By JIM ROWE

A 12AX7 valve audio preamplifier

After many years saying we would never publish a valve circuit, here is a valve preamplifier for guitars and other musical instruments. However, it is a valve circuit with a number of differences, to give it much better performance than was common in the "olden days".

WHAT'S THIS? An audio project using a valve, actually described in SILICON CHIP? After all those scathing things our esteemed Editor and Publisher has said in the past about olde-worlde "bottles"? Yes, Leo finally gave in and approved the development of a valve preamp for guitars and other instruments, using the trusty 12AX7 dual hi-gain triode. We had to brush up on valve design to do it but the performance has turned out to be quite impressive, better in fact, than was commonly achieved when valves ruled the electronics world.

Now you can build one up, so you can hear for yourself just how good "valve sound" compares with that from modern solid state gear.

How it developed

Once we had decided to do a valve preamp, the first step was to see what parts were still readily available. This narrowed down the choice straight away, since the only type of low power amplifier valve that is widely available is the trusty 12AX7. Older readers may remember that this is a dual high-mu indirectly heated triode, which was also known by the European type number ECC83 and the military number 7025.

It comes in a Noval or "miniature 9-pin" all glass envelope, and has a centre-tapped heater designed to operate from either 12.6V (at 150mA) or 6.3V (at 300mA). The 12AX7 is apparently still being made in Russia and a few other countries and Jaycar Electronics stocks the 12AX7WA made by Sovtek. They're brand new and they sell for $24.95 a pop (Cat. ZA-6000). Jaycar also stocks matching Noval sockets, as the PS-2082 ($4.40 each).

Of course, the valve is only part of the story, because valves not only need heater power to "light them up" and make the cathode emit electrons – they also need to operate from a fairly high voltage to attract those electrons to the anode or "plate".

In fact, for reasonable audio performance, a valve like the 12AX7 really needs to be operated from a "high tension" (HT) plate voltage supply of 250V DC or so. They don't draw much current from this high voltage supply (only a few milliamps) but the high voltage is necessary because valves are much higher impedance devices than transistors.

In the old days we'd usually generate this HT voltage with a simple rectifier circuit, based on a mains transformer with a high voltage secondary. But this sort of transformer is no longer readily available.

So the next step in developing our preamp was to come up with a suitable HT power supply, using more reasonably priced parts. Modern technology came to the rescue here, because nowadays it's easy to generate a high DC voltage with a low power DC-DC converter. This type of converter is quite efficient and low in cost thanks to the availability of converter chips like the TL494, fast switching rectifier diodes and high voltage power Mosfets such as the MTP6N60E.

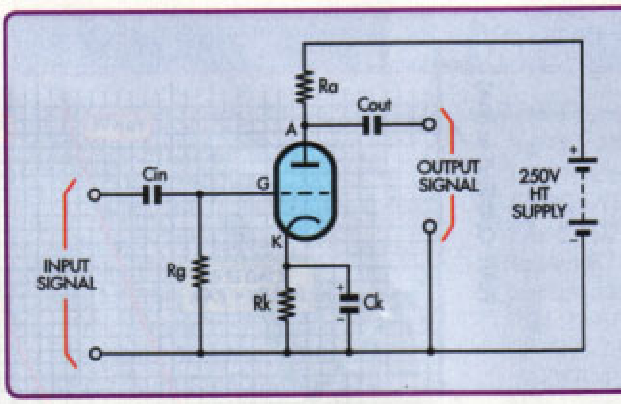


Fig.1: the circuit of a basic common-cathode amplifier stage using a triode valve. It's quite like a common-emitter transistor amplifier.

So as part of the preamp design, we had to come up with a suitable 12V/250V step-up converter to run it. More about this later, but now let's explain a bit more about designing the preamp itself.

One way in which valves are different from solid state devices is that they have much tighter parameter spreads. So the performance of one 12AX7 is almost exactly the same as any other 12AX7; unlike transistors and FETs, where things like the current gain and quiescent current tend to vary over a wide range.

Because of this much more predictable performance, valve amplifier stages are designed in a rather different way. In fact, many valve amplifier stages can be designed using a fairly straightforward graphical method, as we'll now explain.

Fig.1 shows the circuit of a basic common-cathode amplifier stage using a triode valve, such as one section of a 12AX7. As you can see, it's quite like a common-emitter transistor amplifier or a common-source FET amplifier. In fact, if you to think of the valve as a kind of "depletion mode FET" that operates from high voltage, you'll soon get the hang of things.

The anode (A) or plate of the valve is connected to the +250V HT supply via a load resistor Ra, which is rather like the drain resistor of a FET. And the current the plate draws is controlled largely by the voltage applied between the grid (G) and cathode (K), because the grid works very much like the gate of a depletion mode FET.

When there's virtually no voltage

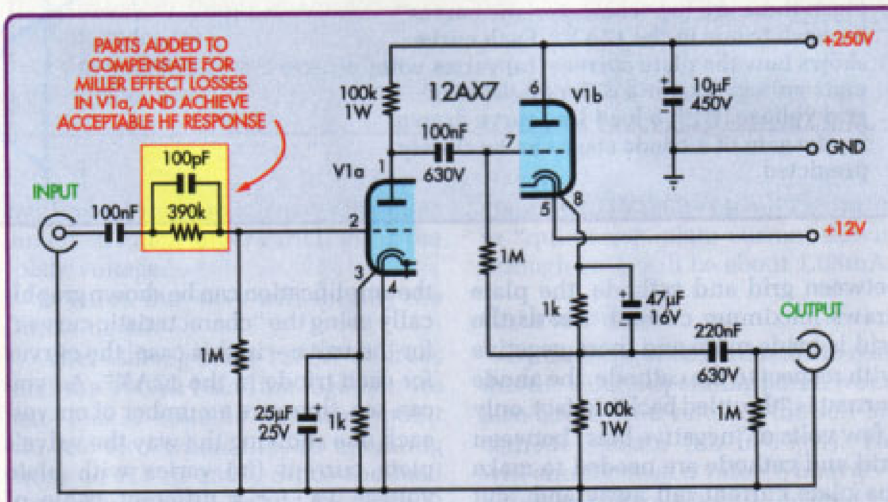


Fig.2: our first attempt at the valve preamplifier. The first circuit stage is a common-cathode amplifier while the second is a "cathode follower" to give low output impedance and avoid the severe performance losses which can occur when driving following stages. The input RC network compensates for Miller Effect high frequency loss.

