The ceramic capacitors can go in next; their polarity does not matter. You will be left with a 1µF type to be soldered across the motor terminals later.

Follow with the small signal transistors, taking care to avoid getting the three types mixed up. Crank their leads out to fit the PCB pads using small pliers. **If you have a low-profile 4MHz crystal, this can be fitted to the top of the board as shown in Fig.13. Otherwise, you will need to cover the metal can with a short length of 10mm diameter heatshrink tubing, shrink it down, bend the leads through 90° and fit it to the underside of the board so that it's laying horizontally under PIC micro IC2.** In this case, solder its leads on the top side of the board.

Note that in our photos, X1 is shown bent over to the left but this was found to interfere with the mains power switch when the board was in place, so we later moved it to the underside and bent it in the other direction as described above.

The right-angle polarised header for the motor is also mounted on the underside of the board, with its pins facing the righthand edge, for the same reason (again, shown differently in the photo). Solder its pins on the top side.

Table 4: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
1µF	1µF	1u0	105
100nF	0.1µF	100n	104
22pF	NA	22p	22

Table 3: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	18kΩ	brown grey orange brown	brown grey black red brown
❑	5	10kΩ	brown black orange brown	brown black black red brown
❑	4	1kΩ	brown black red brown	brown black black brown brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	22Ω	red red black brown	red red black gold brown
❑	1	10Ω	brown black black brown	brown black black gold brown

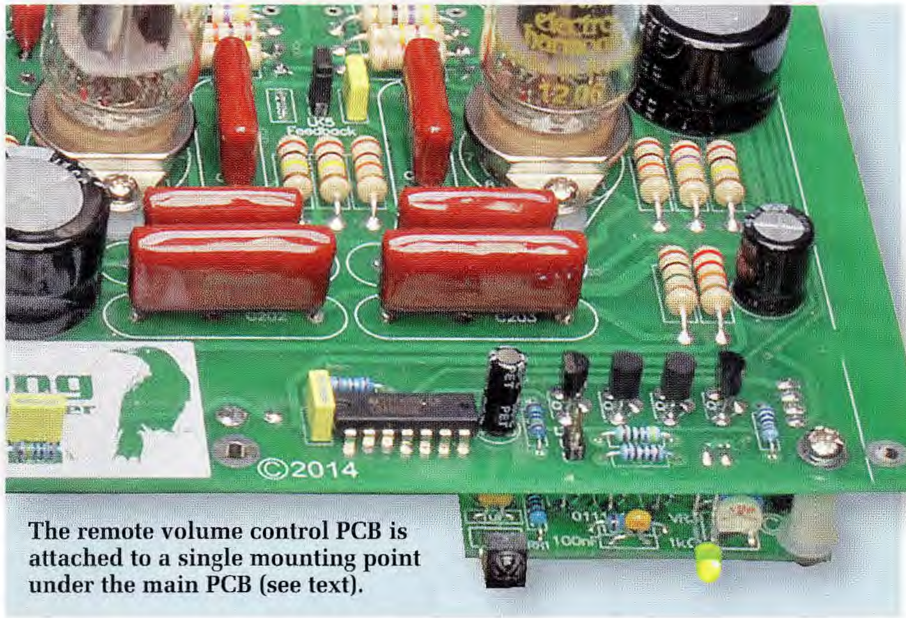
The 3-pin header for LK7 and 4-pin header socket CON11 are fitted as usual, to the top side of the board. Put the shorting block over LK7 in the position shown for mute return or fit it in the alternative position to disable mute return.

Trimpot VR1 is a vertical type, so that it can be accessed once the remote control board has been plugged into the main board. You will need to bend its rear pin out slightly to fit the mounting pads. The three electrolytic capacitors can then go in, with their longer (positive) leads orientated as shown.

The infrared receiver is fitted with its leads bent so that the bottom of the receiver is level with the PCB but it is spaced about 6.5mm away from the bottom of the board – see photo. You will need to bend its leads backwards close to the body of the receiver, then crank them up, then bend them back down again about 8mm behind the body of the receiver to fit through the holes on the PCB.

The final adjustment to make the infrared receiver "look" through its front panel hole will be done later, when the board is fitted.

You can now finish the remote PCB assembly by plugging microcontroller IC2 into its socket, with pin 1 at left.



The remote volume control PCB is attached to a single mounting point under the main PCB (see text).

Installing the remote PCB

Solder a 4-pin male header to the underside of the main PCB, at bottom-right, to match up with the female header socket (CON11) on the remote board. While you're at it, feed the leads of the remaining 1µF ceramic capacitor through the holes in the two terminals on the back of the pot motor and solder them in place. Trim off any excess lead.

Now you will need to make up the lead for the pot motor. Start by cutting a length of light-duty figure-8 cable so that it will reach from the rear of the pot over to the right-angle pin header on the remote board. Be a little generous, keeping in mind the orientation of the plug and the fact that you will need some slack in order to plug it in.

Strip and separate the wires at both ends of this cable and crimp both wires at one end into two polarised header pins. We like to solder the wires after crimping (being careful not to get any solder outside of the crimp section) so that they can't pull out.

Next, push the pins into the polarised block using a small jeweller's screwdriver. They should click into place. If they won't go in, don't force them; you may need to pull them out and straighten the "springy" section before they will go in properly.

Now solder the other ends of the lead to the pot motor terminals (or to the capacitor leads which are already soldered to them). Unfortunately, there's no good way to figure out the polarity so you'll just have to pick one and then reverse the connection if it's wrong but we'll get to that later.

Next, insert an M3 x 6mm machine screw through the sole mounting hole on the remote control board, head on the underside, with a shakeproof washer under the screw head. Place a Nylon washer on top and then screw it into an M3 x 9mm tapped spacer. Do it up nice and tight.

Plug the remote board into the 4-pin header on the main board, then use another M3 machine screw and a flat washer to hold it in place via the provided mounting hole on the main board. Finally, plug the polarised header from the motorised pot into CON11 on the bottom of the remote board and you are ready to test it.

Note that the pot motor lead should not be able to reach the mains switch which, in any case, should be completely covered in heatshrink tubing.

The next step is to drill a 4mm-diameter hole in the front panel for the IR receiver. **This 4mm hole should be positioned exactly 27mm to the left of the power LED (LED1).** Having done that, leave the front panel off for the moment, so that you can set VR1 correctly and if necessary, swap the motor polarity.

Initial power up & testing

When we left off last month, we had built the PCB and plinth, wired up the

WARNING! HIGH VOLTAGES

High AC and DC voltages are present in this amplifier. In particular, mains voltages (230VAC) are present on the IEC socket and the primary side of the mains transformers (including the wiring to the power switch). In addition, the transformer secondaries together provide a 114VAC output and the power supply produces an HT voltage in excess of 300V DC which is present on various parts of the amplifier circuit (including the output transformers).

Do not touch any part of the amplifier or power supply circuitry when power is applied otherwise you could get a severe or even fatal electric shock.

The blue LEDs in the circuit indicate when high voltages are present. If they are lit, the power supply and various parts on amplifier board are potentially dangerous. **The completed amplifier must be fitted with Perspex covers as described in Pt.3 this month, to ensure safety.**

Parts List: Currawong Remote Control

1 double-sided PCB, code 01111144, 50 x 50mm
1 4-pin header, 2.54mm pitch (CON10)
1 4-pin female header, 2.54mm pitch (CON11)
1 1kΩ mini vertical trimpot (VR1)
1 4MHz crystal, HC-49 (low-profile if possible*) (X1)
1 3-pin header, 2.54mm pitch, with shorting block (LK7)
1 18-pin DIL IC socket
1 2-pin right-angle polarised header
1 2-pin polarised header plug with crimp pins
1 200mm length light-duty figure-8 cable
1 9mm tapped Nylon spacer
3 M3 x 6mm machine screws
1 M3 nut
1 3mm ID shakeproof washer
1 3mm ID flat washer
1 3mm ID Nylon flat washer
1 universal remote control (eg, Altronics A1012, Jaycar AR1719)

Semiconductors
1 PIC16F88-I/P programmed with 0111114A.HEX (IC2)
1 infrared receiver (IRD1)
1 7805 5V linear regulator (REG2)
2 BC327 PNP transistors (Q10,Q12)
2 BC337 NPN transistors (Q11,Q13)
1 BC547 NPN transistor (Q14)
2 1N4148 signal diodes (D7,D8)

Capacitors
3 100µF 16V electrolytic
2 1µF monolithic multi-layer ceramic
3 100nF monolithic multi-layer ceramic
2 22pF disc ceramic

Resistors (all 0.25W, 1%)

1 18kΩ	1 100Ω
5 10kΩ	1 22Ω
4 1kΩ	1 10Ω

* If using a full-height can crystal, add 1 x 20mm length of 10mm-diameter heatshrink tubing

power supply and mounted the PCB in place. Now it's time to power it up *without* the valves in place and check that the power supply is working.

