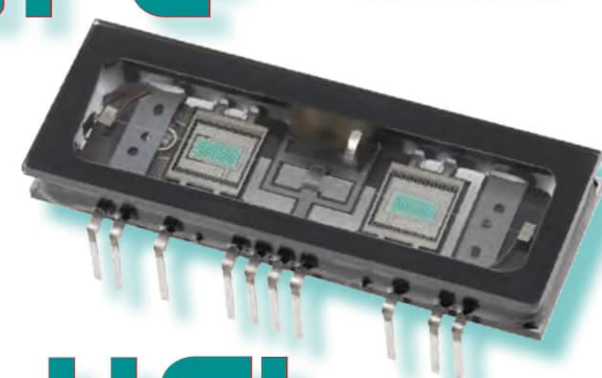
A "RETRO" DESIGN THAT'S AS MODERN AS TOMORROW . . .

"Nutube" miniature valve stereo preamplifier

by
John Clarke



Valves are old hat, right? Not any more, they're not! Korg and Noritake Itron of Japan recently released their Nutube 6P1 twin triode. Its party trick is a very wide range of operating voltages, from just a few volts up to 200V, and meagre power consumption. That makes it ideal for a battery-powered stereo preamplifier. You'll enjoy the sound as well as the retro green glow!

Are you one of those people who simply "loves" the nostalgic sound of valves, both in power amplifiers and preamps? But valves are relatively expensive, and the high-voltage power supplies typically required make building a valve preamp a bit of a pain.

However, at least the part is no longer true with Korg's Nutube 6P1 twin-triode. It works perfectly fine with a plate voltage of just 6-12V, and the heater power and voltage requirements are also modest.

So building a preamp around it is a cinch, and it's a suitable project for beginners and shool students, as there are no dangerous voltages involved.

(In fact, for this reason alone we anticipate that this will be a very popular student project, right up to and including their "major work").

Even if you have built valve gear with high voltage supplies before, we think you will find the unusual construction of the Nutube 6P1 dual triode quite fascinating.

We've taken some care with this design, so that it fits into a very cool (and professional) looking extruded aluminium case, with the inputs and outputs at the rear and a power switch and volume knob at the front. And of course, we've left a window in the clear front panel so that you can see that "warm" blue tube glow.

One of the fascinating aspects of the Nutube is that it's designed and built similarly to a vacuum fluorescent display (VFD). So the

Specifications

- Power supply: 7-18 VDC; draws 29mA @ 9V DC
- Gain: up to 15dB at maximum volume setting
- Distortion: around 0.07% at 200mV RMS output from 20Hz to 5kHz (see Figs.1 & 2)
- Frequency response: 20Hz-20kHz, +0,-0.6dB; -3dB at about 7Hz & 80kHz (see Fig.3)
- Channel separation: typically >45dB (see Fig.4)
- Signal to noise ratio: 83dB with respect to 270mV in, 2V out, 20Hz-22kHz bandwidth
- Maximum output level: 2V RMS with 9V supply, 2.8V RMS with 12V supply

Yes, it really is a thermionic valve (or tube as the Americans like to say). But this Nutube 6P1, shown here from the underside, is quite unlike any valve you've come across before. For a start, those blue windows (see opposite) really do glow blue!

Features

- Stereo valve preamplifier
- Based on the recently released Korg "Nutube" dual triode
- Visible plate glow
- 30,000-hour Nutube life
- *Safe* low-voltage supply (7-18V DC)
- Low power consumption
- Battery or plugpack powered
- Onboard volume control
- Internal balance and distortion adjustments
- Switch-on and switch-off noise eliminated
- Power supply reverse polarity protection
- No transformers needed
- Inputs and outputs are in-phase

heater glow looks like two green squares, similar to large VFD pixels.

Its performance is pretty good, too. Distortion levels below 0.1% are possible across a wide range of frequencies with a little care during calibration. See the spec panel, Figs.2 & 3 and Fig.12 to get an idea of how well it performs.

This Nutube preamp can run from a DC supply between 7V and 18V, with only a modest current draw. It can also be powered using a 9V battery that is housed within the enclosure.

If you want to be able to switch between signal sources, you can mate this Nutube Preamplifier up with the SILICON CHIP Six-way Stereo Audio Input Selector with Remote Control that we described in the September 2019 issue (www.siliconchip.com.au/Article/11917).

Nutube 6P1 dual triode

Korg developed the Nutube 6P1 in collaboration with Noritake Itron of Japan. While it is a directly-heated triode with a filament, grid and plate connections, its construction more resembles a vacuum fluorescent display (VFD) than a traditional valve (or tube).

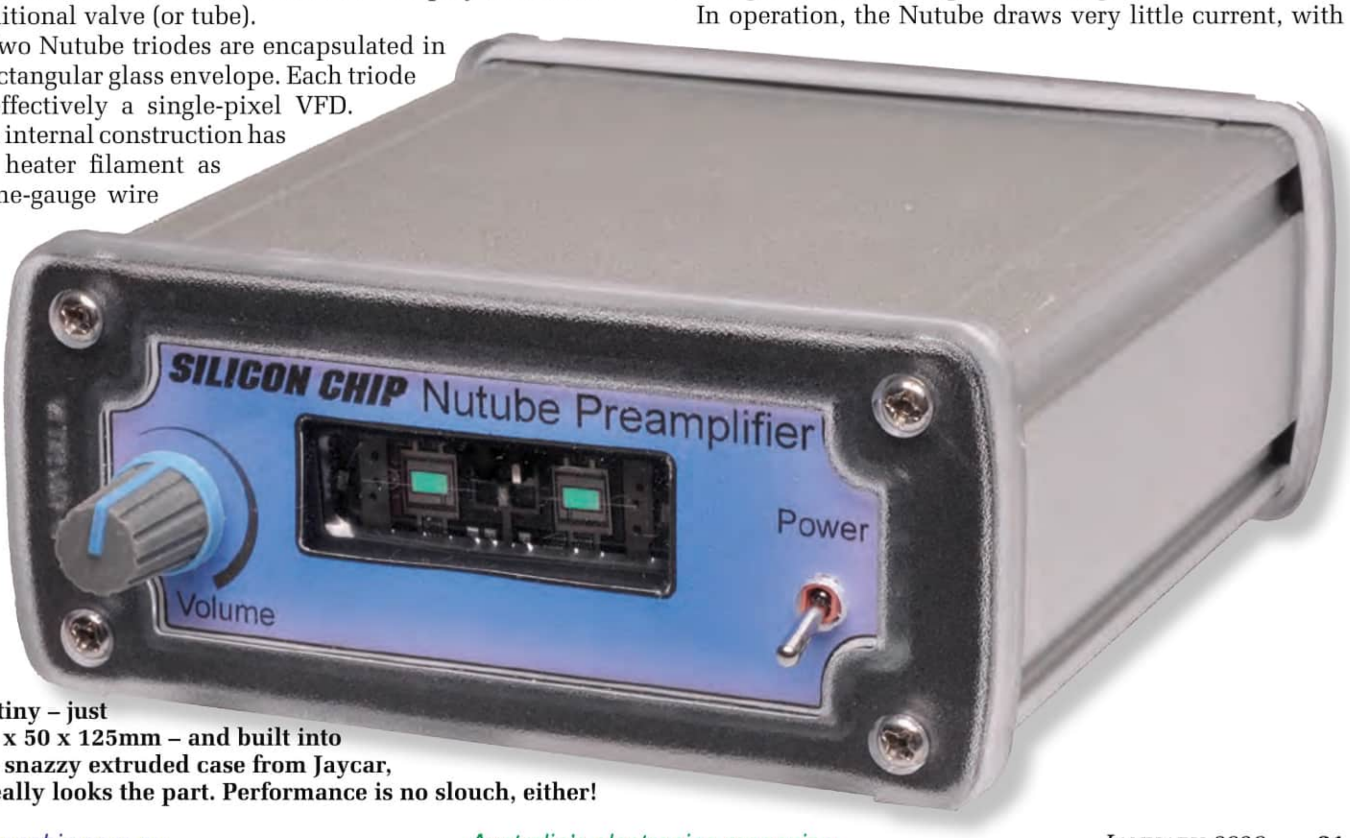
Two Nutube triodes are encapsulated in a rectangular glass envelope. Each triode is effectively a single-pixel VFD. The internal construction has the heater filament as a fine-gauge wire running across the front, with the metal mesh grid located below that. Behind the grid is the plate (also called the anode), which is phosphor-coated and glows when the filament is heated.

The filament wire is held taut, and because of this, it can vibrate similarly to a stringed musical instrument. (The Nutube is, after all, sold by a musical instrument manufacturer).

This vibration is not necessarily a wanted feature, as it can be the source of microphonics – where external sound can couple to the filament and this alters (or modulates) the audio signal being amplified in the triode. The result is that this vibration is heard in the sound output.

The microphonics can be minimised using careful construction methods. This includes protecting the Nutube from surrounding air vibrations, by using flexible wiring and including a vibration-damped mounting.

In operation, the Nutube draws very little current, with



It's tiny – just 115 x 50 x 125mm – and built into this snazzy extruded case from Jaycar, it really looks the part. Performance is no slouch, either!