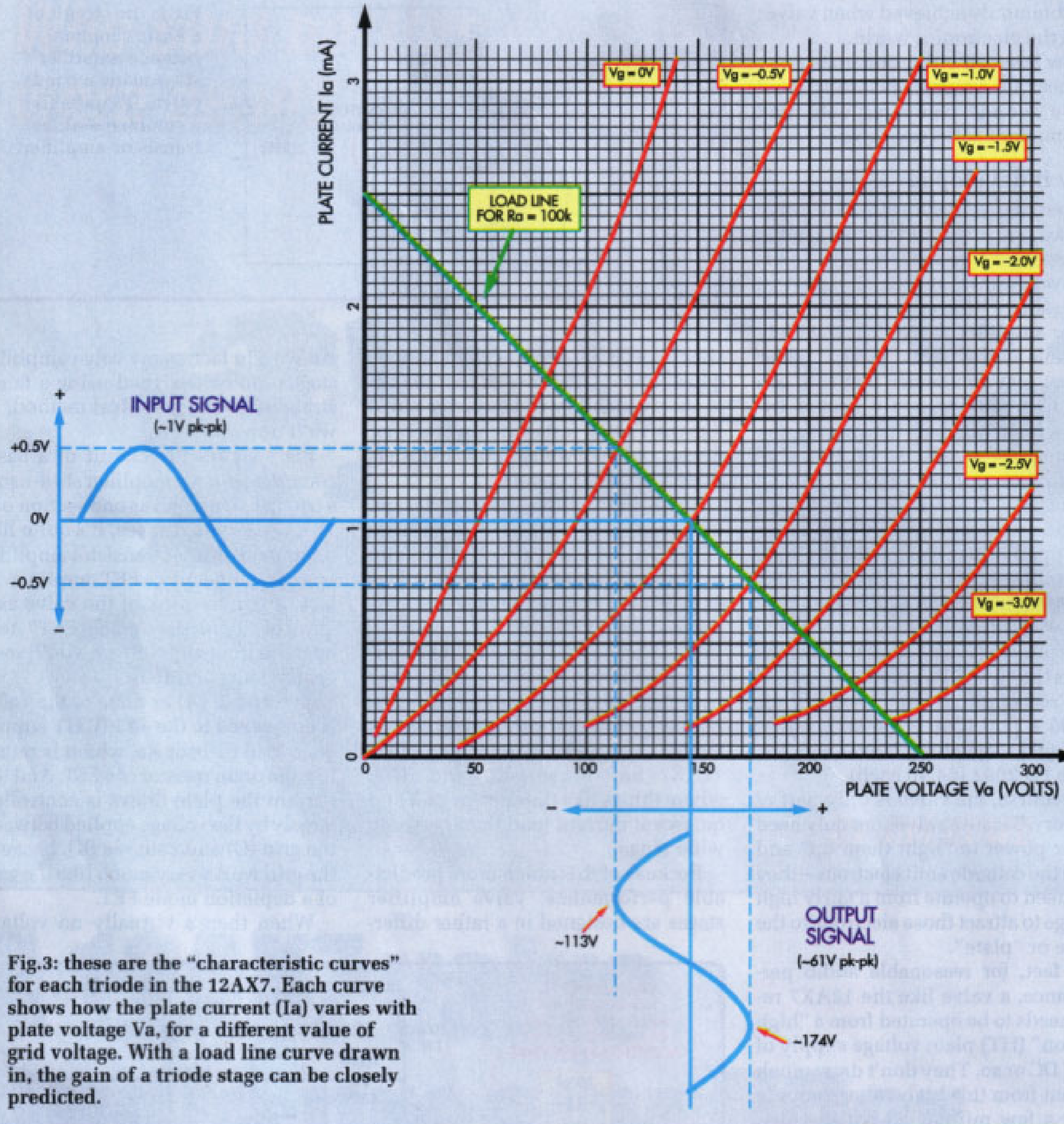


Fig.3: these are the "characteristic curves" for each triode in the 12AX7. Each curve shows how the plate current (Ia) varies with plate voltage Va, for a different value of grid voltage. With a load line curve drawn in, the gain of a triode stage can be closely predicted.

between grid and cathode, the plate draws maximum current. But as the grid is made more and more negative with respect to the cathode, the anode current is "throttled back". In fact, only a few volts of "negative bias" between grid and cathode are needed to make the plate current fall away and "cut off" the valve's conduction. It's this ability for a small voltage change on the grid (relative to the cathode) to control the valve's plate current that makes it a good amplifier.

If you look at Fig.3, you'll see how the amplification can be shown graphically using the "characteristic curves" for the valve – in this case, the curves for each triode in the 12AX7. As you can see, there are a number of curves, each one showing the way the valve's plate current (Ia) varies with plate voltage Va, for a different value of grid-cathode bias voltage Vg.

The steepest curve shows how quickly the current increases when there's no grid bias (Vg = 0). Then the other curves show how increasing levels of negative bias reduce the plate current for the same plate voltages.

Each curve is marked with the corresponding level of negative bias voltage: -0.5V, -1.0V, -1.5V and so on. Notice how with -3.0V applied to the grid, the valve only draws about 0.6mA of plate current even with a plate voltage of 300V.

Note that these curves only show the behaviour of the valve if it is connected directly to an adjustable DC voltage supply. But this isn't the situation in our amplifier stage of Fig.1, because here the valve is connected in series with a fixed "plate load" resistor Ra, across a fixed 250V DC voltage supply. So in this case the voltage drops of the valve and load resistor Ra always add up to 250V. In effect, they share the voltage according to the ratio of their resistances.

For example, when the valve has a small negative bias voltage on the grid (so it's able to draw more current), its effective plate-cathode resistance is smaller than Ra and as a result Ra drops more of the voltage. Conversely, when the valve has more negative grid bias and can only draw a small current, its plate-cathode resistance rises compared with Ra and it now drops more of the voltage.

Because the voltage drops of Ra and the valve must always add up to the HT voltage (here +250V), this also means that the voltage across the valve can always be found by subtracting the voltage drop across Ra from the HT voltage. And since Ra is a fixed resistor, it's easy to find its voltage drop by Ohm's law: the voltage drop is simply Ra times the current.

We can show this graphically by drawing a "load line" to represent the behaviour of Ra on the valve's characteristic curves. As you can see from Fig.3, the load line is simply a straight line (shown in green) drawn between two known points. One is the point on the horizontal (voltage) axis representing the full HT voltage, because this will be the voltage on the valve's plate when no current is being drawn (so there will be no voltage drop across Ra).

The other known point is on the vertical (current) axis, showing the current which would be drawn by Ra by itself from the HT supply, if the valve could be fully "turned on" so that it had no voltage drop at all.

The load line shown is for a load resistor Ra of 100kΩ, so it's therefore drawn between the +250V point on the horizontal axis, and the point on the vertical axis corresponding to a current of 250V/100kΩ, or 2.5mA.

Now what this load line shows is the way the voltage on the plate of the valve must vary for different current levels, operating from a 250V plate supply and with an Ra of 100kΩ. And since the valve's own curves (red) show how its current varies with grid-cathode voltage Vg, we can use the two together to see how variations in Vg caused by an AC input signal will result in plate current variations and then much larger variations in the plate voltage.

In short, the valve will amplify the input signal.

After looking at the 12AX7's curves and the 100kΩ load line together, we can pick a suitable operating point for the two when they're operating from an HT of 250V. Since the load line intersects the Vg = -1.0V curve at about halfway along, this would make a fairly good operating point for a stage handling fairly small input signals (say ±0.5V or less). As you can see, at this point the valve would have a Va of about 146V, while Ra drops the remaining 104V (250 - 146V). The resting or "quiescent" plate current flowing through both will be about 1.05mA.