Start by popping the fuseholder out of the mains input socket using a flat-bladed screwdriver, then fit the fuse (plus a spare) and re-install it. Leave LK4 & LK5 off the board for now. **From this point on until the top cover is fitted, be careful to avoid putting either of your hands near any of the components on the top of the board – touch the assembly using insulated probes only.**

Now set your DMM to DC volts (with a range that goes up to at least 300V), plug in the mains cord, switch on and observe the LEDs. The four blue LEDs adjacent to output transformers T3 & T4 (LEDs3-6) should immediately light. Blue LED2, next to the headphone socket should remain off while LED1 (power) should be red.

If your amplifier doesn't display this behaviour, switch off immediately and wait for the HT voltage to drop to a safe level before troubleshooting. This can be monitored by connecting the negative probe of your DMM to one of the valve socket mounting screws and the positive to the cathode (striped end) of D1. Wait for it to drop below 40V before touching the board and to 10V before doing any soldering or other work on the board.

Assuming blue LEDs3-6 are working properly, these indicate the state of the HT rail. They will be glow brightly when dangerous voltages are present and dim significantly once the HT capacitors have discharged to a safe level. Note that they will continue to produce a small amount of light for a long time after switch-off but will be quite dim by the time the HT rail drops below 10V or so.

If these LEDs do not light up, one or more could be installed with the wrong polarity or might be faulty. Once the HT has discharged, you can connect a current-limited voltage source across each LED to check them. Some (but not all) multimeters can light blue LEDs when set on diode test mode.

If LEDs3-6 are working but LED1 does not come on, this points to a possible fault in the low-voltage AC wiring, the regulator section or a problem with IC1 or Q5-Q8 and associated components. Check these areas, starting by measuring the voltage between pins 4 & 5 (the two topmost pins) of one of the 9-pin valve sockets, which should be stable at just above 12V and proceed from there.

On the other hand, if LED2 is on, that suggests a fault in Q9 or its base resistor or a short circuit in that section of the board.

Assuming that you get the correct LEDs lighting, LED1 should turn green about 20 seconds after switch-on. During this time, you can check that the various voltage rails are correct.

First, measure the DC voltage between pins 4 & 5 of the 9-pin valve sockets as mentioned above and check that you get close to 12.3V. You can also confirm that there isn't too much ripple on the regulated supply by measuring the AC voltage between these pins; it should be below 100mV.

Now check the unfiltered HT supply voltage, between the cathode of D1 and one of the valve socket mounting screws. You should get a reading close to 320V.

The filtered HT voltage can be measured between pin 3 of any 8-pin valve socket and one of the earthed mounting screws. Pin 3 is the pin closest to you, on the right – see Fig.6 in Pt.2 last month. This should give a low reading (a few volts) initially while LED1 is red and then it should shoot up to 318V or so (ie, a couple of volts below the unfiltered HT rail) as soon as LED1 turns green.

The other filtered HT rails can also be checked, at pins 1 & 6 of each 9-pin valve socket (lower-right and upper-left respectively). With the valves not yet fitted, these should all be pretty close to the main filtered HT rail at around 318V although they will rise more slowly after LED1 turns green.

Testing the remote board

If you have fitted the remote control board, this is a good time to test it now that you have determined that the power supply is working properly. First, set your remote control to one of the supported codes. For the Altronics A1012, this is either 023 or 089. For the Jaycar AR1719, use 97948 (Philips 02 CJ 412 TV).

Now aim the remote control at the receiver and hold down the volume up or volume down button. You should see the acknowledge LED (LED1) flash and the pot shaft rotate.

If nothing happens and you have definitely programmed the remote for the correct code then that suggests either a fault on the remote control board or an improperly programmed PIC micro. Check that the board's 4-pin header (CON11) is plugged in correctly to the main board and that there is around 15V between pins 1 & 4.

If the pot rotates in the wrong direction, you will need to switch off and reverse the motor connections (once the HT rail has discharged sufficiently). This can be done by using a fine flat-bladed screwdriver to press in the retention tabs on the polarised header pins, then sliding the pins out of the housing (while holding the tabs down) and refitting them so that they are swapped around.

Once you have the pot motor rotating correctly, press the mute button and check that the pot rotates to the fully anti-clockwise position and stops. If it doesn't stop, turn VR1 clockwise until it does. If it only rotates part of the way, turn VR1 anticlockwise until it mutes properly.

Ideally, VR1 should be set about mid-way between the too-low and too-high positions, to avoid later malfunctions if the pot shaft's mechanical resistance increases slightly.

Note that you may need to manually rotate VR1 clockwise to about half-way (or use the volume up button) before the mute function can be tested. Once it has been set up, you can refit the front panel and if necessary, bend the leads of IRD1 and LEDs1&2 so that they line up with their respective holes.

Fitting the valves

Assuming that the voltages check out, switch off the power and wait for the HT capacitors to discharge, then plug in all the valves. The sockets will probably be very stiff the first time they are fitted; a small amount of contact cleaner on the pins can help ease them in.

Don't push them too hard; you will need to wiggle them in and it's better to push down on the octal valves by holding the base rather than the envelope. The 12AX7s have no base but they should require less insertion force anyway.

The glass envelopes are pretty strong but they can be broken with enough force and there's also the possibility of the glue holding the envelope to the base giving way. So slowly wiggle the valves in. After the first couple of insertions, the sockets will loosen up and fitting/removing the valves will be a lot easier.

This may seem obvious but we should point out that V5-V8 will get very hot during operation and you should not touch them! Even brief contact can result in a painful burn. Consider that with the glass envelopes and about 25W dissipation, they are similar to an incandescent light bulb – ie, they get very hot!

Now, while we have provided a minimal output load on the PCB (~470Ω per channel), it's still a good idea to hook up a "proper" dummy load until you're ready to connect some speakers, to prevent flash-over due to excessive voltage when the amplifier is lightly loaded. A couple of 10Ω 5W resistors connected across the speaker terminals will do, although any value in the range of 3.9-100Ω is acceptable.

Turn the volume control right down initially. If you have an oscilloscope and signal generator, you can feed sinewave signals into the inputs, power the unit up, advance the volume control and check the shape of the output waveforms on each channel. Otherwise, all you can really do is hook up a signal source (eg, a CD player) and some speakers and listen to it.

Note that there won't be much output (if any) until several seconds after HT has been applied (ie, LED1 has turned green), as it takes time for the various bias voltages in the circuit to stabilise. And it takes several more seconds until the amplifier can deliver a significant portion of its rated power. The warm-up is complete and the full ~10W/channel is available around 10 minutes after switch-on.

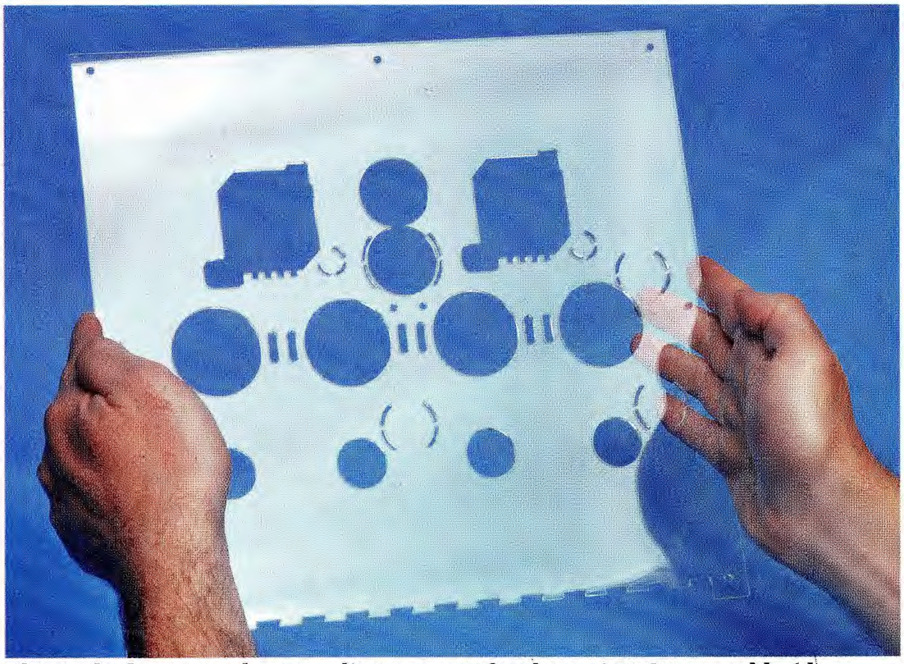
Before that, you'll probably run into clipping at 8-9W per channel. It simply takes that long for the valves to reach operating temperature.

Assuming it appears to be working normally, switch off, turn the volume control back down and fit shorting blocks to LK4 and LK5 to enable global feedback. This dramatically lowers distortion, from around 0.5-1% down to 0.05-0.1% (ie, by at least an order of magnitude) so we definitely recommend operating the amplifier with these links in.