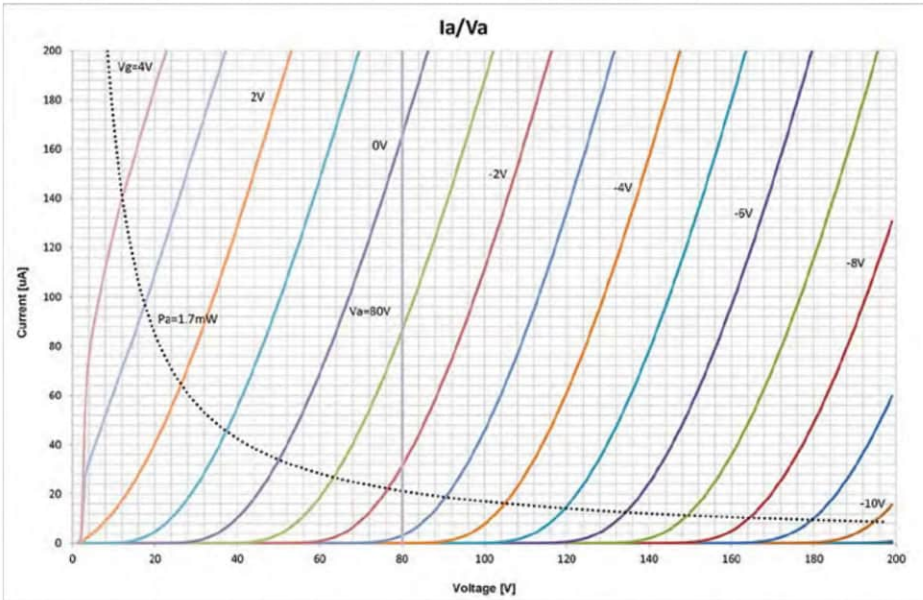


Fig.1: load lines for the Nutube triode showing the relationship between anode (plate) voltage (horizontal axis), anode/cathode current (vertical axis) and grid-cathode voltage (labels on curves). The area below the black dotted line is the continuous safe operation envelope.

each filament requiring just 17mA. Total heater power for the two triodes is around 25mW. The grid and plate current total around 38μA.

The Nutube is best operated with a plate voltage between 5V and 30V, and the load-line curves (Fig.1) reveal that within this voltage range, the grid voltage needs to be above the cathode filament.

This is different from the traditional triode, where plate voltages are much higher, and the grid voltage is usually negative with respect to the cathode.

The Nutube operating point would typically be set so that the distortion from each triode is at a minimum and so that maximum dissipation is not exceeded. To achieve this, our design includes two trimpots to set the grid bias of each triode.

There are three ways to make these adjustments. One is to adjust the trimpots so the Nutube plate glows brightest for each channel, which will generally give good performance.

Another method is to use a signal source and multimeter to adjust the grid bias for maximum output signal level, or better still, by observing the distortion products and setting each trimpot for the desired result.

Freely-available computer software can be used to measure the distortion and view the waveform. This allows for easily setting up the desired distortion characteristic. We describe what software you need and how to use it in a panel later in this article.

Preamplifier performance

Fig.2 shows the total harmonic distortion plus noise (THD+N) figure as a percentage, plotted against frequency and output level. As you can see from Fig.3, the performance is best with an output level in the 100-400mV RMS range.

This is a typical level that you might feed into a 100W (or thereabouts) stereo amplifier to get a reasonable listening volume. Such an amplifier would generally have a full power sensitivity between 1-2V RMS.

Below 100mV RMS output, noise starts to dominate the THD+N figure. In other words, preamp performance at lower volume levels is limited by its 83dB ultimate signal-to-noise ratio (SNR). Above 400mV RMS, triode non-linearities dominate.

The rise in distortion with frequency is mild, with THD+N only increasing by about 50% between 1kHz and 10kHz. The

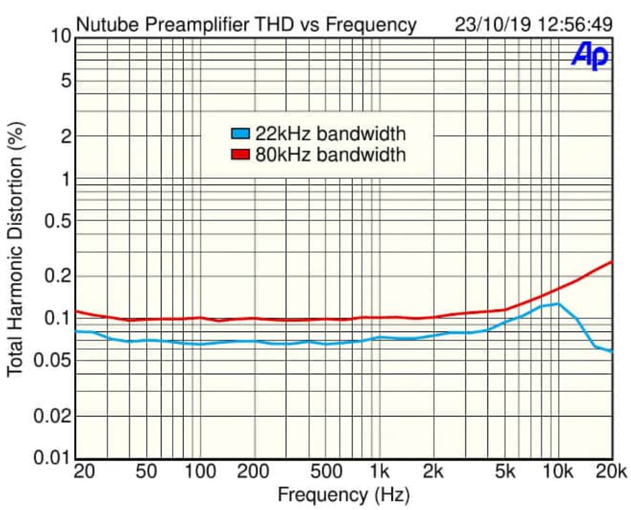


Fig.2: a plot of total harmonic distortion, including noise, against signal frequency. These measurements were made at about unity gain, with around 200mV RMS in/out, and with two different filter bandwidths. The blue curve (20Hz-22kHz) includes the distortion products and noise which are audible to the human ear, while the red curve (20Hz-80kHz) includes higher harmonics for more realistic readings at higher frequencies (8kHz+).

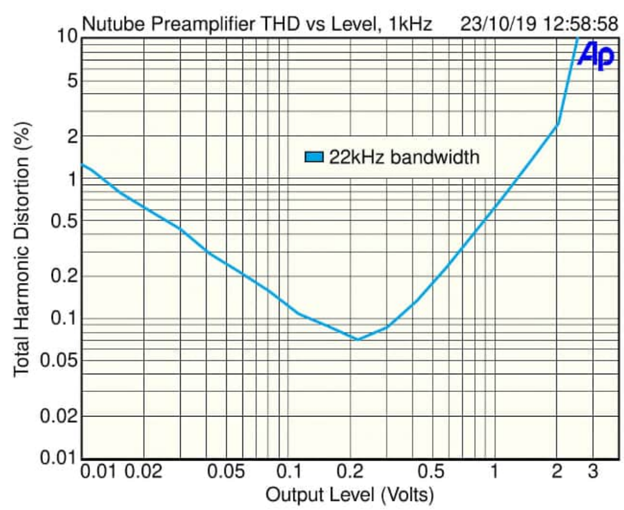


Fig.3: distortion plotted against output level. This graph demonstrates that the output level is the largest determining factor in the preamp's distortion performance. At low levels, noise begins to intrude, while at high levels, the waveform shape gets 'squashed' and so distortion increases significantly. The middle section, where distortion is lowest, is the range in which the preamp will generally be used.

measurement shown in red on Fig.2 is with an ultrasonic (80kHz) bandwidth in order to measure the harmonics of higher test frequencies.

The blue trace gives a most realistic measurement up to about 10kHz, then falls off due to the 22kHz filter limit cutting out the harmonics.

You may wish to compare Figs.2 & 3 to Fig.12, which shows a spectral analysis of the distortion at 1kHz and around 200mV output.

As you can see from Fig.12, this method of reading the distortion gives much the same result as the Audio Precision system used to produce Figs.2 & 3.

Fig.4 demonstrates that the preamp has a very flat response, with no peaks or wobbles. The output is down well under 1dB by 20Hz at the bass end, and an even smaller fraction of a decibel by 20kHz at the upper end. This plot has an extended frequency range of 10Hz-100kHz so you can get an idea of the actual -3dB points.

Fig.5 shows the channel separation. This is produced by feeding a signal into the right channel, monitoring the left channel output level and sweeping the test signal across the audible frequency range. The channels are then swapped, and the test is repeated.

As you can see, there is more coupling from the right channel to the left, and the separation figures are not amazing, at around 45-68dB.

However, this is more than good enough for a stereo system, and sounds panned entirely to the left or the right will still appear to be coming from just one speaker.

Fig.6 is a scope grab showing the output of the preamp (at the top, yellow) at around 200mV and 1kHz, with the ~0.07% residual distortion signal below, in blue. You can see that this is primarily third harmonic, with some second harmonic.

Fig.7 shows the much higher-level distortion present in the output if the triode is adjusted further away from its ideal operating point. This is around 0.3% THD+N, the majority of which is second harmonic distortion.

Fig.8 shows the noise residual when the output level is much lower. This is a fairly typical wideband white noise signal.

Circuit description

The full circuit is shown in Fig.9. One of the triodes in the Nutube provides amplification for the left channel (V1a), while the other triode is used for the right channel (V1b). These are connected as common-cathode amplifiers, where the cathode filament is referenced to ground. The signals are applied to the grids, and the resulting amplified signals appear at the corresponding anode (or plate).

The anode loads are 330kΩ resistors from the positive supply, with 150Ω/100µF low-pass filters to prevent supply noise from reaching the anodes.

The Nutube triodes have relatively low input impedances at the grids and high output impedances at the anodes, so op amp buffers are used at both ends. IC1a and IC2a ensure that the grids are driven from low impedances. IC1b and IC2b minimise the anode loading, as they have very high input impedances of 600MΩ, which is effectively in parallel with 1MΩ resistors.