Parts List

Preamp PC Board

1 PC board, code 01111031, 125 x 62mm
1 UB3 jiffy box, 130 x 67 x 44mm
1 piece of 1mm aluminium sheet, 125 x 62mm
1 12AX7WA or ECC83 twin triode valve
1 Noval 9-pin valve socket
2 PC-mount RCA sockets
2 2-way PC terminal blocks
6 6mm untapped metal spacers
4 M3 x 12mm machine screws
8 M3 nuts and star lockwashers

Capacitors
1 220µF 10/16V PC electrolytic
1 47µF 450V PC electrolytic
1 220nF (0.22µF) 630V metallised polyester (greencap)
1 100nF (0.1µF) 100V metallised polyester (greencap)
1 100nF (0.1µF) 630V greencap

Resistors (0.25W 1% metal film)
3 1MΩ 1 8.2kΩ
2 33kΩ 2 1kΩ
2 100kΩ 1W carbon film

Power Supply

1 PC board, code 01111032, 122 x 58mm
2 TO-220 mini heatsinks (6073B type)
2 2-way miniature PC-mount terminal blocks
1 1m-length .08mm enamelled copper wire
1 3m-length 0.25mm enamelled copper wire
1 Ferroxcube ETD29-3C90 ferrite transformer assembly (2 ETD29-3C90 cores; 1 CPH-ETD29-1S-13P bobbin and 2 CLI-ETD29 clips); OR
1 Neosid ETD29-F44 ferrite transformer assembly (2 ETD29 F44 32-580-44 cores; 1 ETD29 59-580-76 bobbin and 2 ETD29 76-055-95 clips)
1 2.5mm PC-mount DC socket
4 6mm untapped metal spacers
2 M3 x 10mm machine screws
4 M3 x 15mm machine screws
6 M3 nuts and lockwashers

Semiconductors
1 TL494 switchmode controller (IC1)
1 7812 3-terminal regulator (REG1)
1 BC337 NPN transistor (Q1)
1 BC327 PNP transistor (Q2)
1 MTP6N60E 600V/6A or STP-6N50B 500V/5.8A Mosfet (Q3)
1 1N4004 1A power diode (D1)
1 UF4004 400V fast switching diode (D2)

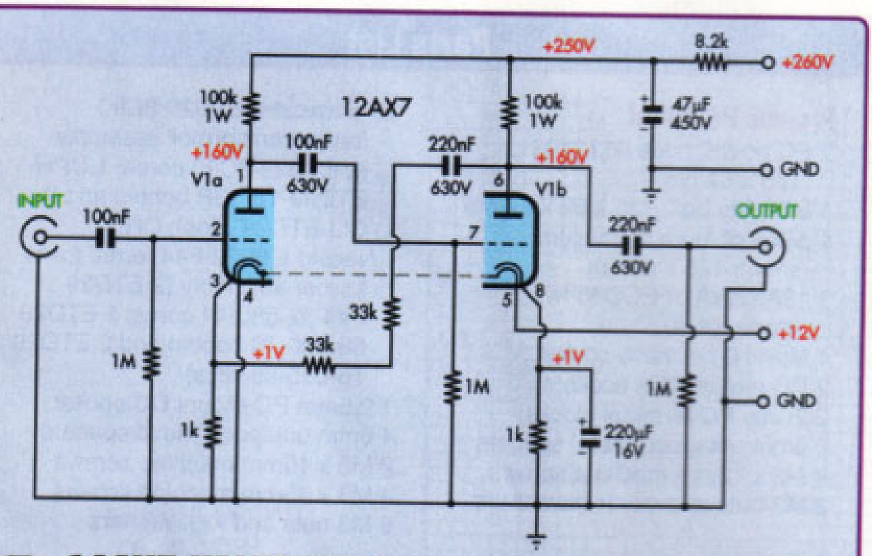
Capacitors
1 2200µF 16V PC electrolytic
1 470µF 25V PC electrolytic
1 10µF 450V PC electrolytic
1 10µF 35V TAG tantalum
1 1nF (.001µF) MKT metallised polyester

Resistors (0.25W 1%)
3 680kΩ 1W 1 39kΩ
1 220kΩ 1 4.7kΩ
1 47kΩ 1 1kΩ
1 100kΩ horizontal trimpot (VR1)

Cathode bias

By the way, once we decide to make this the valve's operating point, we can also choose the value of the self-bias cathode resistor (Rk in Fig.1). This will simply need a value which gives a voltage drop of 1.0V (the desired Vg), at the desired plate current (1.05mA). So Rk will have a calculated value of 952Ω, meaning that we can use the nearest preferred value: 1kΩ.

It's now fairly easy to show the valve's amplification at this operat-



12AX7 VALVE PREAMP

Fig.4: the final preamp circuit uses two triode common-cathode stages with negative feedback from pin 6 to pin 4, to greatly improve distortion and frequency response. Note the HT filtering network which reduces noise and hash on the 260V supply.

ing point, as you can see in Fig.3. If we draw a horizontal line off to the left from the operating point, this becomes the zero axis for our audio input signals fed to the valve's grid via capacitor C_{in}. Similarly by drawing a vertical line down from the operating point, this becomes the zero axis for the amplified audio signals that will appear at the valve's plate and are coupled out via capacitor C_{out}.

So when we draw a sample sine-wave input signal of say 1.0V peak-to-peak (±0.5V) as shown, we can run horizontal lines through from the signal's peaks to the points where they intersect the load line. Then we can draw vertical lines down from those points, because these must represent the plate voltage and current levels which will correspond to those signal peaks. Then we can reconstruct the valve's output signal as shown, underneath the curves.

Notice that the output from such a 1.0V peak-to-peak input signal will have a peak-to-peak amplitude of about 61V (174V - 113V), showing that the valve should provide an amplification or "gain" of about 61 times. As you can see the output waveform is also `upside down' with respect to the input waveform (positive input peak becomes negative output peak), showing the way the valve inverts the signal polarity – just like a transistor or FET.

So that's the basic way a triode valve amplifier stage is designed, using the graphical method. Practical design is a little more involved than that though, because there are a few complications. For example, the gain will never be quite as high as we find from the curves, because whatever AC load we connect to the output capacitor C_{out} is effectively in parallel with Ra (as far as the AC signals are concerned), which reduces its effective value – and hence the gain we can achieve.

Miller Effect high frequency loss

There's also another complication when the stage is amplifying higher audio frequencies, caused by the valve's internal capacitance between its grid and plate. In each section of the 12AX7, the internal grid-plate capacitance is about 1.7pF, which rises to about 2pF when the valve is plugged into a socket.

Now this capacitance is connected directly between the amplifier's input and output, and because the two are opposite in phase due to the signal's inversion, the capacitance provides a path for negative feedback. In addition, because of the valve's amplification, the capacitance tends to pass much more reactive current than it would as a result of the input signal alone. In fact, it draws (A+1) times the current, where A is the stage gain.

So this internal capacitance acts as if it was a capacitor A+1 times larger than its real value, a phenomenon known as the "Miller Effect". As a result, this kind of triode amplifier stage tends to have a fairly poor high-frequency response. For example, due to the Miller Effect our 12AX7's 2pF of grid-plate capacitance will have an effective value of about 124pF in the circuit of Fig.1, which has a drastic effect on its frequency response.