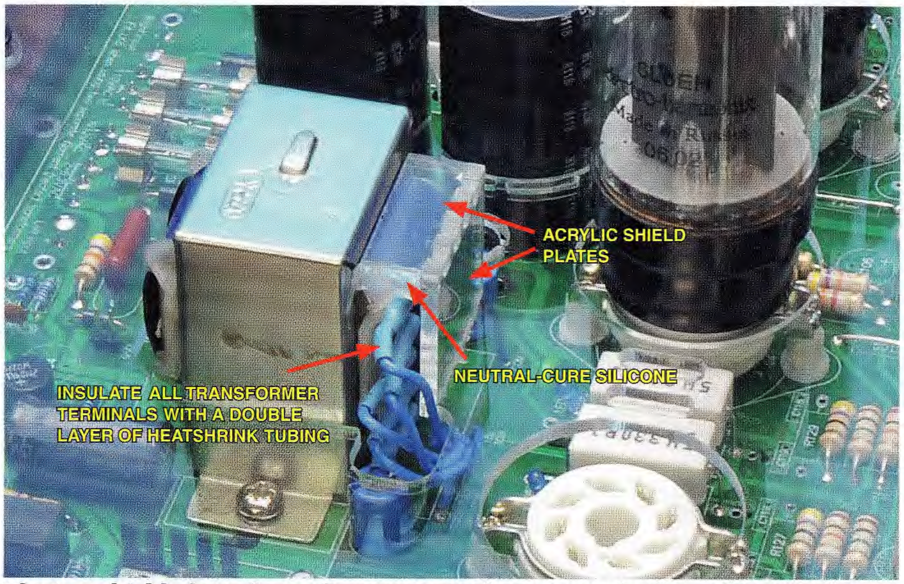
Now switch the amplifier back on, slowly turn the volume back up and check that it's still working properly. If you get a high-pitched squeal, you may have wired the output transformers improperly, turning the negative feedback into positive feedback and causing oscillation. You'll have to switch off and check the transformer wiring and feedback components (resistors/capacitors).

Making the top cover

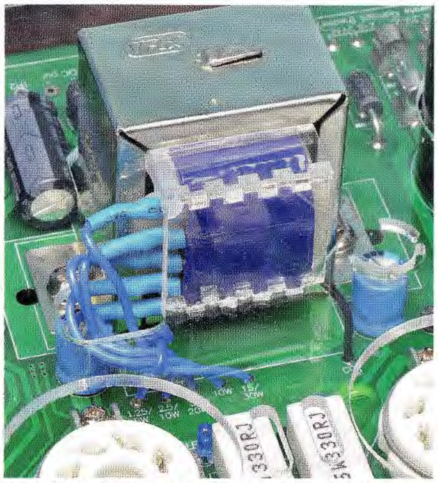
The top cover is vital since contact with some of the components during operation could be lethal. We've designed a clear acrylic top cover to suit the plinth as described last month, so you can still see all the circuitry while keeping it safe. It also helps to keep dust and dirt off the board (although



This is the laser-cut clear acrylic top cover for the main PCB assembly (the white colour is a reflection). Not shown are the front cover and the four pieces that are attached as shield plates to guard the output transformer connections. Acknowledgements: we'd like to thank Ada Lim and the people at Sydney hackerspace "Robots & Dinosaurs" for their help with the laser cutter.



The two shield plates for each output transformer are glued together at right angles and then glued at right angles to the main cover. Some neutral-cure silicone is also used to provide further protection and to help hold the acrylic shield plates in place.



Another close-up view of the output transformer shield. Don't leave this shield out – the transformer terminals operate at 308V DC so it's an important safety feature.

not entirely, since there are cooling slots cut into it).

Technically, acrylic plastic is polymethyl methacrylate and is sold (with some variations in the formulation) under several brand names, including Plexiglas, Perspex and Lucite.

The cover panel likely won't be included in any kits but you can purchase it direct from SILICON CHIP (eg, via our online shop). Alternatively, if you have access to a laser cutter with a bed of at least 300 x 300mm, you could cut it yourself. The cutting file is available on our website in various formats including DXF, SVG and PDF (as a free download for subscribers).

We used a laser cutter with a 50W CO_2 laser and found that we got good results cutting the 3mm acrylic using two passes at 50% power.

Once you have your cover, check which way around it goes (the cutouts are not symmetrical), then slip it over the top of the assembly to make sure that it fits in place and that the plinth mounting holes are not too far out of their expected positions. Leave the protective film on for the time being. **If you're using valves with large envelopes (eg, KT66s) then you may have to remove them in order to fit the cover.** 6L6s can be left in place. Push it down until it sits on top of the low-profile 39µF capacitors.

If it won't go all the way down, chances are you haven't positioned transformers T3 & T4 in the middle of their mounting locations. It's possible to carefully loosen their mounting screws, just enough to move the transformers, then tighten them again without having to remove the board.

Now remove the cover and peel the protective film off the five pieces to be glued. These all have crenellated edges (like a castle rampart, with a series of square protrusions). **While super glue (cyanoacrylate) is suitable for gluing acrylic, we strongly recommend that you use a proper, solvent-based adhesive as this will give a much stronger bond.**

We used SciGrip Weld-On 16, fast-setting "clear, medium-bodied solvent cement". This states on the label that it's suited for Butyrate, Polycarbonate, Styrene and Acrylics. You are unlikely to find this type of adhesive in a hardware store but should be able to get it from a plastics supplier. Ours came from Plastix [Sydney (02) 9567 4261; Sydney Northern Beaches (02) 9939 0555].

This forms a strong bond quickly so you only have about 30 seconds to mate the pieces and ensure that they are square before it's too stiff to manipulate. Full strength is achieved after about 24 hours. The bond is clear but you don't want to get excess adhesive on the material as it will affect the surface finish and you definitely don't want to drip it on the cover. It tends to get a bit "stringy" (sort of like melted mozzarella) after coming in contact with the acrylic.

In fact, to give yourself the best chance of getting a clean-looking bond, we'd recommend squeezing some of the adhesive out onto a smooth piece of timber or metal (not plastic!) and using a small paintbrush (hair, not Nylon) to apply it to the acrylic. This makes it easier to control how much you are applying compared to using the tube directly. You'll also need a clean rag on hand.

Start by gluing the two pairs of transformer shield plates together. Before applying any adhesive, figure out which surfaces will be in contact (they are on two faces). That done, apply a thin layer of adhesive to all those surfaces, then press the two pieces together. Make sure that they are at a 90° angle and that the tabs are fully inserted into the slots. Wipe off any excess adhesive and be careful not to get it on areas of the acrylic away from the join.

You can then lay the part on its side to cure. Do the same for the other identical piece. Note that while there are two different orientations in which these pieces can be glued together, it doesn't matter which way you do it as they are symmetrical.

Once you've done those, you can move onto gluing the front and top sections together. This is a much larger join but the technique is basically the same. **However, the orientation does matter in this case – be sure to glue the front section on such that when the cover is in place, it hangs down rather than sticks up.** Acrylic adhesive is very strong so if you get it wrong, you probably won't be to get them apart

This view shows the amplifier with the acrylic cover in place. It provides an attractive finish while protecting against dangerous voltages. Note that the output valves get hot so be sure to place the amplifier away from young children and where there is plenty of ventilation.

Before Switching On

- Check that the IEC socket's Earth pin is connected to all exposed metalwork.
- Check the isolation between the Active & Earth pins and Neutral & Earth pins of the IEC socket.
- Check the output transformer and mains switch insulation. The output transformer terminals must be fully insulated with a double layer of heatshrink.
- Don't touch any parts if the unit is being tested without the cover.
- Be sure to fit the cover when testing is complete.

again without breaking something.

Again, it's important to make sure that the sections are at right angles and pushed fully together to get a neat result. You will need to peel away the protective film from the top cover near the front but it's a good idea to leave it in place on the rest of the panel to protect it during gluing. The best way to do this is to peel back the film around the area to be joined and then use a pair of scissors to cut a strip of it away, so the rest can be laid back down on the surface.

Once you've joined those parts, leave it for a few minutes and it should then be strong enough to allow you to glue the two transformer cover pieces prepared earlier into the crenellated sections at the front of the transformer cut-outs. Glue the pieces in so that the horizontal pieces at the top project out over the cut-out areas in the top cover below (ie, not pointing towards the front of the panel).

Fitting the top cover

While full strength won't be achieved for 24 hours, the joins should be strong enough after about 10 minutes to allow you to (carefully) fit the cover to the amplifier. Again, if using KT66s or other valves with envelopes larger than the 6L6s, remove them first.

Lower the cover until it's resting on top of the five low-profile capacitors. Take care to avoid touching the underside as this may leave visible fingerprints. If you do get fingerprints, polish them off with a soft cloth.

You may need to push down on it gently but firmly to get it to go all the way down. If it won't go, re-check the positioning of T3 and T4 and move them slightly if necessary.

You can then mark out the seven mounting hole positions around the perimeter of the cover and drill 2mm pilot holes a few millimetres deep in each location. You can remove the cover to do this if you want to (which makes it easier to remove the resulting wood particles), however it isn't strictly necessary.