These op amps have very low noise (3.3nV/√Hz) and distortion (0.00006% @ 1kHz & 3V RMS) figures when operated at unity gain. Therefore, these op amps do not affect the sound of the signals. The properties of the Nutube triodes dominate any effect that the op amps have on the signals.

We'll now describe the signal path in more detail, but only for the left channel, as both channels are almost identical. The input signal is fed in via RCA socket CON1a and passes through a 100Ω stopper resistor and ferrite bead (FB1). These, in conjunction with the 100pF capacitor, significantly attenuate RF signals entering the circuit, which could result in unwanted radio frequency detection and reception.

The signal is AC-coupled to 50kΩ volume control VR1a via a 470nF DC blocking capacitor. This capacitor removes any DC voltage that may be present at the input to prevent pot crackle, and also produces a low-frequency

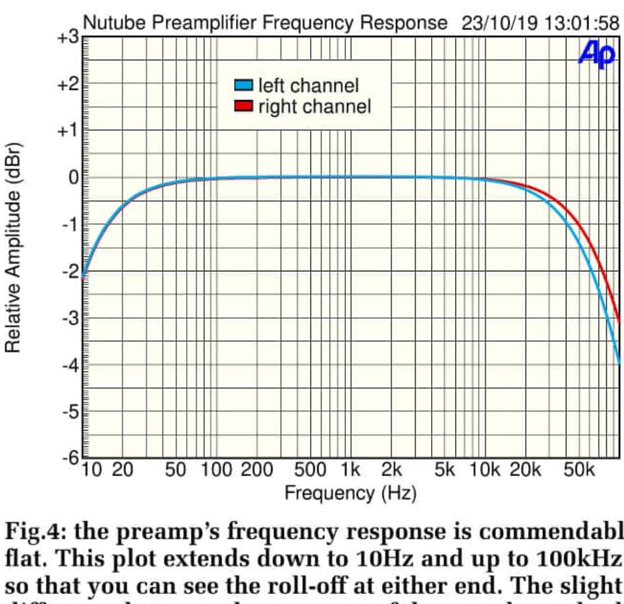


Fig.4: the preamp's frequency response is commendably flat. This plot extends down to 10Hz and up to 100kHz so that you can see the roll-off at either end. The slight difference between the response of the two channels above 10kHz is likely due to slightly different biasing; we had purposefully biased the two channels slightly differently to see the difference in distortion.

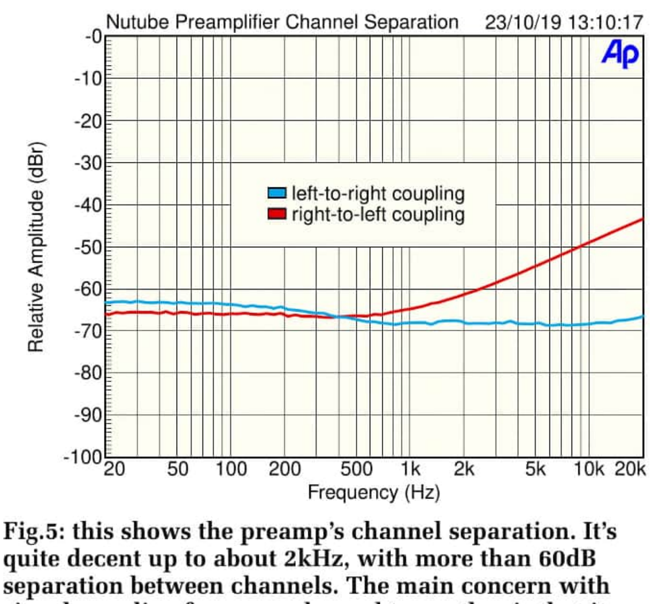


Fig.5: this shows the preamp's channel separation. It's quite decent up to about 2kHz, with more than 60dB separation between channels. The main concern with signal coupling from one channel to another is that it introduces distortion; however, as this is not an ultra-low-distortion device, it isn't that big of a concern. We included this plot mostly for completeness.

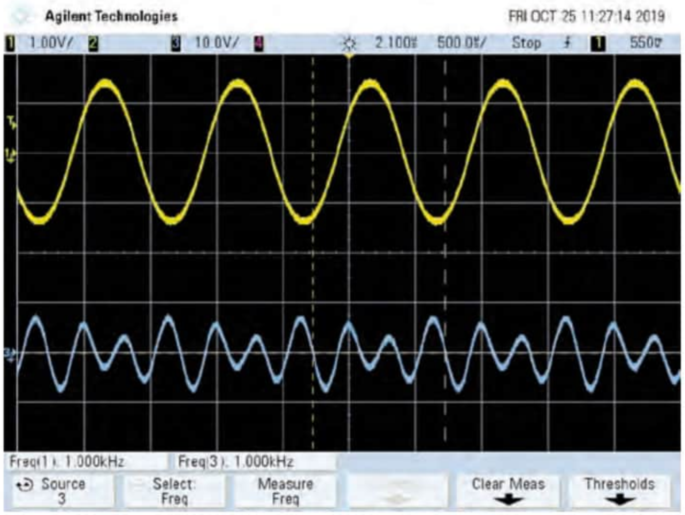


Fig.6: the output of the unit with the triode biasing adjusted for lowest distortion. The yellow trace is the output signal, while the blue trace is the distortion residual (ie, the yellow trace with its fundamental removed). It contains significant second and third harmonics.

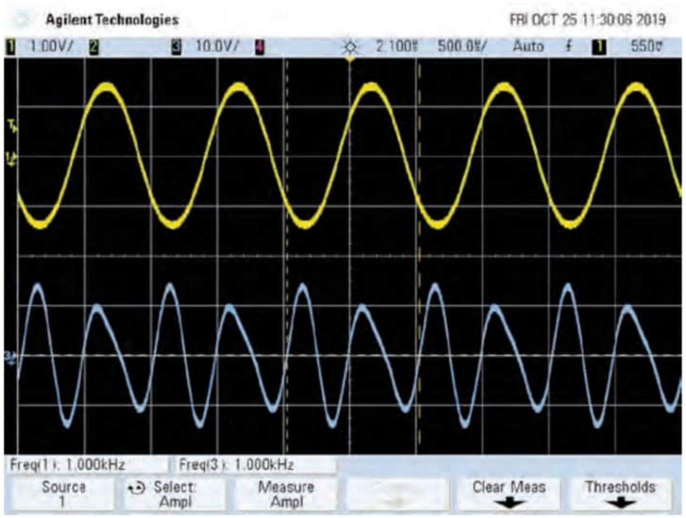


Fig.7: this plot is the same in Fig.6, but the triode biasing has been adjusted away from its optimal condition. Total harmonic distortion has risen to around 0.3%, with the second harmonic now the dominant distortion signal.

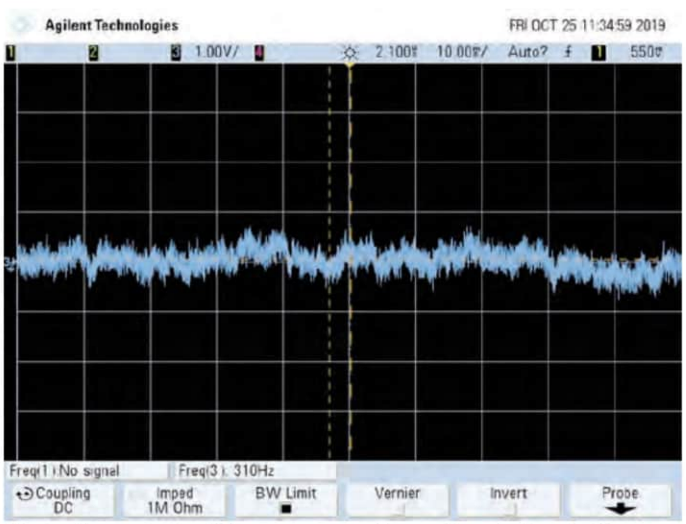


Fig.8: the output of the preamp with no input signal. Some devices produce more high-frequency or more low-frequency noise. In this case, it appears quite close to white noise.