Performance

Voltage Gain: 61

Frequency response: -1dB at 20Hz and 160kHz (see Fig.5)

Harmonic distortion: <0.2% for output levels up to 3V RMS (see Figs.6 & 7)

Signal-to-noise ratio: -81dB unweighted (22Hz to 22kHz) with respect to 2V

Input impedance: 1MΩ

Output impedance: 1.5kΩ at 1kHz

First prototype circuit

But enough of theory. Our first attempt at a preamp circuit using the 12AX7 used the circuit shown in Fig.2. As you can see it consists of a voltage amplifier stage just like that in Fig.1, with a 100kΩ plate load resistor, a 1kΩ self-bias resistor and a 1MΩ grid resistor.

To try and achieve as high a gain as possible, even when the output of the preamp was connected to a main amplifier or mixing desk with a fairly low input impedance, we used the second triode section of the 12AX7 as a "cathode follower" with its 100kΩ load resistor connected from the cathode to ground rather than from the plate to +250V.

This makes the second stage have a gain of slightly less than unity, but at the same time it provides a high AC load impedance for the first stage plus a low source impedance to drive the following amplifier. This means that capacitance effects of the output signal cable will not cause further reductions in the high-frequency response.

This arrangement gave an overall gain of about 36 times but the high-frequency response was quite poor, due to Miller Effect in the first stage. The upper -3dB point was only 5kHz but we were able to compensate for

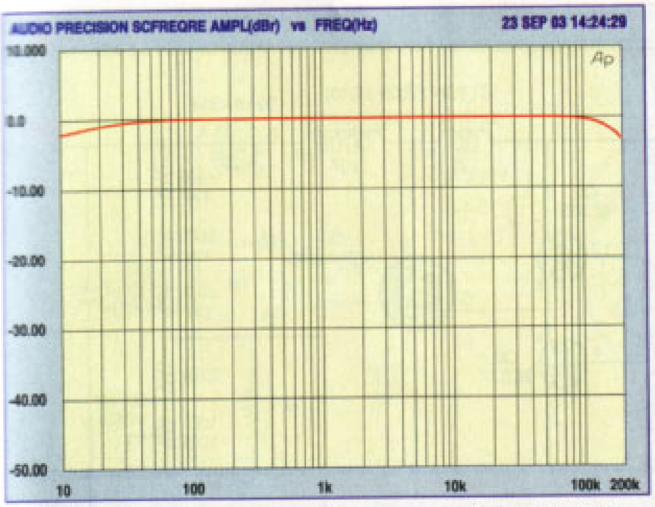


Fig.5: the frequency response is very smooth, with -1dB points at 20Hz and 160kHz, measured at 2V into a 50kΩ load. Because the output impedance is low, the frequency response will not be curtailed by an amplifier load.

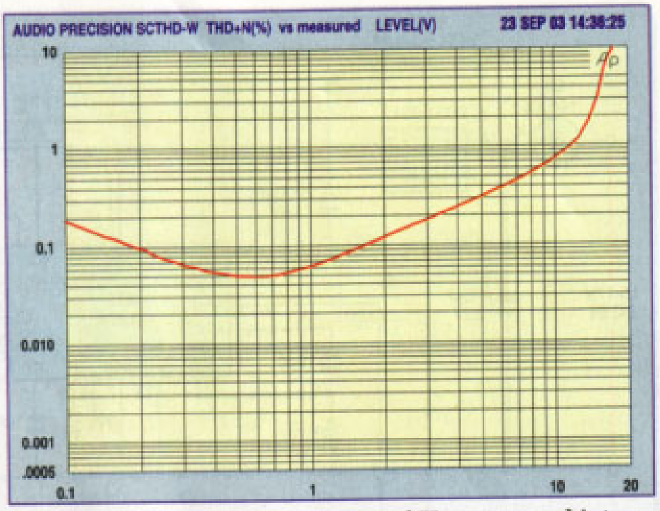


Fig.6: total harmonic distortion at 1kHz, measured into a 50kΩ load and with a measurement bandwidth of 22Hz to 22kHz. Note that most valve circuits do not have negative feedback and so their distortion is considerably worse.

that loss by adding an input compensation circuit (shown highlighted in Fig.2). However, this dropped the gain to 34 times, which we judged to be inadequate.

The distortion level we achieved with this configuration was also fairly high – about 0.9% with an output level of 3V RMS, and rising to above 5% for an output level of 16V RMS. These are very high levels of distortion compared to good solid-state designs but this was typical of valve stages operating without any negative feedback – which was the usual approach.

At Silicon Chip we have always tried to produce the best available audio performance, so we decided to try a different approach, converting the second preamp stage into a common-cathode amplifier like the first, and then applying a fair amount of negative feedback around the two.

The goal was higher overall gain, combined with a much more extended frequency response and much lower harmonic distortion. The negative feedback would also reduce the output impedance of the second stage, to make it easily drive following stages without high frequency loss.

To cut a long story short, this new configuration worked much better and as noted at the start of this article, the overall performance is far superior to that normally achieved by valve audio circuits from the "olden days".

Circuit description

Fig.4 shows the final circuit configuration. The input signal is coupled into the grid of triode V1a via a 100nF capacitor, with a 1MΩ resistor to tie the grid at DC earth potential.

The idea of using a 1MΩ grid resistor is to achieve the best possible low-frequency input response with the 100nF coupling capacitor (1MΩ is the highest allowed value for the 12AX7's grid resistor).

V1a has a 100kΩ plate resistor, as before, and the cathode bias resistor is also 1kΩ. But the latter isn't bypassed with a capacitor, because we use it as part of the negative feedback divider. The output from the plate of V1a is coupled to the grid of V1b, the second triode section of the 12AX7, via a second 100nF capacitor. This capacitor is rated at 630V because it has to be able to withstand the full HT voltage.

The second stage is almost identical to the first except that its 1kΩ cathode resistor is now bypassed with a 220µF capacitor, to achieve the maximum possible gain. The preamp's output is taken from the plate of V1b via a 220nF coupling capacitor, which again must be rated to withstand the full HT voltage. The final 1MΩ resistor to ground is to allow the 220nF capacitor to charge up as soon as the HT voltage is applied, rather than running the risk of it only charging later on when we connect the preamp to a load (which would cause a loud "plop" sound).

A second 220nF capacitor is connected to the plate of V1b, to couple the negative feedback signal back to the cathode of V1a via the two 33kΩ series resistors. (We use two resistors in series because of the fairly high voltage swings.)