Next, peel the protective film off seven of the small doughnut-shaped laser-cut pieces. Once you've cleared the area around each hole, slip these "doughnut" spacers under the cover and push them into place (eg, using a screwdriver). You can then feed a 4G x 12mm self-tapping screw in from the top and do it up until the top panel is resting on the spacer. You may want to do up all seven screws loosely and then slightly adjust the top cover position before making them all tight to hold it in place.

All that's left now is to squeeze a small bead of neutral-cure silicone sealant into the gap at the upper-left corner of each output transformer. This helps hold the acrylic covers in place and also prevents small fingers or other objects from being pushed into this gap (see photo). The easiest way to do this is to cut a thin strip of plastic from a take-away container lid or similar, place a bead of silicone on the end and use it like a trowel to push it into the gap and wipe off any excess.

Once it has all dried you can plug the valves back into their sockets and the amplifier is ready to go! **Note that the output valves get hot in operation so be sure to place the amplifier where there is plenty of ventilation.** SC

Modifying the Currawong Valve Amplifier ... is it worthwhile?

By Allan Linton-Smith & Leo Simpson

While the Currawong amplifier has created a great deal of interest, some readers would like to see it with improved frequency response, better output transformers, more expensive valves and so on. We have investigated a number of these possibilities and you can judge for yourself whether all or any of the modifications discussed are worthwhile.

MOST READERS would regard the output transformers we used as looking physically puny compared to the much larger transformers fitted to valve amplifiers in the "olden days" and we would have to agree. So could bigger and better output transformers improve the performance? Possibly.

Before we had a look at that topic we had to address a query about the low-frequency response of the Currawong. As depicted in the graph of Fig.5 on page 38 of the November 2014 issue, the frequency response had a slight upturn at around 20Hz. Some people blamed this on the relatively small 100µF capacitors at the cathodes of the 6L6 output valves.

These supposedly did not allow sufficient decoupling at the lowest frequencies and the gain climbed slightly as a result. We did not agree with this contention for the following reason: increasing the cathode bypass capacitors will actually increase the low frequency open-loop gain but the effect of negative feedback will be to negate this anyway, and it will therefore have negligible effect.

Thus, we ran the frequency response test with an 8-ohm load again and compared the response with 100µF and 200µF capacitors (ie, with another 100µF in parallel) bypassing the 330Ω cathode resistors. Fig.1 shows the results and as expected, there is negligible difference in the two curves.

By the way, these curves are even flatter than those originally published in the November 2014 issue and we can only put this down to a slightly different valve line-up and wiring layout in the final prototype of the amplifier. We should also point out that, as in any

The Hashimoto HW-40-5 is much larger, heavier and more expensive than the Altronics M1115 line transformer. While its frequency response is flatter above 3W, the M1115 actually provides substantially lower distortion over most of its frequency range. This is likely due to its use of grain-orientated steel in the core

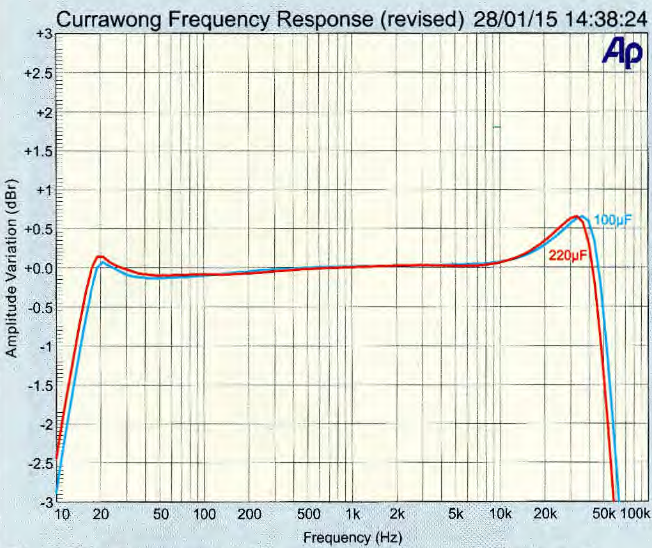


Fig.1: the Currawong frequency response as designed (blue) and with extra output stage cathode resistor bypass capacitance (red).

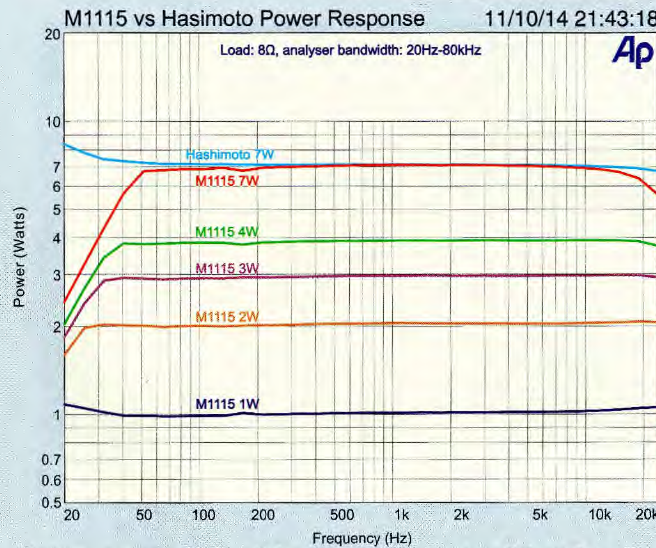


Fig.2: a comparison of the power response of the M1115 and Hashimoto transformers in the Currawong at various power levels.

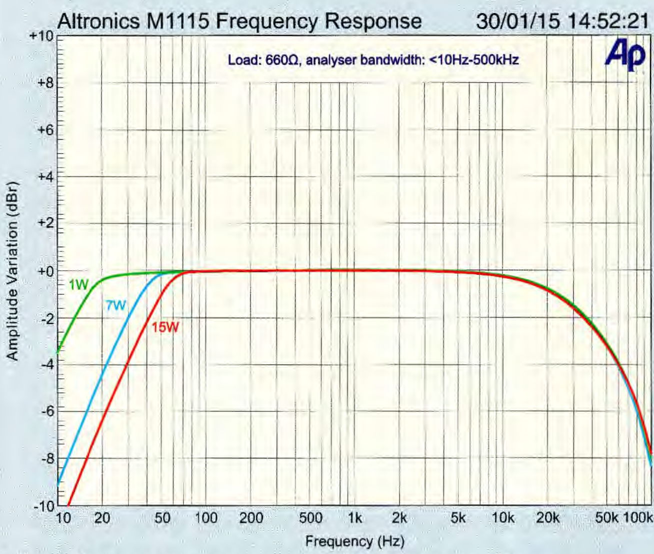


Fig.3: frequency response of the M1115 transformer operated open loop into a 660Ω resistive load. The load resistance gives 15W at its design output voltage of 100V.

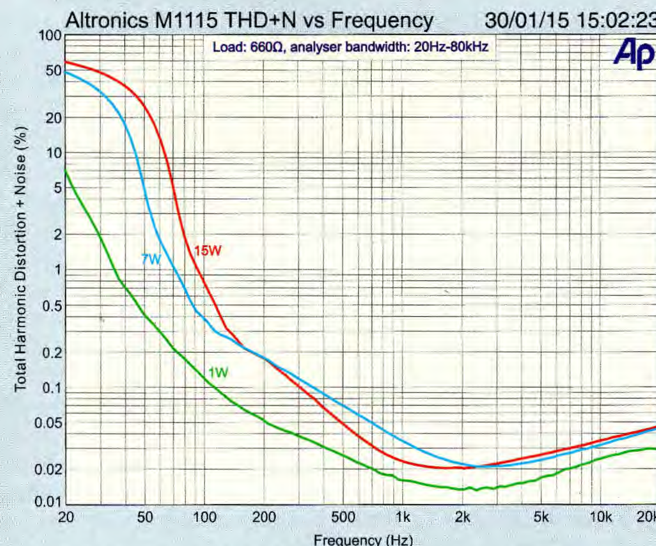


Fig.4: distortion of the M1115 transformer with the same set-up as in Fig.3. The distortion is quite low at 1W but increases at higher power levels and lower frequencies.

typical high-performance valve amplifier, the Currawong needs to run for at least half an hour before it produces the best performance.

Now to the question of the output transformer. A number of readers have pointed out that we should have published power response curves for the Currawong as these would soon throw up the deficiencies of the Altronics line transformer.

Hence we have prepared a series of power response curves and compared these to a highly regarded substitute transformer, the Hashimoto HW-40-5, made by Hashimoto Electric Ltd in Tokyo, Japan (available at more than US$700 for a pair). The frequency response claimed by the manufacturer is flat from 10Hz-60kHz ±0.1dB and it has an input impedance matched specifically for 6L6 valves of 5kΩ and output taps at 4Ω, 8Ω and 16Ω. It is suitable for amplifier powers up to 40W.

These transformers weigh 2.4kg each and are far too big and heavy to be mounted on the Currawong PCB, so they were externally mounted with longer leads.