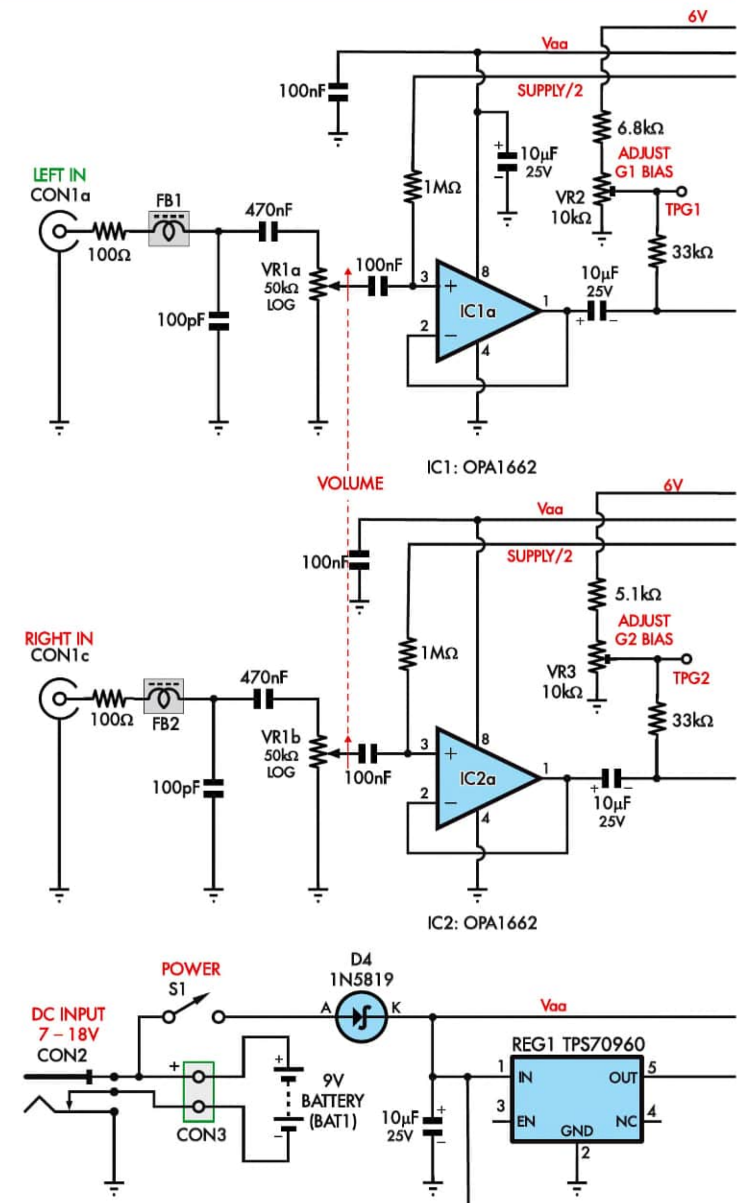
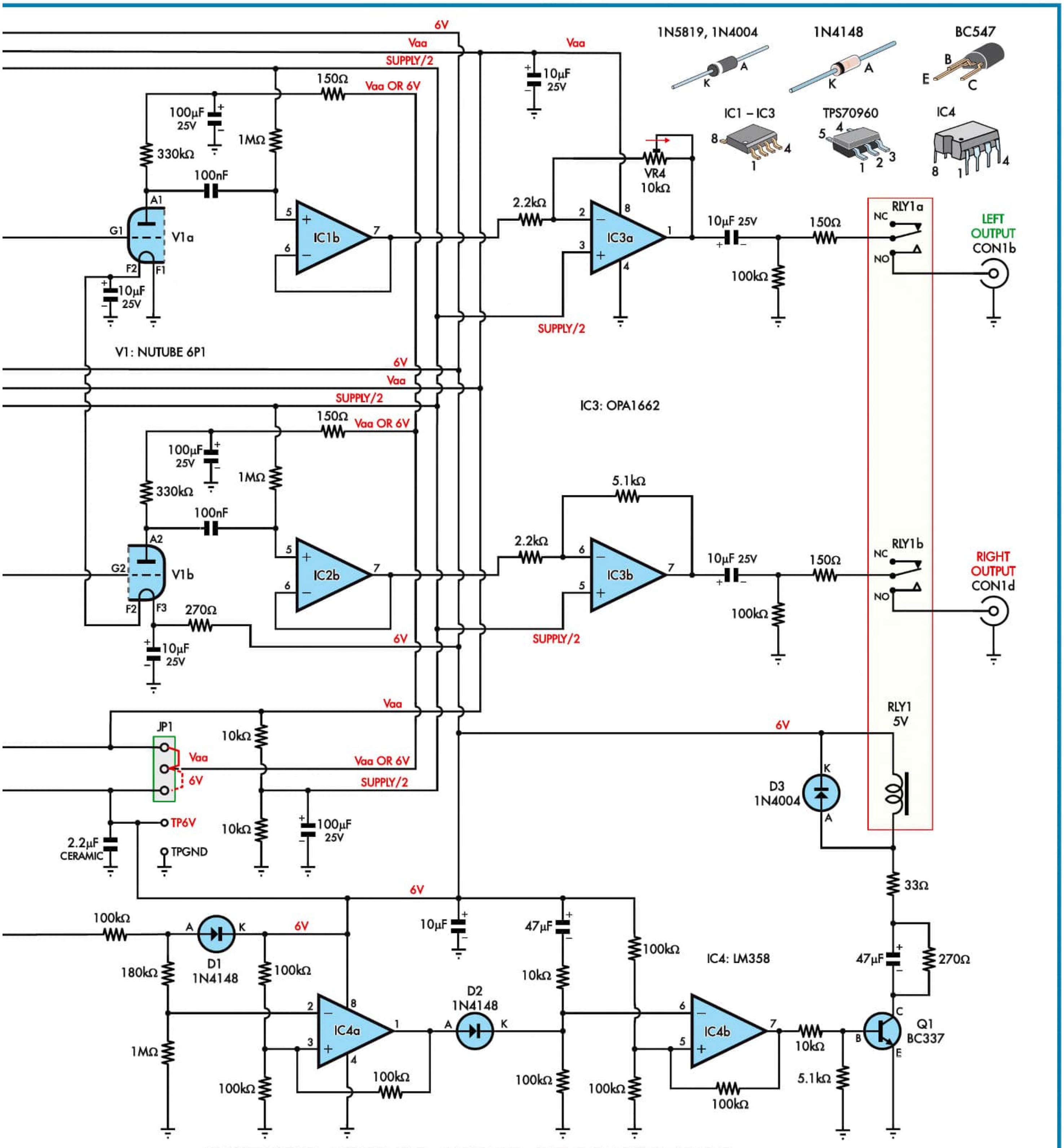


Fig.9: the input signals from CON1a and CON1c pass through RF filters and volume control pot VR1 before being AC-coupled to ultra-low-distortion buffer op amps IC1a & IC2a. These feed the signals to the grids of V1a & V1b, while VR2 and VR3 allow you to adjust the DC grid bias levels. The inverted output signals at the anodes of V1a & V1b are AC-coupled to the inputs of buffer op amps IC1b and IC2b. The signals are then re-inverted by op amps IC3a & IC3b before being fed to the outputs via the contacts of RLY1. VR4 allows the gain of the two channels to be matched. IC4 controls RLY1's coil so that it switches on around five seconds after power is applied, and switches off immediately upon power removal, eliminating clicks and thumps.

roll-off below about 7Hz. The signal is then AC-coupled from VR1a's wiper to the non-inverting input (pin 3) of op amp buffer IC1a via a 100nF capacitor.

Pin 3 of IC1a is biased near to half the supply voltage via a 1MΩ resistor that is tied to a half supply rail (Supply/2). The input bias current at pin 3 of IC1a will cause the DC voltage level to shift from this half supply level due to the



NUTUBE STEREO VALVE PREAMPLIFIER

current flowing through the 1MΩ resistor. This causes the signal voltage to rise about 0.5V above the half supply rail, reducing the maximum symmetrical voltage swing.

But since the nominal supply voltage is 9V (down to 7.2V if the 9V battery is getting flat), the signal swing is still sufficient to prevent signal clipping of line-level audio signal levels.

IC1a's output drives V1a's grid (G1) via a 10µF coupling capacitor. This grid is DC-biased via a 33kΩ with a voltage that's set using trimpot VR2. This is adjusted to set the operating point and hence, the distortion produced by V1a.

V1a's plate anode load is a 330kΩ resistor which connects to either the Vaa or 6V supply via a 150Ω decoupling resistor. Which supply is used depends on the position of jumper JP1. When a 9V battery is used for power, using the fixed 6V selection prevents anode (plate) voltage variations as the battery discharges. When used with an external regulated supply, the Vaa setting would be selected.

The high-impedance amplified anode signal is again AC-coupled op amp buffer IC1b via a 100nF capacitor. IC1b is also biased to half supply via another 1MΩ resistor to Supply/2. This 1MΩ resistor loads the anode, reducing the Nutube anode signal to 75% of the unloaded signal. This is unavoidable in a circuit with such high impedances.

Note that the signal at the triode's anode is inverted compared to that applied to the grid. In some cases, it is important to maintain the phase of audio signals between the inputs and outputs. So the output signal from the triode is re-inverted by op amp IC3a, connected as an inverting amplifier.

VR4 is included so that the gain of IC3a can be adjusted. The gain of IC3b in the right channel is fixed at -2.3 times (-5.1kΩ ÷ 2.2kΩ), so the gain for IC3a is typically set at a similar level. The gain may need to be slightly different between the two channels to get equal gains for both outputs, due to variations in gain between the two triodes at similar bias levels.

Finally, the signal from IC3a is AC-coupled with a 10μF capacitor to remove the DC voltage and DC-biased to 0V with a 100kΩ resistor. The output is fed through a 150Ω isolation resistor to prevent oscillation of IC3a should long leads with a high total capacitance be connected.