The negative feedback divider formed by the two 33kΩ resistors and the 1kΩ cathode resistor has a division factor of 1/(66+1) or 1/67. This gives

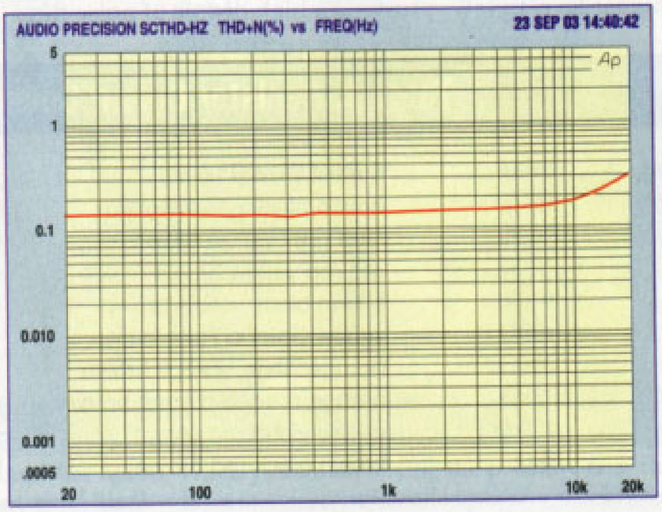
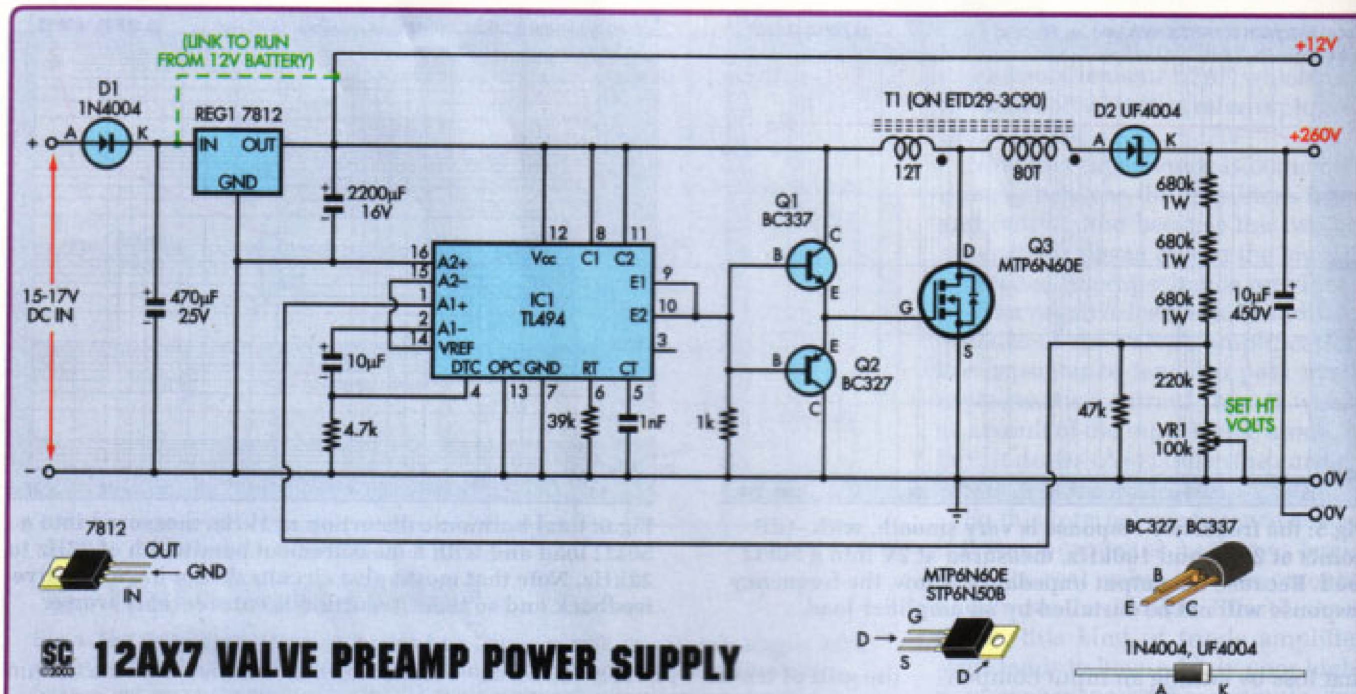


Fig.7: total harmonic distortion versus frequency, measured at 2V into a 50kΩ load and with a measurement bandwidth of 22Hz to 80kHz. Even the very best valve amplifier circuits (with negative feedback) of the past would have been struggling to match this performance.



12AX7 VALVE PREAMP POWER SUPPLY

Fig.8: the DC-DC converter uses a TL494 switchmode controller to drive Mosfet Q3 in a boost converter running at around 33kHz. T1 is wired as an auto-transformer to step-up the voltage developed in the 12-turn primary winding.

the preamp a theoretical final gain of very close to 67. In practice, the measured gain was 61.

The performance of this final preamp configuration is shown in the plots, produced on SILICON CHIP's Audio Technology test system. Fig.5 shows the very smooth frequency response, with -1dB points at 20Hz and 160kHz, measured at 2V into a 50kΩ load.

Figs.6 & 7 shows the harmonic distortion performance. Total harmonic distortion (THD) is below 0.2% for output levels up to about 3V RMS (8.5V peak-to-peak). The distortion remains below 1% at output levels up to about 12V RMS and then goes into soft clipping at higher levels.

The distortion is mainly second harmonic, as expected.

The preamp's signal-to-noise ratio is better than -81dB unweighted (22Hz to 22kHz measurement bandwidth) with respect to 2V RMS output. Most of the noise is a low-level "frizzle" from the 33kHz switching hash of the DC-DC converter.

The preamp's input impedance is very close to 1MΩ while its output impedance measures very close to 1.5kΩ, thanks to the negative feedback.

Before leaving the preamp circuit, note that the HT supply is fed to the circuit via an 8.2kΩ resistor which is then bypassed by a 47µF 450V electrolytic capacitor. This RC network provides a high degree of noise filtering and removes most of the residual high frequency noise and hash superimposed on the HT line from the DC-DC converter. The voltage on the decoupled line is +250V which means that the DC-DC converter needs to deliver about +260V.

DC-DC converter

Now let's look at the DC-DC converter circuit shown in Fig.8. As we

Table 2: Capacitor Codes

Value	µF Code	EIA Code	IEC Code
220nF	0.22µF	224	220n
100nF	0.1µF	104	100n
1nF	.001µF	102	1n

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	3	1MΩ	brown black green brown	brown black black yellow brown
☐	3	680kΩ	blue grey yellow brown	blue grey black orange brown
☐	1	220kΩ	red red yellow brown	red red black orange brown
☐	2	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	47kΩ	yellow violet orange brown	yellow violet black red brown
☐	1	39kΩ	orange white orange brown	orange white black red brown
☐	2	33kΩ	orange orange orange brown	orange orange black red brown
☐	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	3	1kΩ	brown black red brown	brown black black brown brown

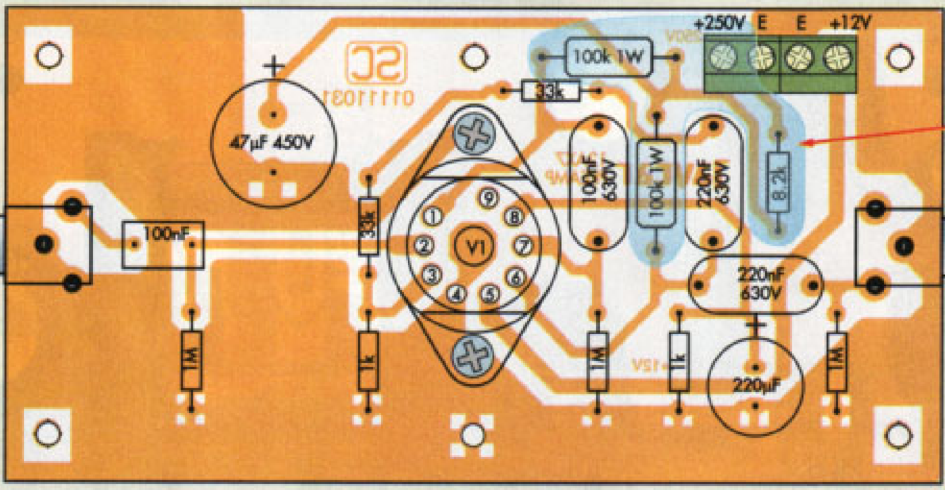


Fig.9: the parts layout for the preamp board. Make sure that the electrolytic capacitors are installed with the correct polarity and note that the high-voltage components must be covered with neutral-cure silicone sealant.