Fig.2 shows a number of power response curves run with the Altronics transformer and one with the Hashimoto transformer at an output power of 7W into an 8-ohm load. Looking at the curves, the Altronics transformer does lack bass power at higher levels but is quite adequate up to about 3W RMS whereas the Hashimoto transformer has a flat power response down to below 20Hz.

The Hashimoto transformer was also tested for frequency response at various power levels up to 20W without negative feedback. Under this condition, the Hashimoto performs much better than the Altronics unit, as would be expected. Given that result, you might expect that the Hashimoto would produce significantly less harmonic distortion when feedback is applied (as in the normal Currawong

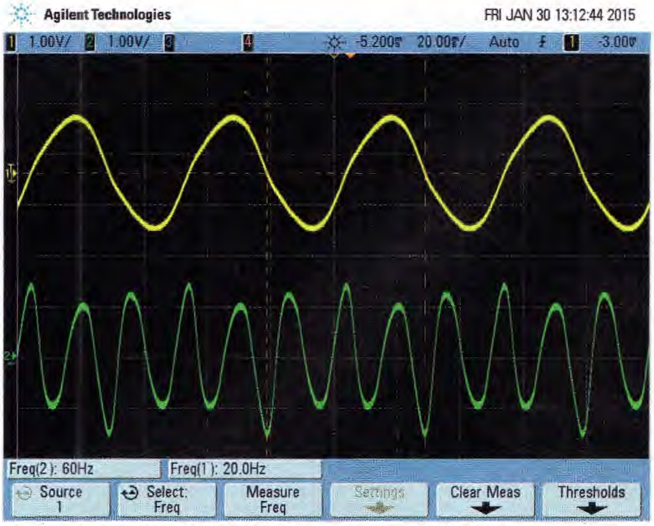


Fig.5: distortion from the Currawong with M1115 output transformers driving an 8Ω load at 20Hz & 1W. The residual is largely third harmonic and while the waveform distortion is clearly visible, it's still somewhat sinusoidal.

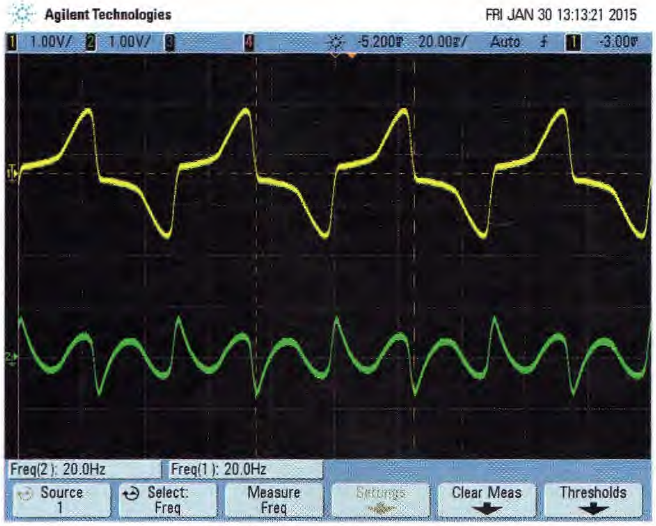


Fig.6: same as for Fig.6 but at 4W. It certainly doesn't look like a sinewave any more! The global feedback is applying maximum bias to try to correct the waveform but the transformer is saturated and it simply isn't possible.

configuration) but surprise, surprise, it turned out that the THD+N at 1W was higher than the cheaper transformer, as shown in Fig.7.

The negative feedback in the Currawong circuit is quite high for a valve amplifier and this will linearise the response and reduce harmonic distortion in the smaller transformer. Hence, the negative feedback was reduced to zero to see if the Hashimoto could do with less and therefore produce more power. It did and the best we could squeeze out of it was 20W but the harmonic distortion was a whopping 20% at 1kHz (with zero feedback).

Subjective listening tests

Subjective listening tests proved that the Hashimoto is a very good transformer but at more than 40 times the price of the Altronics M1115, it really is only marginally better. Of course, both transformers could deliver more power if the Currawong amplifier was run with much higher power supply rails and the circuit bias modified to suit.

However, the cheaper transformer would still be deficient in power response at the low frequency end, simply because its core is not big enough. To illustrate just how good (or bad, depending on your viewpoint), we decided to do a number of tests on the Altronics M1115 transformer when driven by a high-quality solid-state amplifier. In this case, the amplifier was connected to the primary winding and the transformer was used in step-up mode, as a 100V line transformer.

The secondary winding was loaded with a 660Ω 15W resistor (three 220Ω 5W resistors in series). In this mode, the transformer delivers 15W.

Fig.3 shows its frequency response at power levels of 1W, 7W & 15W. As can be seen, it's pretty good at 1W and obviously somewhat deficient at the low-frequency end when driven at 7W or 15W. This is due to core saturation.

The equivalent THD+N curves in Fig.4 reinforce the story and you can see that harmonic distortion rises drastically at the lower frequencies and particularly at high power levels.

To further demonstrate how transformer core saturation affects the low-frequency response, have a look at the scope grabs of Fig.5 & Fig.6. Fig.5 shows a 20Hz signal at 1W with the upper (yellow) trace being the transformer output while the lower (green) trace is the harmonic distortion; predominantly third harmonic at 60Hz.

Fig.6 is significantly worse with a 20Hz signal at 7W. Here the output of the transformer is running well into saturation and the harmonic distortion waveform is quite a bit worse, with more higher-order harmonics. At higher power levels, the story is similar with the distortion climbing to over 60%, as can seen from Fig.4.

Now let's consider the low-frequency power response and harmonic distortion of the Currawong amplifier. This demonstrates the miracle of negative feedback. Without negative feedback applied in the Currawong amplifier circuit, the performance is pretty awful and even with the Hashimoto transformer, it is pretty ordinary. Negative feedback makes all the difference in the Currawong, as it does in any other high-performance valve amplifier.

Next time you read how valve amplifiers can sound good without negative feedback, you will know that the writers are simply ignorant!

Various valves

A quick search of the internet will glean a lot of information, opinions and prices for various valve brands, ages and types. You will also see how many valve aficionados prefer "NOS" valves (New Old Stock) which have been manufactured up to 50 years ago but have never been used (and sometimes in the original box). If you go to **www.tubedepot.com** you will find more than 30 different types of 12AX7 priced from US$11.95 for a basic Electro-Harmonix right up to US$540.95 for a "Black Sable Mullard".

You may well wonder how much improvement you might get from the higher-priced valves. We would advise extreme caution. NOS valves can command high prices but it is very much a case of "buyer beware". Such valves may have been used (definitely not "new"!) and there are even forgeries of the most popular types.

If you have built the Currawong and then start swapping valves you may notice differences between similarly priced valves such as Electro-Harmo-

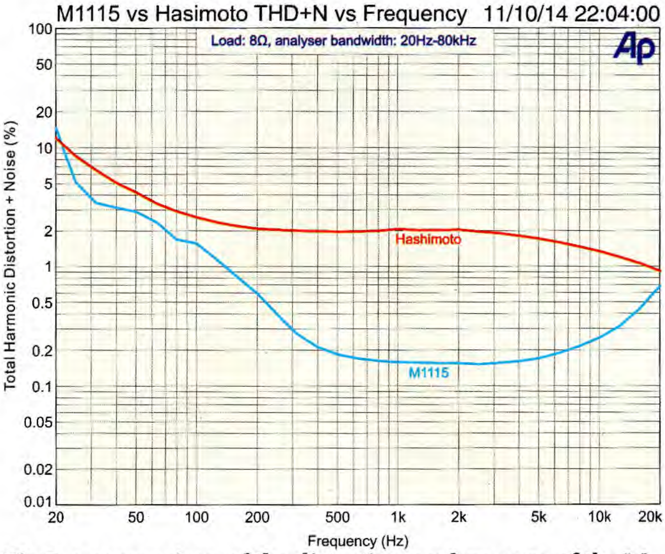


Fig.7: a comparison of the distortion performance of the M-1115 and Hashimoto transformers at 1W without negative feedback. Surprisingly, the M1115 has much lower distortion.

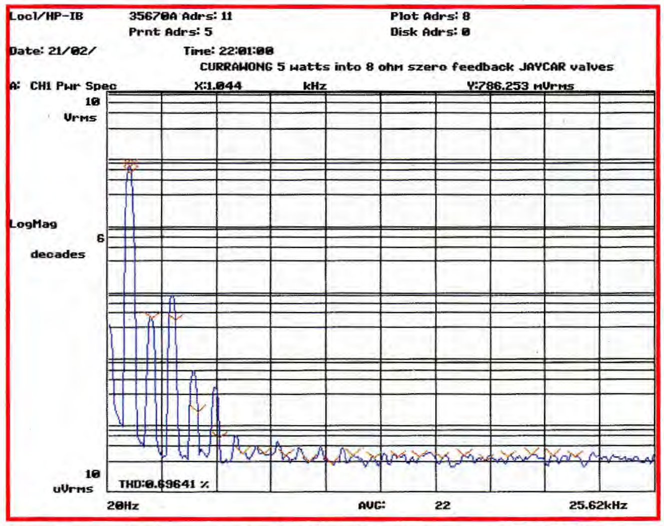


Fig.8: spectral response for the Currawong at 5W into an 8Ω load using the Jaycar-supplied Sovtek 12AX7 valves. The result is slightly different to that achieved when substituting valves from other manufacturers.