To prevent noises when power is switched on and off, the output signal passes to the output RCA sockets via a pair of relay contacts that are open when power is off. At power-on, the relay is only switched on to allow signal through to the output terminals after everything has settled down. At power off, the relay is switched off immediately. This isolates the signal while the power supply voltages decay.

Filament current

Just like a traditional valve, the Nutubes have heater filaments. These are connected between F1 and F2 for V1a, and between F2 and F3 for V1b. So the F2 connection is shared between the two.

There are two ways to drive the filaments. One is to supply current to F1 and F3 via separate resistors and have the common F2 terminal tied to ground. In this case, the resistors are chosen for 17mA flowing in each filament, giving a total filament current of 34mA.

But in our circuit, we connect the filaments in series, so the same 17mA flows through each filament for a 17mA total current but with twice the voltage across the filaments. This is a more efficient way to drive the filaments, and saves power when using batteries.

In our circuit, F1 is tied to ground, F2 is left open and current supplied via a 270Ω resistor from 6V to F3 ((6V - 0.7 - 0.7) ÷ 270Ω = 17mA). Note that F2 and F3 are bypassed to ground with 10μF capacitors. This reduces noise in the circuit.

There is one extra consideration when the filaments are in series. As the Nutubes are directly heated, V1b's cathode will be 0.7V higher than V1a, due to the voltage drop across V2's filament before the current reaches V1. This changes the bias voltage requirement at the grid (G2) for V1b compared to G1 for V1a.

The extra voltage required for G2 is provided by having a wider voltage range for VR3 due to a lower-value resistor connecting it to the 6V supply compared to VR2.

Note that the grid bias voltage derived from VR2 and VR3 is relative to the output of 6V regulator REG1. This is a fixed voltage, so the grid bias voltage does not vary with the supply voltage.

Power supply

When no DC plug is inserted into DC socket CON2, the internal 9V battery supplies power to the circuit, via CON2's normally-closed switch connecting the negative of the battery to ground. When a power plug is inserted, then power is from the DC input and the battery negative is disconnected.

Power switch S1 connects power to the rest of the circuit whether from the battery or an external source, while diode D4 provides reverse polarity protection.

REG1 is a low-dropout, low quiescent current 6V regulator. It is included to maintain a constant grid voltage for the Nutube when power is from a battery, as battery voltage naturally varies over time. The 6V rail also powers relay RLY1.

The input of REG1 is bypassed with a 10μF capacitor, while a 2.2μF ceramic capacitor filters the output. This output capacitor has the required low ESR (effective series resistance) to ensure stability at the regulator output.

The half supply rail is derived by two 10kΩ resistors connected in series across the anode supply for V1. It is bypassed with a 100μF capacitor to reduce noise and lower the rail impedance.

Power switching and output isolation

As mentioned earlier, the relay contacts at the left and right outputs connect the signals some time after power-up and disconnect the signals quickly when power is switched off. IC4, Q1, RLY1 and associated components provide this signal switching.

IC4a and IC4b are two halves of an LM358 single supply, low-power dual op amp. They are used as comparators with hysteresis. Hysteresis is provided by 100kΩ resistors from their outputs to their non-inverting inputs, while the nominal comparator threshold at these inputs is set around 2V when the output is low and 4V when the output is high.

So in each case, the output goes high when the voltage at the inverting input drops below 2V, and then goes low again when the voltage at the inverting input rises above about 3.5V (you might expect 4V, but the LM358's output can't swing to the positive rail). In other words, there is about 1.5V of hysteresis.

RLY1 is initially off, and when power is applied via switch S1, several things happen. Firstly, power is supplied via D1 to the preamplifier circuitry, including REG1, V1 and IC1-IC4. The supply and signal coupling capacitors begin to charge up to their operating conditions.

At the same time, the inverting pin 2 input to IC4a is pulled high, to near the incoming supply voltage, via the 100kΩ and 180kΩ resistors connecting to switch S1. Diode D1 prevents more than 6.5V from being applied to this pin.

The 180kΩ and 1MΩ resistors form a voltage divider so that their junction tends to sit at around 5.5V when there is more than 6.5V at the anode of D4.

This is above the pin 3 voltage, and so the output of IC4a goes low, near 0V. Pin 3 is therefore around 2V. Diode D2 is reverse-biased and pin 6, the inverting input of IC4b, is initially held high near to 6V, due to the 47μF capacitor being initially discharged. The 10kΩ resistor in series with the capacitor reduces the pin 6 voltage down to about 5.7V initially.

This is above the 4V at the non-inverting pin 5 input, so the output of IC4b will be low. Pin 5 will be at 2V. The low output of IC4b means NPN transistor Q1 is off, and the relay is off. The relay contacts will be open, so no audio passes through to the output.

As the 47µF capacitor charges via the 10kΩ and 100kΩ resistors, after about five seconds, the voltage at pin 6 will drop below the voltage at the pin 5 input (2V). The output of IC4b then goes high, driving transistor Q1 and switching on RLY1. The audio signals are then connected to the left and right channel output sockets.

Note the 47µF capacitor with a parallel 270Ω resistor and series 33Ω resistor between the collector of Q1 and the coil of RLY1. The 33Ω resistor is included so that the 5V-rated relay coil is initially driven with 5V rather than the full 6V of the supply.

Then, as the 47µF capacitor charges, the voltage to the relay coil is reduced until it is instead supplied current via the 270Ω resistor. This reduces relay coil voltage and current, saving power but still holding the relay's contacts closed.

The value of the 270Ω resistor means that the current drawn by the relay coil drops from 30mA initially down to about 12.8mA, extending battery life.

When power is switched off via S1, the pin 2 voltage at IC4a's input immediately drops to 0V. That voltage is below the pin 3 voltage, so IC4a's output goes high. Diode D2 conducts and pulls pin 6 of IC4b above the pin 5 threshold, so IC4b's output immediately goes low. Q1 switches off and the relay contacts open. This all happens well before the supply capacitors in the circuit have time to drop significantly in voltage. So the output signals are cut before anything in the circuit can misbehave.

The 10kΩ resistor between the diode D2 and the 47µF capacitor is so that the pin 6 input to IC4b can be immediately taken high, without having to wait for the 47µF capacitor to discharge.

Construction

The Nutube stereo preamplifier is built using a double-sided PCB coded 01112191 which measures 98 x 114mm. It is housed in an extruded aluminium enclosure with clear end panels, measuring 115 x 51 x 119mm. Fig.10 has the PCB assembly details.

Start by fitting the surface mount parts. Mostly, these are used because the same parts are not available in through-hole packages. They are not difficult to solder using a fine-tipped soldering iron.

Good close-up vision is necessary, so you may need to use a magnifying lens or glasses to see well enough. These parts are IC1, IC2 and IC3, REG1 and its associated 2.2µF ceramic capacitor.

Make sure that each component is orientated correctly before soldering it, ie, rotated as shown in Fig.10. The ceramic capacitor is not polarised.

For each device, solder one pad first and check alignment and readjust the component positioning by reheating the solder joint if necessary before soldering the remaining pins.

If any of the pins become shorted with solder, solder wick can be used to remove the solder bridge. But note that pins 1 & 2 and pins 6 & 7 of both IC1 and IC2 connect together on the PCB, so a solder bridge between these pins is acceptable.

Continue construction by installing the resistors (use your DMM to check the values), followed by the two ferrite beads. Each bead is installed by using an offcut length of wire (from

Parts list – Nutube Valve Preamp

1 double-sided PCB coded 01112191, 98 x 114mm
1 set of front and rear panel labels (see text)
1 extruded aluminium enclosure with clear end panels, 115 x 51 x 119mm [Jaycar HB6294]
1 Korg Nutube 6P1 double Triode thermionic valve (V1) [RS Components 144-9016]
1 1A DPDT 5V relay (RLY1) [Altronics S4147]
1 SPDT sub-miniature toggle switch (S1) [Altronics S1421]
1 double stereo horizontal PCB-mount RCA socket assembly (CON1) [Altronics P0211]
1 PCB-mount DC power socket (CON2) [Jaycar PS0520, Altronics P0621A]
1 2-pin 2.54mm pitch vertical polarised header (CON3) [Jaycar HM3412, Altronics P5492]
1 inline plug to suit CON3 [Jaycar HM3402, Altronics P5472 + P5470A x 2]
1 3-way pin header, 2.54mm pitch with shorting block (JP1)
2 5mm-long ferrite RF suppression beads, 4mm outer diameter (FB1,FB2) [Altronics L5250A, Jaycar LF1250]
1 9V battery
1 9V battery clip with flying leads
1 13-16mm diameter knob to suit VR1
1 8-pin DIL IC socket (optional)
1 100mm cable tie
4 15mm-long M3 tapped spacers
2 M3 x 25mm Nylon or polycarbonate panhead machine screws
4 M3 x 6mm panhead machine screws
2 M3 hex nuts
1 No.4 x 8mm self-tapping screw
1 90mm length of medium-duty hookup wire
1 solder lug
4 PC stakes

Semiconductors
3 OPA1662AID dual op amps, SOIC-8 (IC1-IC3) [RS Components 825-8424]
1 LM358 dual op amp, DIP-8 (IC4)
1 TPS70960DBVT 6V regulator, SOT-23-5 (REG1) [RS Components 900-9876]
1 BC337 NPN transistor (Q1)
2 1N4148 small signal diodes (D1,D2)
1 1N4004 1A diode (D3)
1 1N5819 1A schottky diode (D4)

Capacitors
3 100µF 25V PC electrolytic
2 47µF 16V PC electrolytic
10 10µF 25V PC electrolytic
1 2.2µF X7R SMD ceramic, 2012/0805 package [RS Components 6911170]
2 470nF MKT polyester
6 100nF MKT polyester
2 100pF ceramic

Resistors (all 0.25W, 1% metal film)

5 1MΩ	2 330kΩ	1 180kΩ	10 100kΩ	2 33kΩ
4 10kΩ	1 6.8kΩ	3 5.1kΩ	2 2.2kΩ	2 270Ω
4 150Ω	2 100Ω	1 33Ω		

1 dual-gang logarithmic 50kΩ 9mm PCB-mount potentiometer (VR1) [Jaycar RP8760]
2 10kΩ horizontal 5mm trimpots (VR2,VR3)
1 10kΩ top-adjust multiturn trim pot 3296W style (VR4)

the resistors) feeding the wire through it and then bending the leads down through 90° on either side to fit the PCB. Push each bead all the way down so that it sits flush against the PCB before soldering its leads.