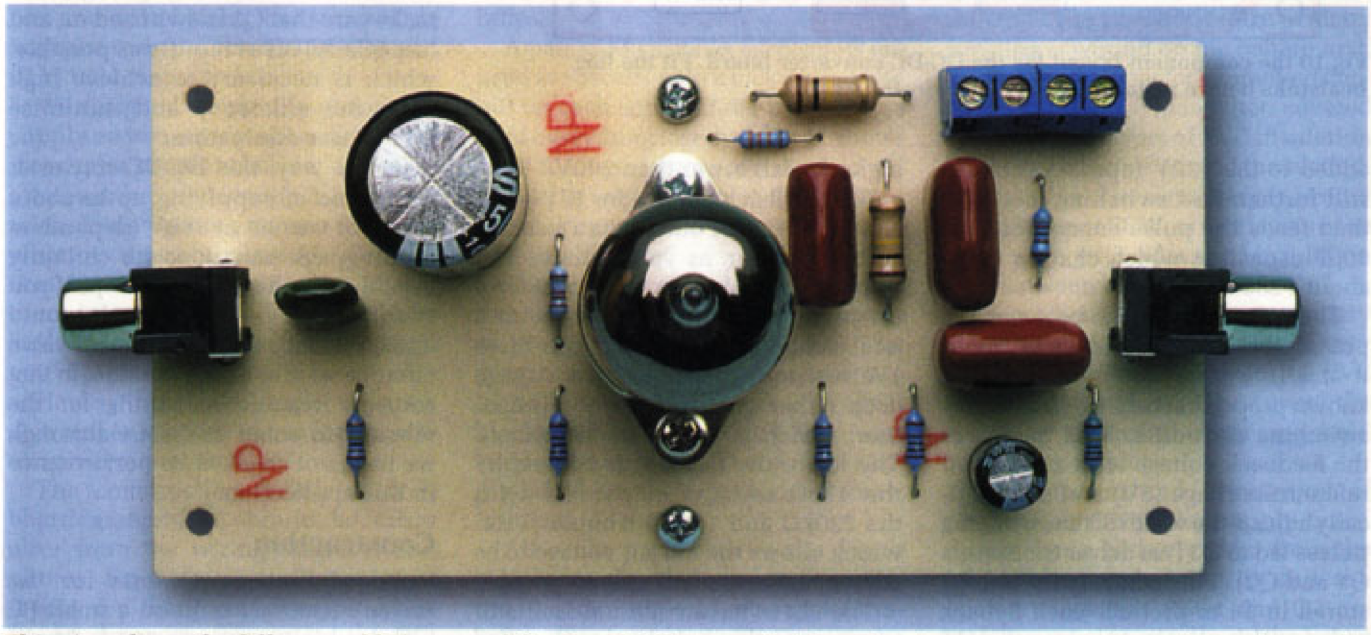
mentioned earlier, we have to provide the valve with an HT supply of about +260V in addition to the low voltage needed for its heaters. Current requirements from the HT supply are quite small – only about 2mA for both preamp stages. Since the 12AX7's heaters can also run from 12V DC, this has the advantage that the complete preamp can be run from either a 12V battery or a suitable 12V DC plugpack. The total drain from the 12V source is only about 250mA.

By the way, it's actually very desirable to run the 12AX7 heaters from 12V DC in an audio preamp, because this removes a major source of hum. When the valve heaters were run from 12.6VAC in the "valve days", it was very difficult to avoid a small amount of 50Hz hum caused by heater-cathode leakage and capacitance – plus some 100Hz hum caused by thermal modulation.

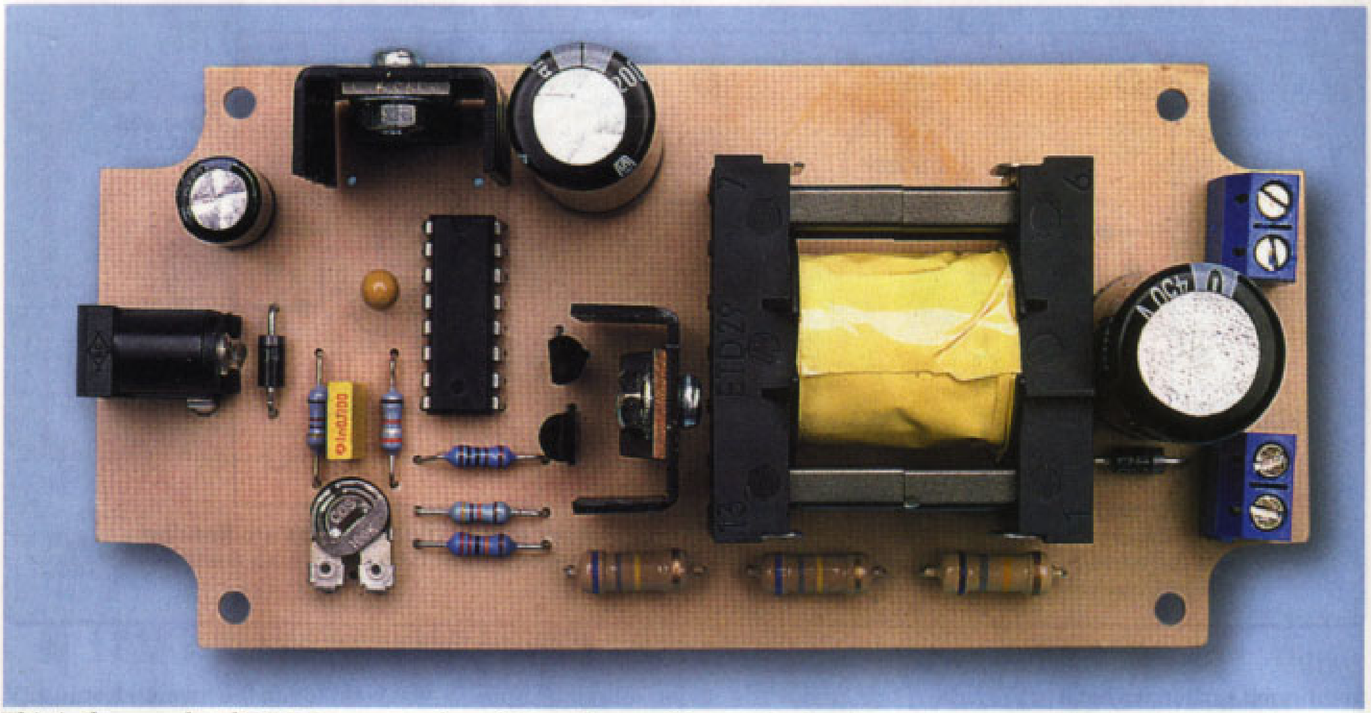
As you can see from the circuit of Fig.8, the power supply is quite straightforward. Regulator REG1 is included so that the preamp can be operated from an unregulated plug pack, while still providing both the valve heaters and the DC-DC converter with smoothly regulated 12V DC. If you want to run the preamp from a 12V battery, the regulator is simply omitted and replaced by a wire link.