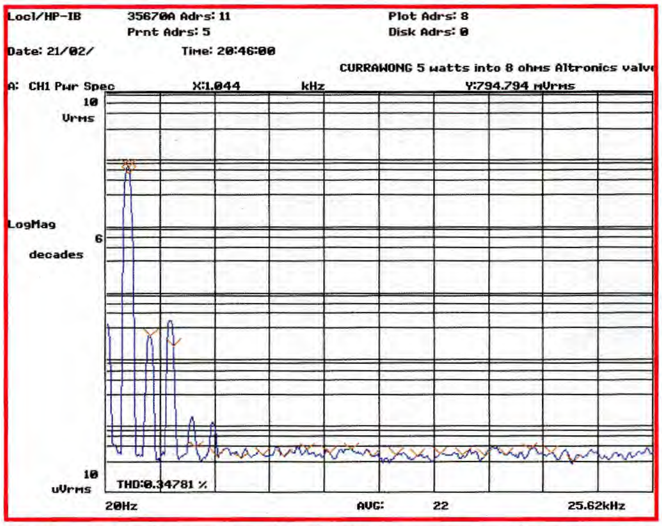


Fig.9: spectral response for the Currawong under the same conditions as Fig.8 but with the Electro-Harmonix 12AX7 valves supplied by Altronics instead.

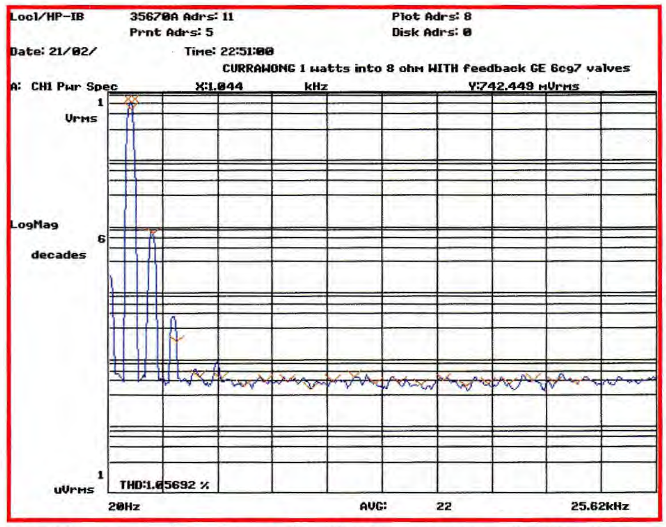


Fig.10: spectral response for the Currawong at 1W using 6CG7 valves but with feedback enabled. Note that these valves require a 6.3V filament supply.

nix (from Altronics) versus Sovtek (from Jaycar). But while these differences may be discernible and you might like one or the other depending on the type of music you prefer, objective tests will show that frequency response and total harmonic distortion are quite similar.

With that in mind, you might discount subjective differences. But it turns out that the differences are real and hence perceptible, which is backed up by the different spectra for these valves. You can see the results in Fig.8 & Fig.9. In both cases, the input signal is a 1kHz sinewave and spectra show the amplitudes of the various harmonics.

Apart from the multiple different brands of 12AX7 and 6L6 valves, you could also try 6CG7s in place of the 12AX7s but then you will need to run the filaments at 6.3VAC, not 12VAC. The 6CG7 is a very linear valve previously used in TVs for vertical oscillators to maintain a non-distorted picture. These valves are now available at Altronics.

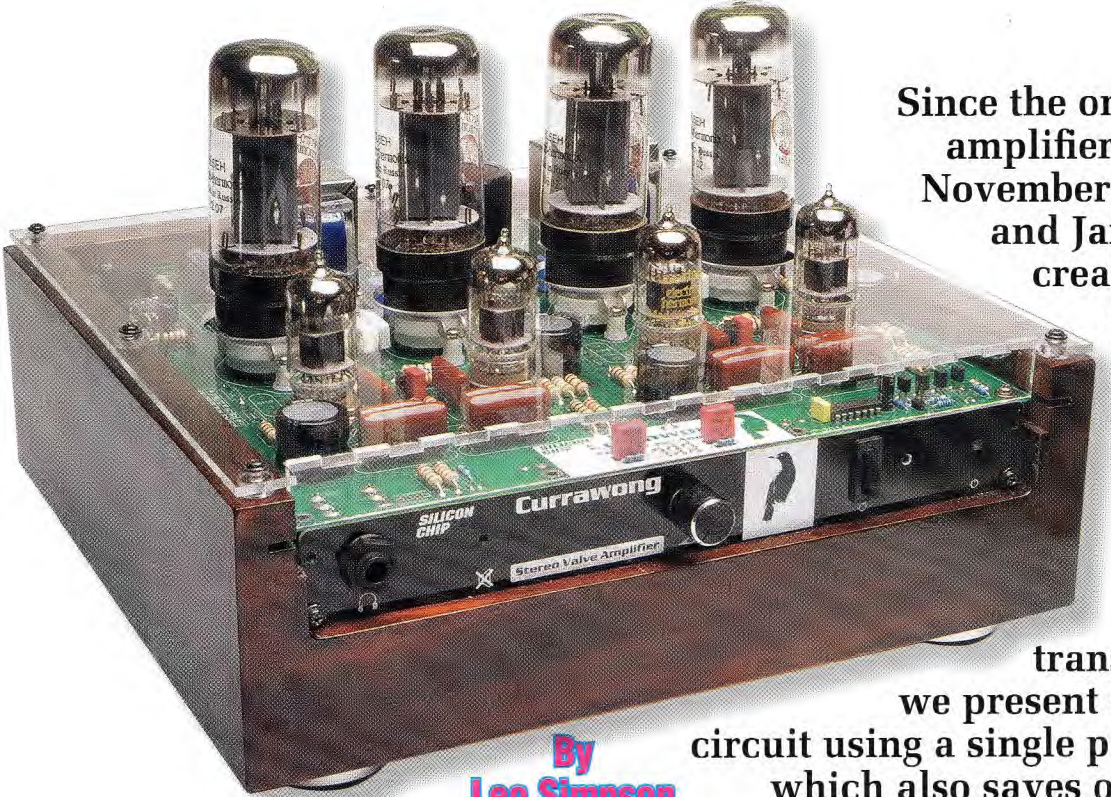
The spectrum for the 6CG7 is shown in Fig.10. Note, though, that this was plotted at a 1W power level and with feedback enabled, in contrast to Figs.8 & 9. So use caution when comparing these results.

There is also the possibility for using KT66 valves in place of the 6L6s. These are significantly bigger and bulkier which does look more impressive. The performance is again very similar but they are more expensive. The Currawong PCB is designed to accommodate them.

Conclusion

We hope that readers now understand that the Altronics M1115 transformer really does deliver quite a respectable performance in the Currawong and especially so, given its low price.

Yes, we could have selected much more expensive transformers but the major increase in cost would simply not be justified in view of the small difference in performance. However, swapping valves to find which ones you prefer can be worthwhile and a lot of fun. **SC**



Since the original Currawong amplifier was published in November & December 2014 and January 2015, it has created quite a deal of interest and those who have built it have been most enthusiastic. However it had a complicated power supply employing two transformers – so now we present a much simplified circuit using a single power transformer, which also saves on the overall cost.

By Leo Simpson

A New Power Transformer for The Currawong 2 x 10W Stereo Valve Amplifier

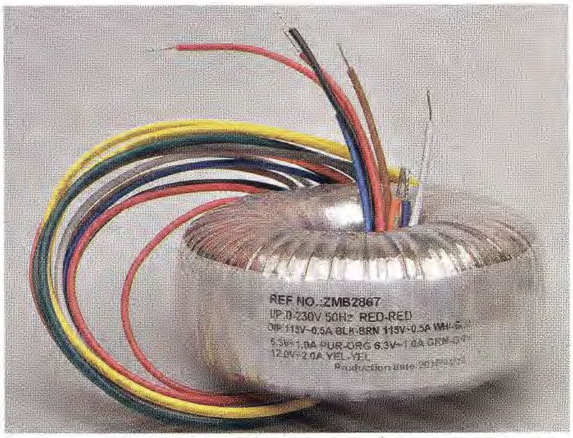
All electronic design work involves maximising performance from the cheapest, readily available components.

That certainly applied to the power and output transformers used in the Currawong stereo valve amplifier. The output transformer used in both channels were actually a 100V audio line transformer with the multi-tapped 100V windings being used to provide an (almost) ultra-linear connection to the plates and screens of the 6L6 beam tetrodes.

It works surprisingly well for a cheap transformer.

And while we would have preferred to use a single transformer in the power supply, the fact was that there simply wasn't a suitable unit available, at the time.