Install diodes D1-D4 next. Take care to orientate each correctly, as shown in the overlay diagram, and make sure each is in its correct position (ie, don't get the different types mixed up) before soldering.

Following this, fit the IC socket for IC4. Make sure that the socket is seated flush against the PCB and that it is orientated correctly. It's best to solder two diagonally opposite pins of the socket first and then check that it sits flush with the board before soldering the remaining pins.

You could skip the socket and solder IC4 straight to the board. This would improve long-term reliability but would make it much more difficult to swap or replace IC4 should that be necessary.

The MKT and the two 100pF ceramic capacitors can now go in, followed by the electrolytic capacitors. The polarised electros must be orientated with the correct polarity, ie, with the longer lead into the pad marked with the + sign.

Now install the two single-turn trim pots, VR2 and VR3. These might be marked as 103 rather than 10kΩ. Next, mount multi-turn trimpot VR4. Orientate it with the adjusting screw positioned to the left, as shown. It also may be marked as 103 instead of 10kΩ.

The next step is to fit Q1 by splaying its leads slightly to suit the hole arrangement on the PCB. Also install PC stakes for GND, TPG1, TPG2 and TP6V. The three-way header for JP1 and the two-way header for the battery lead can be mounted now, followed by RLY1, CON1, CON2 and switch S1.

Potentiometer VR1 is mounted and soldered in place and is secured against the PCB using a cable tie around the pot body. This stops force on the shaft from breaking the solder joints or lifting tracks off the board.

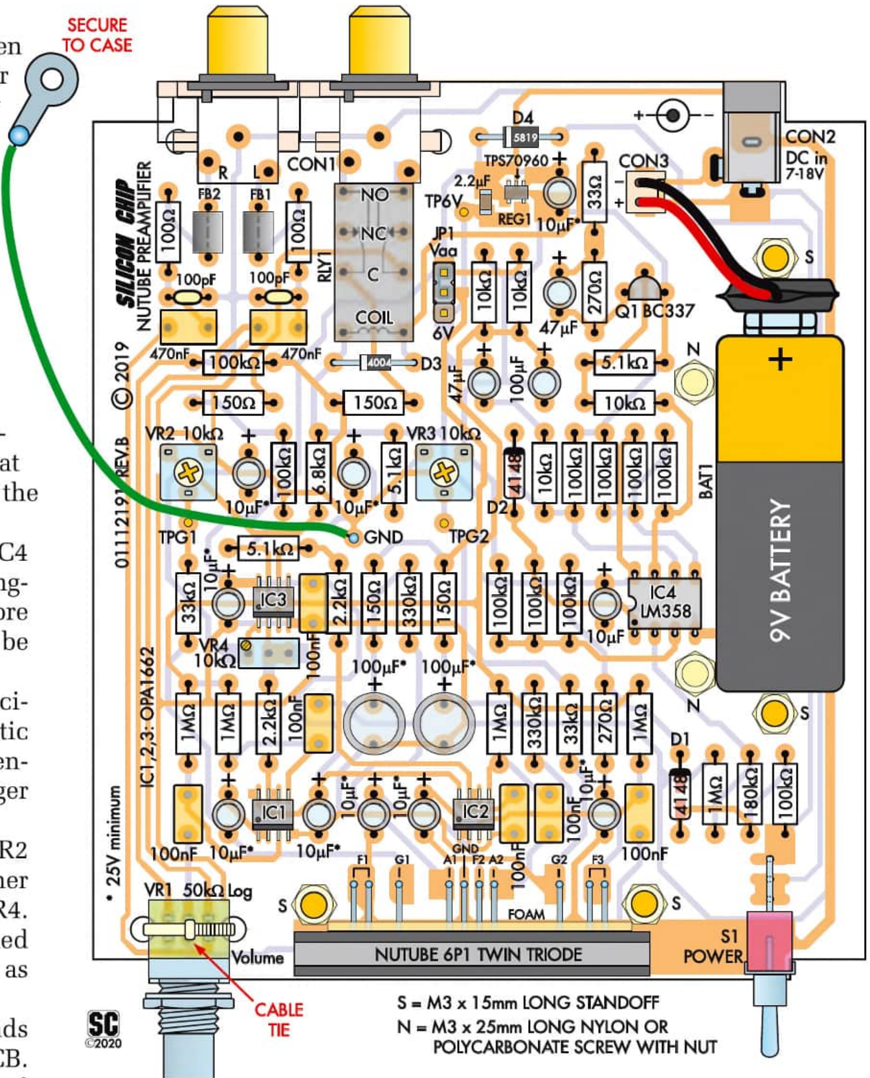


Fig.10: all the Nutube preamp components mount on one double-sided PCB as shown here. They are mostly standard parts, but IC1-IC3 and REG1 are only available in SMD packages. The Nutube (V1) is in a SIL-type package with right-angle leads that are surface-mounted to pads on the top of the board. The whole assembly slides into an extruded aluminium case.

Feed the tie through the holes in the PCB on each side of the pot, and tie it underneath.

Nutube V1 is mounted so that the front glass is vertical and with its leads soldered to the top pads on the PCB, similar to a surface-mount component. Pins F1 and F3 at each end of the Nutube utilise two adjacent leads on the Nutube device. In addition to the leads, it is supported by two 15mm-long tapped spacers, one on either side of the device, which hold a piece of foam against the Nutube envelope.

Secure these spacers to the PCB using short machine screws fed in from the underside of the PCB.

We will later sandwich the foam between the spacers and the Nutube, stopping it from flexing its leads too much. Also fit one 15mm standoff at each end of the battery outline on the PCB (see photos).

The sides of the battery are held in by two M3 x 25mm Nylon or polycarbonate screws passed up from the underside of the PCB and secured with M3 nuts.

Wiring

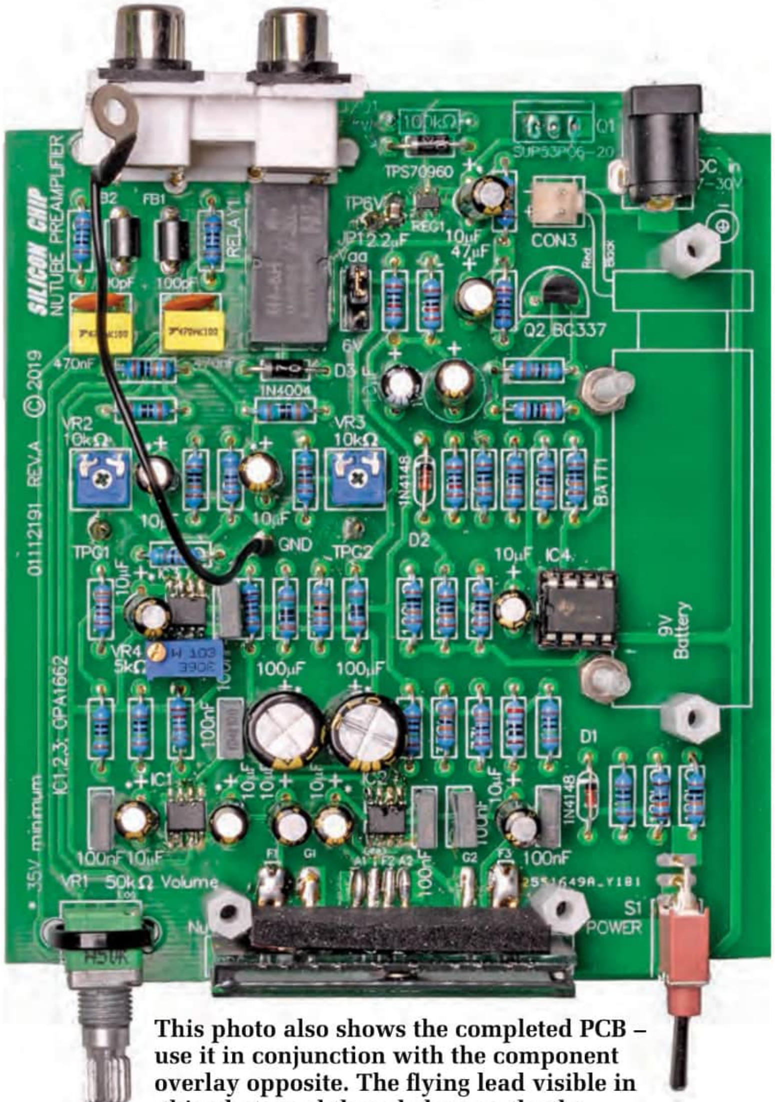
Crimp and/or solder the battery wires to the header socket terminals after cutting these wires 60mm long. Then insert these terminals into the header socket shell, making sure you get the red and black wires in the correct positions, as marked on the PCB.