The DC-DC converter uses a standard "flyback boost" circuit, where energy is first drawn from the +12V supply and stored in the 12-turn primary winding of transformer T1, by turning on Mosfet Q3 (which acts as a high-speed switch). Then Q3 is turned off, so that the stored energy is returned to the circuit as a high voltage "flyback" pulse, induced in both windings of T1.

Because the two windings are connected in series, this output pulse is



This view shows the fully assembled preamplifier board. When you finish testing the preamp, coat the 100kΩ resistors, the 8.2kΩ resistor the HT connection on the terminal block with neutral-cure silicone sealant – see Fig.9.



This is the completed DC-DC converter board. Note the small heatsinks fitted to transistor Q3 and to regulator REG1.

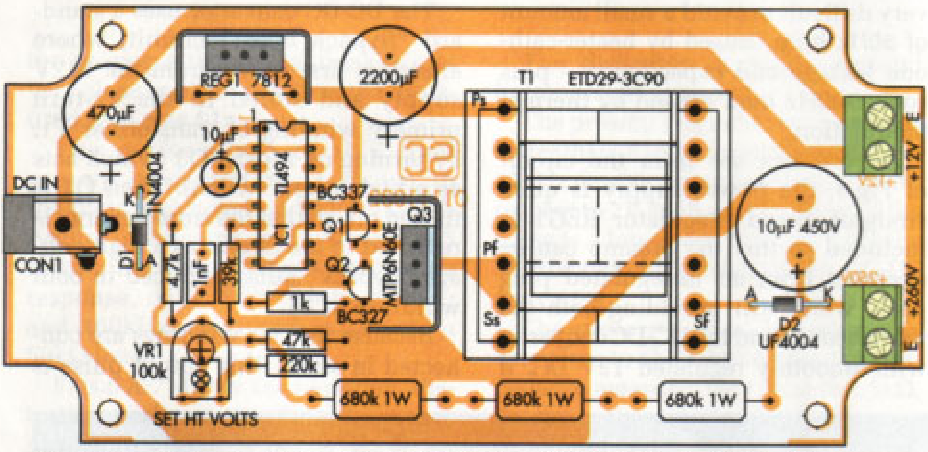


Fig.10 the component layout for the DC-DC converter board. Fit the flag heatsinks before installing REG1 and Mosfet Q3.

added to the +12V input, boosting it still further. Fast switching diode D1 then feeds the pulse energy into the 10µF capacitor, which charges up to about +260V.

The capacitor voltage becomes the preamp's HT supply and we maintain it at a little over 260V by feeding a known proportion back to IC1, a TL494 switching controller. This compares the feedback voltage with an internal reference voltage (5V) and automatically adjusts the width of the switching pulses fed to Q3 (via driver transistors Q1 and Q2). This controls the energy stored in T1 to produce each flyback pulse and hence makes sure the HT output voltage is not allowed to rise higher or fall lower than 260V.

The feedback voltage for IC1 is derived from the HT output via a resistive voltage divider, as you can see. The three 680kΩ 1W resistors in series form the upper arm of the divider, with a total value of 2.04MΩ (we use three 1W resistors to handle the voltage drop rather than the power dissipation, which is only 30 milliwatts!). The lower divider arm is formed by the 47kΩ resistor in parallel with the 220kΩ and 100kΩ trimpot (VR1) which allows the output voltage to be adjusted over a small range.

The TL494 has an internal oscillator to generate the switching pulses fed to Q3, and the oscillator's frequency is set by the values of the resistor and capacitor connected to pins 6 and 5. The values shown (39kΩ and 1nF) give the converter an operating frequency of 33kHz, which is high enough to ensure that any output ripple which finds its way into the preamp (either via the HT line or by radiation) will be inaudible.

Transistors Q1 and Q2 are used to buffer the PWM (pulse width modulated) pulses generated by IC1, providing a low impedance high current drive for the gate of Q3. This is to make sure that Q3 is switched on and (especially) off as rapidly as possible, which is necessary to achieve high converter efficiency and minimise Q3's power dissipation.

By the way, this DC-DC converter is capable of supplying up to about 40mA of current at 260V (dependent on plugpack rating), so it's certainly capable of feeding two preamps if you wish to have a stereo pair. It would also be suitable for running other valve circuits, such as a mantel radio. In that respect, it could substitute for the vibrator in some 12V sets, although we have not checked its performance in this application.

Construction

All of the components for the preamp itself are built on a small PC board which measures 125 x 62mm – just the right size to mount on the top