So we ended up using two toroidal power transformers, rated at 160VA and 80VA. We had their secondary windings connected to provide 114VAC for the HT supply and 12V for the series-connected tetrode heaters and the 12V regulated DC rail. This rail runs the heaters for the 12AX7 dual triodes, relay speaker switching and remote control circuitry.



The new 160VA transformer from Altronics. Note that this is a pre-production sample and lead colours in the stock item may be quite different.

New transformer

But the above 160VA transformer has since been discontinued, so we have now arranged with Altronics Distributors (who stock the Currawong amplifier kit) to source a new single transformer which will do the job by itself.

It is a 160VA toroidal unit (Altronics Cat MA5399) with two

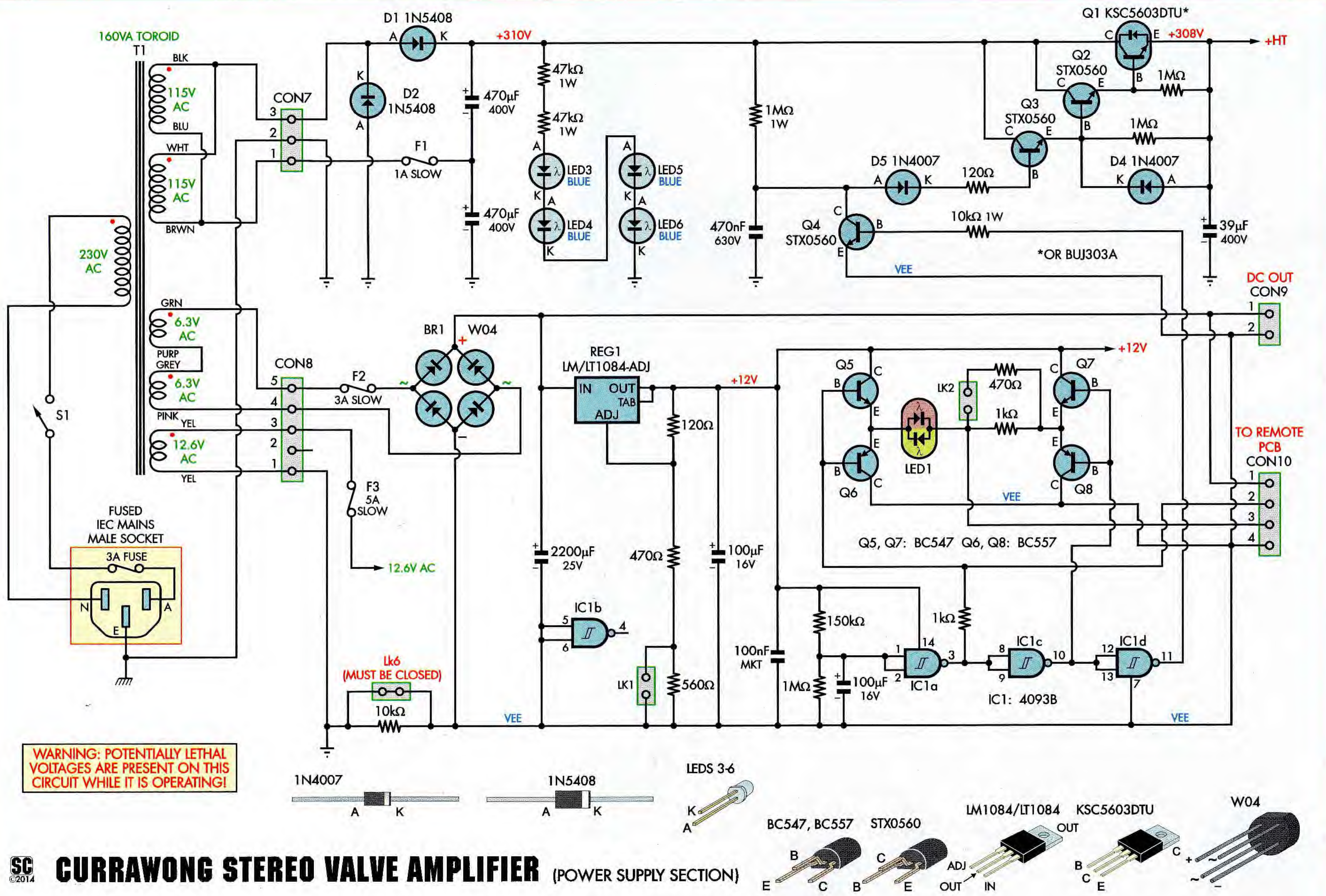


Fig.1: the 115VAC secondaries of transformer T1 are connected in parallel and rectified using a voltage doubler to produce a 310V HT rail. Most of the ripple is filtered out by a capacitance multiplier comprising high-voltage transistors Q1-Q3 and a 470nF polyester capacitor. T1's 12.6VAC secondary drives the 6L6 filaments directly in a series/parallel configuration. The two 6.3VAC windings are connected in series to drive bridge rectifier BR1, a 2200µF filter capacitor and linear regulator REG1 to produce a regulated 12V rail to run the 12AX7 filaments. IC1 provides an HT turn-on delay and soft start.

The new transformer mounted inside the same plinth as held the original two transformers. Again, ensure that any exposed mains wiring (for example, the IEC mains input socket) is properly covered, as shown here. NOTE: Altronics expect this transformer to be in stock from early to mid November.

115VAC 0.5A windings, two 6.3VAC 1A windings and a single 12.6VAC 2A winding. While that may seem like more windings than we actually need to run the Currawong, we have arranged it this way so that the transformer can be used in other applications, of which there are several (see panel).

However, the main game is to run it in the Currawong, as you can see from the power supply circuit shown in Fig.1.

Apart from the transformer connections and the connection for LK6, this circuit is identical the original version published in the November 2014 issue on page 32.

If you make comparisons between the two diagrams you will see that the connections for the new transformer are considerably simplified.

The two 115VAC windings are connected in parallel to pins 1 & 3 of CON7 and thence to the voltage doubler rectifier comprising diodes D1 & D2, together with the two 470µF 400V electrolytic capacitors.

The two 6.3VAC winding are connected in series and go to pins 4 & 5 of CON8 and then via a 3A slow blow fuse F2 to bridge rectifier BR1. The single 12.6VAC winding is connected to pins 1 & 3 of CON8 and then via slow blow fuse F3 to power the series-connected connected heaters of the 6L6 beam power tetrodes.

No change needs to be made to the componentry on the main PCB except for the fact that link LK6 must be fitted (the 10kΩ resistor that it shorts out can be omitted if you wish).

Wiring it up

Fig.2 shows the much simplified wiring inside the timber base of the Currawong and you should compare it with the photo on page 93 of the December 2014 issue, which shows the same details.

The transformer should be located as shown in the wiring diagram and in the photo. Leave enough room between the transformer and rear panel so that you can later reach behind the main PCB as it's being slid in and plug the various connectors into the underside (this requires more clearance than is available above the transformer).

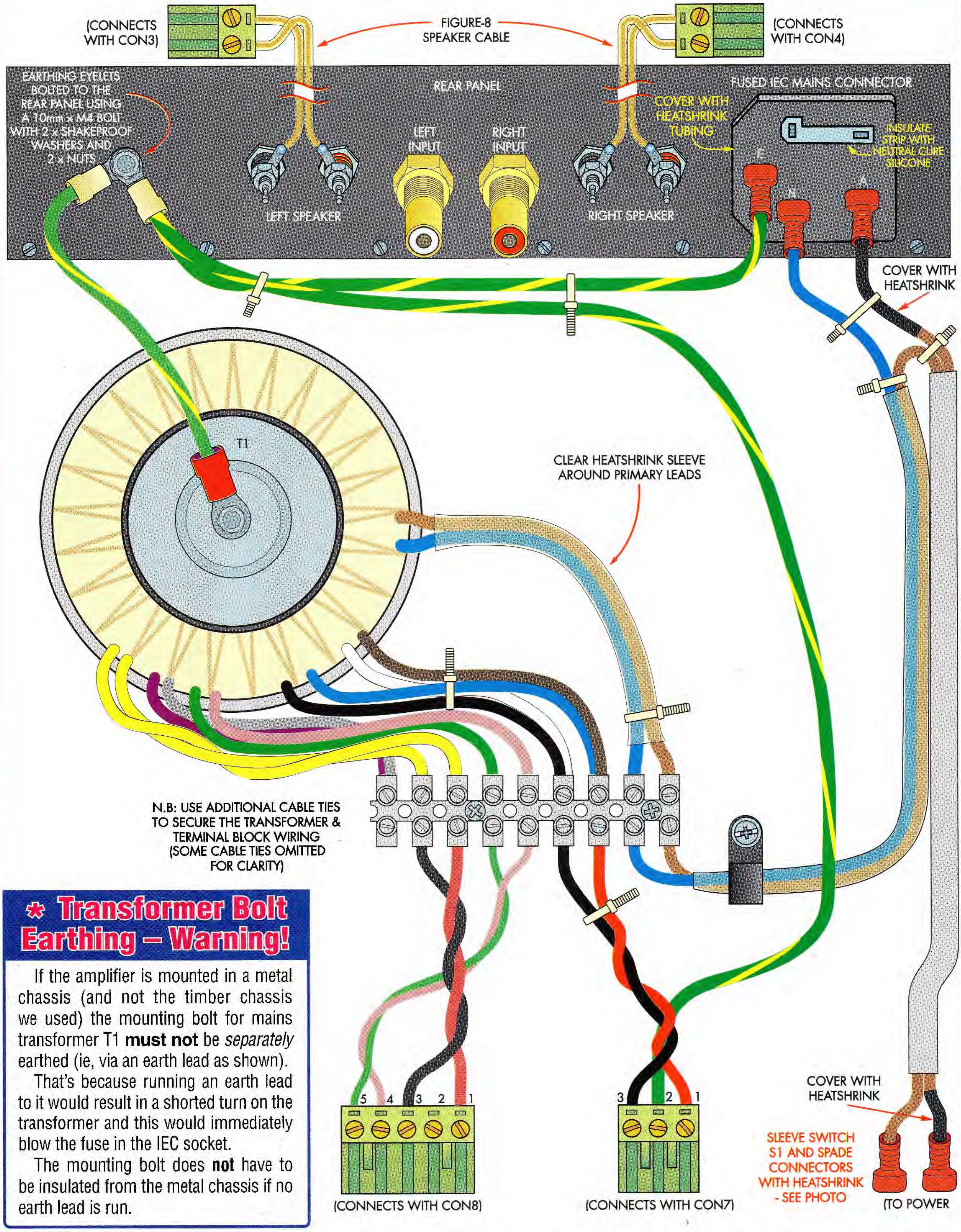
We suggest a gap of no less than 60mm between T1 and the rear of the case. In practice, this means positioning the transformer mounting bolt so that it is approximately 120mm from the back edge of the plinth (ie, about 100mm from the inside rear edge).