An Earth wire is also required to prevent hum injection to the circuit if the case is touched. This connects the metal case to the GND terminal on the board. Solder it to the solder lug at one end and the GND terminal on the board at the other. Heatshrink tubing can be used over the lug terminal and PC stake for GND.

When the case is assembled, the solder lug is captured in the top corner end-cap screw, adjacent to the RCA terminals.

Powering up and testing

If you are planning to use a battery to supply power, connect a jumper shunt in the 6V position for JP1. That way, any voltage changes from the battery will not affect the anode plate voltage. If using a DC plugpack, use the Vaa position for JP1.



This photo also shows the completed PCB – use it in conjunction with the component overlay opposite. The flying lead visible in this photo and those below earths the aluminium case to the PCB to minimise hum.

Initially set VR2 and VR3 to midway. Apply power to the circuit from a 7-18V DC supply. Check that TP6V is between 5.88 and 6.12V. Also check the relay switches on after about five seconds; you should hear it click in.

Adjust VR2 so that the left-hand plate of the Nutube lights up at its brightest. Similarly, adjust VR3 so that the right-hand plate of the Nutube glows brightest. If using a supply that's over 12V, make sure the grid voltage is less than 2.5V; otherwise, the device's maximum dissipation rating will be exceeded. The grid voltage for each Triode can be measured at TPG1 and TPG2, relative to the GND PC stake.

VR4 adjusts the output of the left channel so that it can match the right channel in level. This can be done by connecting up the preamplifier to your sound system and rotating VR4 so both channels have the same output level, just by listening.

For more accurate adjustments, you need a signal generator. You can use a standard hardware-based signal generator, or computer software.

You will also need suitable leads to connect the generator to the RCA inputs. For connection to a computer, you typically need a stereo lead with RCA plugs one end and a stereo 3.5mm jack plug at the other. Leads for a hardware signal generator will require an RCA plug one end and a connector for the generator, such as a BNC plug, at the other end.

Apply a 1kHz signal of about 1V RMS to the right channel preamplifier input (red input socket). Monitor the right channel output with a multimeter set to measure AC volts.

Set the volume control for about 500mV signal at the output. Adjust VR3 for maximum signal, but when doing this, adjust the volume control so the level does not exceed about 500mV. That's required to ensure the signal is not clipped. When the maximum level is found, take note of the level reading.

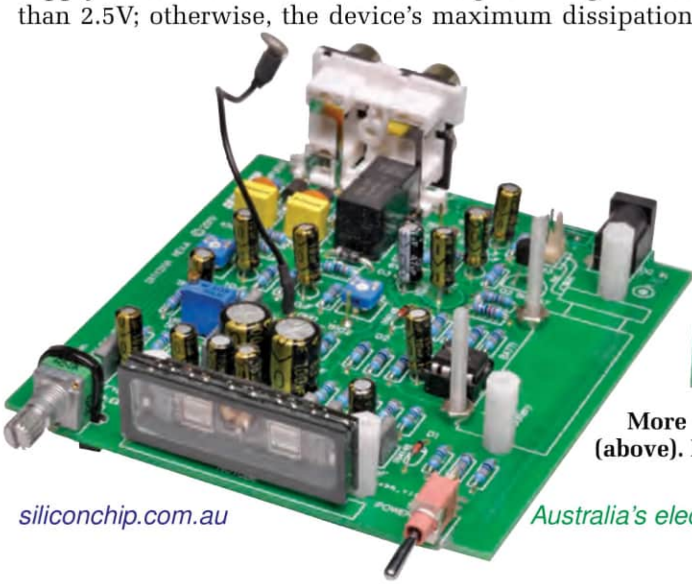
Now apply the same signal to the left channel (white RCA input) and measure the left channel output. Do not change the volume setting, but you may need to adjust VR4 for a suitable level, not much more than 500mV. Adjust VR2 for maximum signal as before. Now adjust VR4 so that the measured level is the same as that already measured in the right channel.

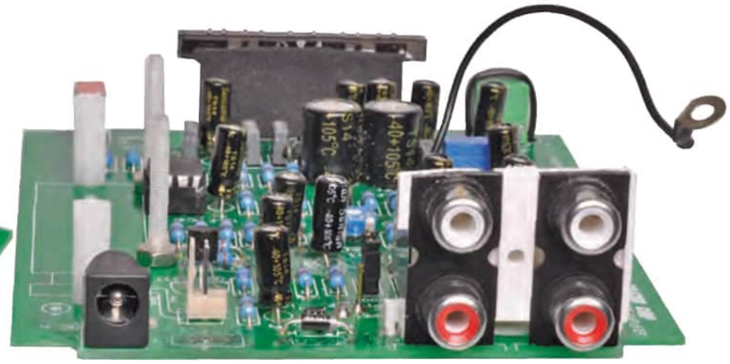
If you wish to set the grid bias more accurately, spectrum analyser software can be used. The spectrum analyser will show the distortion products of the preamplifier, including the fundamental and harmonics. The fundamental is the reproduction of the actual applied signal.

With a perfect preamplifier, without distortion, you would only see the fundamental at the output.

However, with a real preamplifier, there will be noise and distortion. This will show up in the analyser as other spikes rising above the noise floor.

Typically, the distortion will have second, third, fourth, fifth harmonics etc. For a 1kHz signal, the fundamental (first





More views of the completed PCB from the front (at left) and the rear (above). Neither photo has the 9V battery in place but its support standoffs and screws are ready for it.

Free audio signal generator and analyser software

If you want an audio signal generator that runs on a computer, you can use the free Audacity software (siliconchip.com.au/link/aaxk). This is available for Windows, macOS, GNU/Linux and other operating systems. Download and install the version that suits the operating system on your computer. Once installed and running, select Generate -> Tone and then set the waveform to sine, frequency to 1kHz and volume to maximum (ie, set the level value to one). You can also set the duration over which the tone is generated. Press the play button for the audio to start.

Another good, easy-to-use option is WaveGene (siliconchip.com.au/link/aaxl).

For spectrum analysis, you could use WaveGene in combination with WaveSpectra (siliconchip.com.au/link/aaxl). See the setup instructions at: siliconchip.com.au/link/aaxm

We used Visual Analyser, available from siliconchip.com.au/link/aaxn, mainly because this allows the actual measured waveform to be seen as a 'scope' view, along with the output spectrum.

Once you have installed the signal generator and spectrum analyser software, it's a good idea to use it to analyse the performance of your computer sound interface. That can be done with a cable with 3.5mm stereo jack plugs at each end, with one end plugged into the sound input and one into the sound output.

To do this with Visual Analyser, on the main screen, then select "floating windows mode" and then the Scope, Spectrum and Wave need to be opened from the top row of selections.

Select a 1kHz sinewave for the Wave generator, select interlock (that causes both A and B channels to change together) for the output levels and bring up the output level on the waveform generator. Then press the on/off button below the output level slider.

The on/off selection at the top left of the main screen also needs to be selected so that the analyser measures the signal. Both will show "off" when the signal is generated and measured. You can choose to view the A channel (left) or B channel (right), or both, in the main settings channel selection.

We chose to use a 16,384 sample FFT window and a sampling rate of 44.1kHz in the main menu. Output gain (adjustment along the top row at right) was set just below maximum, yielding the lowest distortion figure of 0.0626%.

In our case, noise is mostly more than 80dB below the fundamental (see Fig.11). That indicates that this is not a particularly good sound card, but good enough to evaluate the distortion from the Nutube Preamplifier.

Now the Nutube Preamplifier can be connected between the computer sound input and output. Adjust signal levels using the volume control and/or the signal generator level so that the waveform is not clipped (ie, so the top of the sine wave is not plateauing) and instead showing a clean sinewave.

In the main menu, you can select the left channel (A) and adjust trimpot VR2 for the lowest distortion reading, with minimal harmonics – see Fig.12. This shows the waveform as a clean sinewave, with the analyser showing the main 1kHz fundamental at 0dB level and the second harmonic (2kHz) at around -70dB. The third, fourth and sixth harmonics are at a similar level.

Once you've finished tweaking VR2, select the right Channel (B) and adjust VR3 for the lowest distortion reading.

VR4 can then be adjusted while viewing in the A channel of the analyser, so that fundamental level is the same as that in the B channel.