Mount the transformer using the supplied rubber mounting washers, metal plate and washers via a 6mm hole drilled in the bottom of the plinth but do not tighten nut at this stage.

Then position the 9-way terminal block, as shown in Fig.2. Use two 12mm self-tapping screws to hold it in place, as shown.

Wiring colours

It is important to note that the colours of the transformer connection wires shown in Fig.1 and Fig.2 are those on our pre-production trans-



* Transformer Bolt Earthing – Warning!

If the amplifier is mounted in a metal chassis (and not the timber chassis we used) the mounting bolt for mains transformer T1 **must not** be *separately* earthed (ie, via an earth lead as shown).

That's because running an earth lead to it would result in a shorted turn on the transformer and this would immediately blow the fuse in the IEC socket.

The mounting bolt does **not** have to be insulated from the metal chassis if no earth lead is run.

Fig.2: the Currawong wiring diagram with a single power transformer. Compare it closely with the transformer wiring in the circuit of Fig.1. Note that the IEC socket must be covered with heatshrink tubing (see photo). This diagram assumes a *timber* cabinet as per our prototype – see warning above re earthing if a metal chassis is used.

former. It is likely that these may change in the production transformers which will become available in the month of the November. So while we refer to particular colours in this article, to match those shown in the photo, it is important to look at the labelling of the supplied transformer to identify the particular winding colours.

For example, although our prototype transformer had two red wires for the 230VAC primary winding, it is likely (and preferable) that the production version will have blue and brown wires.

With that in mind, cut a length of 5mm diameter clear heatshrink tubing to cover the entire length of the primary winding wires, except for about 10mm at the ends. Then shrink the tubing down. Bend the wires so they run as shown on the wiring diagram and terminate them in the terminal block.

Now, twist the four 115VAC secondary wires together (black/blue and white/brown). This will help to minimise the radiated hum and buzz fields. Join the black and white wires together and connect them to one of the terminals of 9-way terminal block. Then do the same with the blue and white wires. Doing it in this way means that both 115V windings have the starts and finishes connected together. If you don't do this right, one winding will effectively short the other and the transformer would very rapidly overheat and (hopefully) blow the fuse.

On the other side of the 9-way terminal block, the 115VAC red & black wires are terminated at pins 1 & 3 of the green connector which mates with CON7 on the main PCB.

Now twist the four 6.3VAC wires (green, purple grey & pink) together in the same way and connect to the 9-way block. The green and pink wires provide 12.6VAC to pins 4 & 5 of the green connector which mates with CON8 on the main PCB. Then twist the yellow 12.6VAC wires together and connect to the 9-way block. These provide 12.6VAC to pins 1 & 3 on the same green connector.

Once all the wires are in place, measure the resistance between pins 1 & 3 on the CON7 connector.

You should get a reading of about 5Ω. There should be an infinite reading between pins 1 & 2 and pins 2 & 3.

Similarly, between pins 1 & 3 and pins 4 & 5 on the CON8 connector, you should get a very low value; less than 1Ω.

Any higher readings than these suggests at least one wire is not making good contact in the terminal block, so go over them again.

From this point on, you can follow the original wiring and assembly instructions which were featured in the December 2014 issue of SILICON CHIP.

However, before making connections to the main PCB via CON3, 4, 7 and 8, we suggest that you connect power to the transformer and check the voltages present at the green connectors for CON7 & CON8.

Remembering that the transformer has no load at this stage and assuming a mains input voltage of 230VAC, you should have about 127VAC at pins 1 & 3 of CON7 and 13.7VAC or thereabouts at pins 1 & 3 and 4 & 5 of CON8. **SC**

What else can you use this transformer for?

As described in the main article, the prime application of this new 160VA toroidal transformer is to power the Currawong valve amplifier. But it's quite a versatile transformer, offering a variety of other applications – nothing to do with the Currawong! Some of its possible uses include:

An Isolation Transformer

Fig.3(a) shows it with the two 115VAC windings connected in series so it can be used as a standard isolation transformer (ie, where you need to keep the device isolated from the mains supply) with a rating of about 150VA.

A Stepdown Transformer for 115V Equipment

Fig.3(b) shows it with the two 115VAC windings connected in parallel so it can be used as 230VAC to 115VAC transformer to run equipment rated up to about 150VA.

A Voltage Adjustment for High (or Low) Mains

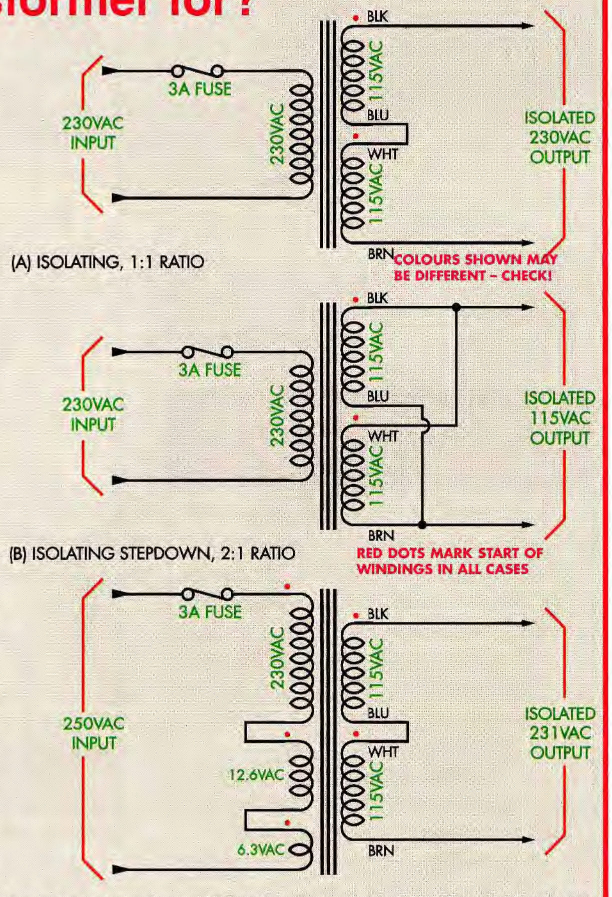
Fig.3(c) shows it with one 12.6VAC winding and one 6.3VAC winding connected in series across the incoming mains (primary) winding and with the two 115VAC windings connected in series.

You would use this connection if your mains voltage is very high at around 250VAC or more and you want to improve the reliability of connected equipment by running it at a much safer 230VAC, or thereabouts.

This arrangement can yield other voltages, eg, by using only one of the 12.5VAC or 6.3VAC windings in series with the primary (to yield a slightly higher output voltage than shown here) or connecting one or more of the low voltage windings in series with the 115VAC secondaries to step up the output voltage (eg, if you have a consistently low mains voltage).

However, you must ALWAYS check (carefully!) that you have the phasing of the windings correct – if the transformer gets hot or hums loudly, chances are they're wrong!

Above all, remember that you are dealing with lethal voltages!



As noted elsewhere, the Altronics catalog number is MA5399 and its recommended retail price is $79.95 including GST.