Fig.13 shows the waveform and spectrum when the grid bias (with VR2) is adjusted incorrectly. The top half of the sine waveform is very rounded, and the second harmonic is only 10dB below the fundamental. The distortion reading is around 30%.

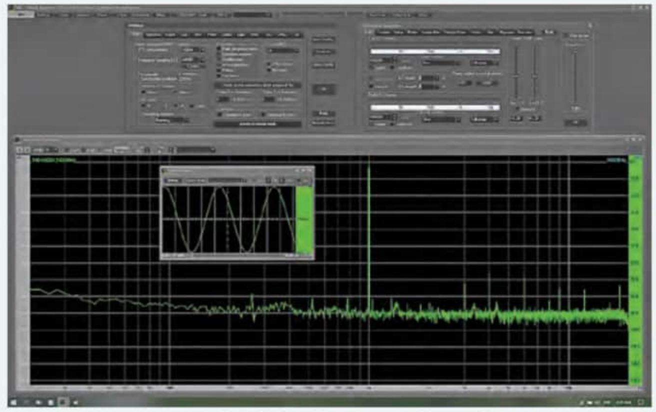


Fig.11: a screen grab of the free Visual Analyser PC software performing a 'loopback' test, with the sound card output fed directly into its input. This lets you analyse the distortion inherent in the system. In this case, the reading is 0.0626% THD+N at 1kHz. You therefore won't get a reading lower than that when measuring the performance of external devices like the Nutube preamp.

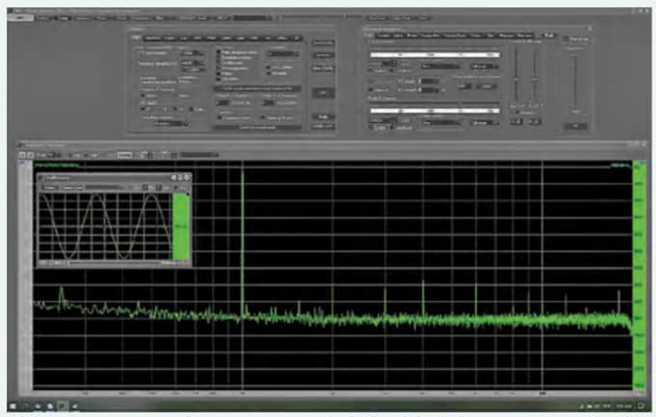


Fig.12: now we have connected the Nutube preamp 'in the loop' between the sound card output and input, using two stereo jack plug to red/white RCA plug cables. The output levels have been set to 41% full-scale, which corresponds to around 250mV RMS, The distortion reading has only risen slightly, to 0.07%, because the Nutube preamp and sound card distortion figures are similar.

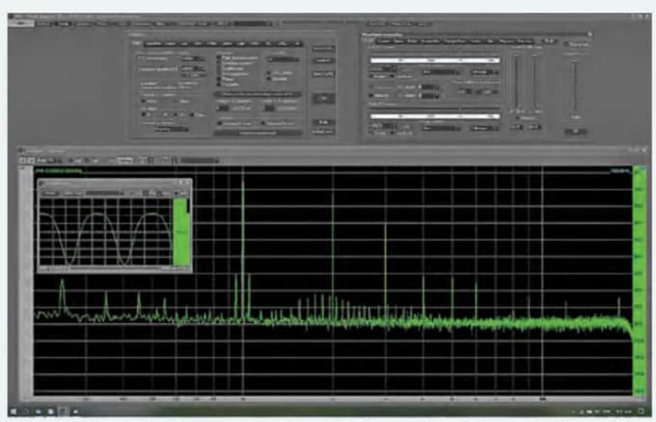


Fig.13: here is the same test as Fig.14, but the triode grid bias voltage adjustment is completely wrong. You can see the heavily distorted sinewave in the "Oscilloscope" window, with many harmonics in the spectrum analysis. The THD reading is 30%. This is about as bad as it gets; more realistically, a slightly misadjusted grid bias voltage can lead to distortion levels in the 0.1-1% range.

Where can you buy a 6P1 Dual Triode?

As mentioned in the parts list, the 6P1 is available from RS Components (https://au.rs-online.com). So far they are the only local source we've found (and who has stock).

We have to warn you, though, it's not a cheap device: RS Components list it as $78.98 each (inc GST, plus postage)! (RS stock no is 144-9016).

We would expect prices will eventually come down as they become more popular and more suppliers carry them.

The completed PCB simply slides into the extruded case sothat the pot shaft and switch emerge from the front panel. No PCB screws are necessary as it is held tight by the front and rear case ends.

harmonic) would show as a peak at 1kHz, with the second harmonic at 2kHz, the third harmonic at 3kHz, the fourth at 4kHz etc. These harmonic distortion products hopefully will be at a lower level than the fundamental, and not all harmonics will necessarily be present.

Once you can see this, you can adjust the grid bias for minimum distortion. For that matter, you could also adjust it for maximum distortion, if that's what you're after! (See panel opposite).

Final assembly

The Nutube Preamplifier PCB is housed inside an aluminium enclosure with clear end panels, measuring 115 x 51 x 119mm.

If you are not using a battery for power, unplug the battery clip from CON3 to prevent the contacts from shorting onto a part of the circuit.

The end panels include 3mm-thick foam plastic that can be used as padding for the Nutube device. The end pieces just require this foam to be placed within the outer surround, where the end panels connect to the aluminium body.

The central pieces that cover the window and the button-shaped pieces for the corner securing holes are not required for the case.

Cut out a piece of foam 38 x 17mm and place this behind the Nutube. This is held between the two 15mm standoffs at the rear of the Nutube.

Note that the enclosure has a specific top and bottom orientation for both the aluminium extrusion and end panels. The front and rear panels have a slightly different profile at the top and bottom edges. While the top edge is straight, the lower edge has a slightly lower moulding below the two left and right corner holes. That matches the same profile on the aluminium extrusion.

Holes need to be drilled for the volume potentiometer and power switch at the front and the DC socket and RCA sockets at the rear. The required front panel hole locations are shown on the label artwork of Fig.14. These can also be downloaded as PDF files from the Silicon Chip website.

A small portion along the top edge of the RCA terminal housing plastic needs to be shaved or filed off, as it is slightly too high to fit in the case otherwise. Less than 1mm needs to be removed.

You can place the labels on the inside of the panels, cutting around the outside perimeter of each label. Or you can cut out the smaller-sized inner perimeter so the labels can be affixed to the outside of the end pieces.

For more detail on making labels, see www.siliconchip.com.au/Help/FrontPanels

If the panel label is to be inside the end panel, a paper label could be used. For the front panel, the central window in the artwork will need to be cut out with a hobby knife, to expose the Nutube.

The RCA sockets should be secured to the rear panel with the self-tapping screw, and with the rear edge of the PCB touching the inside of the rear panel.

You can then slide the PCB into the case on the second slot up from the bottom. Don't forget to attach the GND solder lug to the top corner screw at the rear adjacent to the RCA sockets. The wire end of the solder lug will need to be orientated diagonally inward, so it does not foul the end cap border.

Additionally, the anodising layer on the aluminium is a good insulator. It will need to be scraped off at the point where the solder lug makes contact with the screw entry point to ensure good contact with the metal.

Finally, the rubber feet provided with the enclosure can now be fixed to the base using their self-adhesive. SC

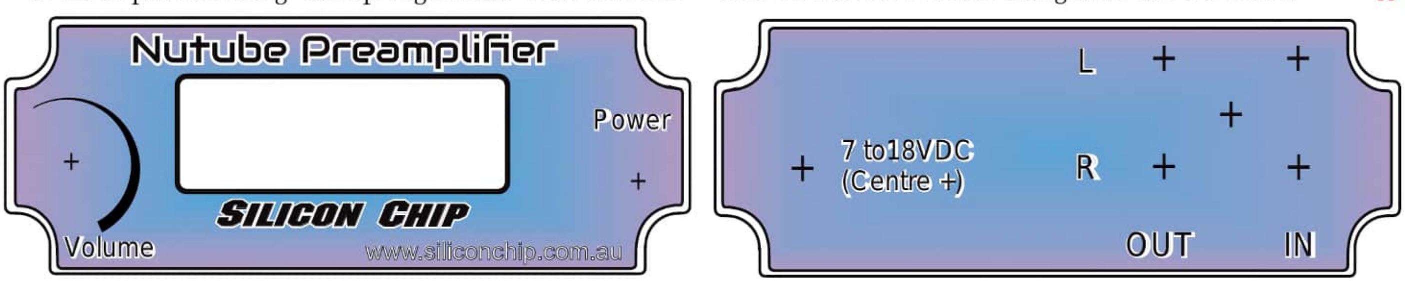


Fig.14: the 1:1 front and rear panel artwork can also be used as a template. V1 requires a 43 x 15mm cutout; the volume control a 10mm hole and the power switch a 5mm hole. On the rear panel, the RCA sockets require 10mm holes where shown with a 3mm hole in the middle; the DC socket is 5mm. These can also be downloaded from siliconchip.com.au