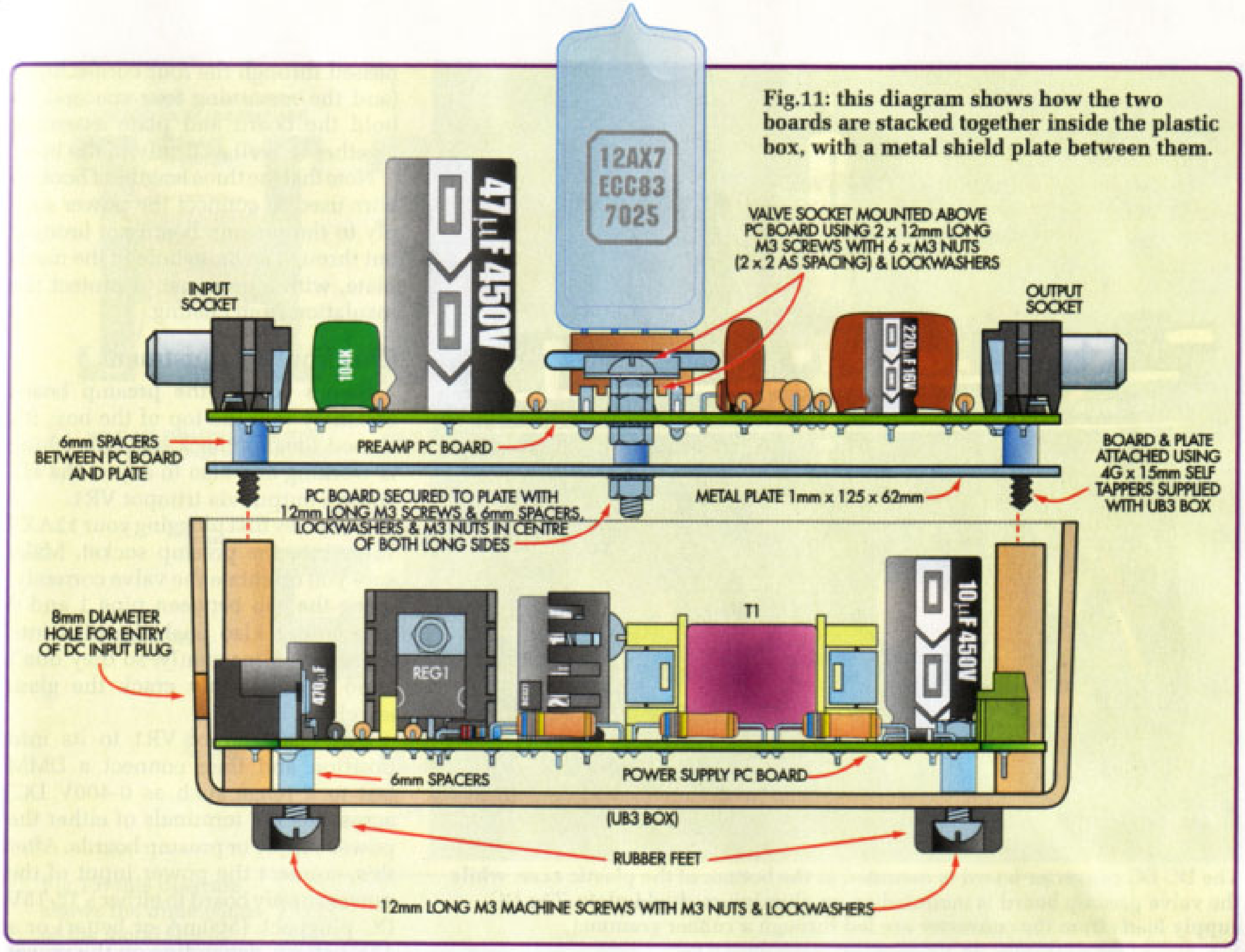


Fig.11: this diagram shows how the two boards are stacked together inside the plastic box, with a metal shield plate between them.

of a standard UB3 size jiffy box, as you can see from the photos. The power supply is built on a slightly smaller PC board measuring 122 x 58mm, which is designed to go down inside the UB3 box and out of sight. The two boards have the code numbers 01111031 and 01111032 respectively.

We designed the preamp and power supply on two separate boards to make it easier for people to build a "2 preamp + 1 power supply" combination, if they wish. It also gives you more options when it comes to physical construction, because you don't have to build them into a jiffy box. They could be built side-by-side in a metal box, if you'd prefer.

Having the power supply separate also makes it easier to use it to power other valve projects.

The construction details of both board assemblies should be fairly clear from the wiring diagrams and photos. Fig.9 shows the component layout for the preamp board while Fig.10 shows the layout for the DC-DC converter board.

Note that the valve socket for the 12AX7 is mounted above the centre of the preamp board, using two 12mm-long M3 machine screws through the flange holes and the matching board holes.

A pair of M3 nuts on each screw are used as spacers, with a lockwasher and nut on each screw under the board to hold everything together. Fig.11 shows how the two boards are stacked together, as well as the way the preamp board is mounted to the metal box lid and shield plate.

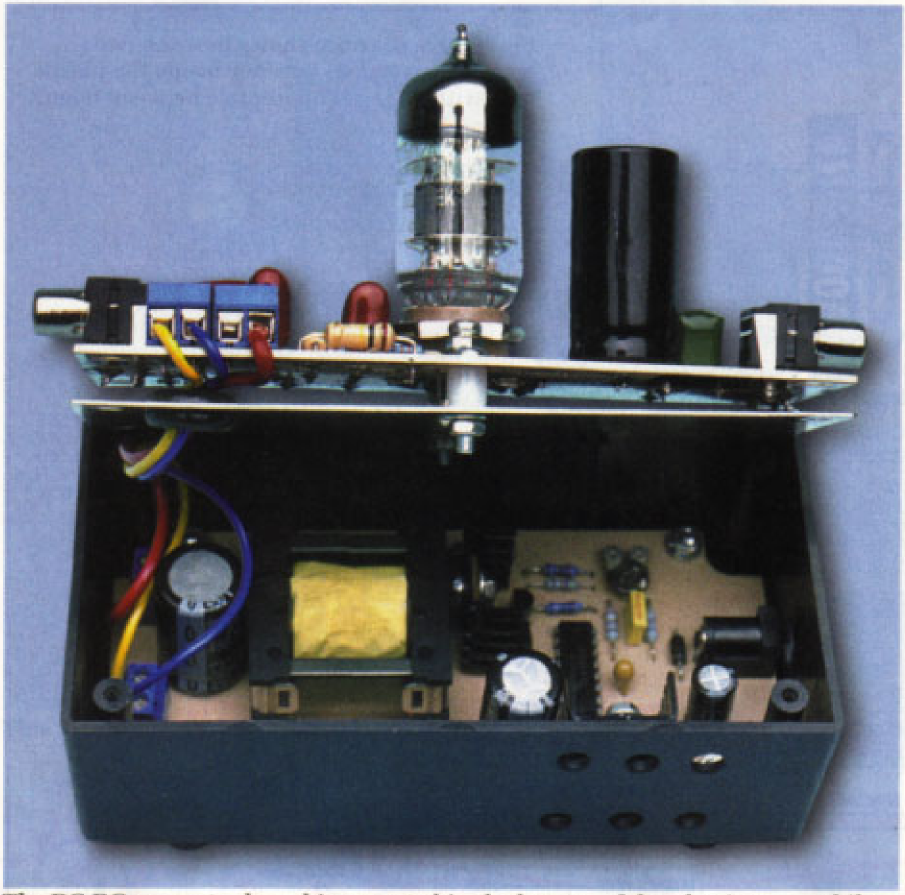
The audio input and output connectors are RCA sockets, mounted directly on the preamp board at each end. The power connections are brought out to board-mounting mini screw terminal blocks, which accept suitable insulated hookup wire. The power supply board has the same kind of screw terminal blocks.

All of the parts used in the power supply are also built directly onto the board, including converter transformer T1. This is wound on a Ferroxcube ETD-29 ferrite transformer assembly, which uses two E-cores made from 3C90 ferrite material plus a bobbin type CPH-ETC29-1S-13P, and two clips type CLI-ETD29.

The construction details for T1 are shown in Fig.12. The 12-turn primary winding is wound on the bobbin first, using 0.8mm diameter enamelled copper wire (ECW). This is then covered in a couple of layers of PVC insulation tape, over which is wound the secondary winding. The secondary is wound using 0.25mm ECW, as two layers of 40 turns each with a layer of insulation tape between the two layers.

Then when the end of the secondary is soldered to the appropriate former pin (Sf), another few layers of PVC tape are applied over the top of the windings to protect them and hold everything in place.

The location and orientation of all parts on the power supply board should again be fairly clear from the wiring diagram of Fig.10 and the photos. Note that REG1 and Q3 are both mounted vertically on the board and each is fitted with a TO-220 mini



The DC-DC converter board is mounted in the bottom of the plastic case, while the valve preamp board is mounted on an aluminium shield plate. The DC supply leads from the converter are fed through a rubber grommet.

heatsink (19 x 19 x 10mm) like the Jaycar HH-8502. These ensure that they run within ratings. In practice, you will find that the Mosfet (Q3) runs cool, while the 3-terminal regulator gets quite warm or even, depending on the input voltage from your DC plugpack.

Take care when you're fitting all of the polarised parts to the board – especially the electrolytic capacitors, the diodes, the transistors and the IC and regulator.

The finished power supply board is mounted in the bottom of the UB3 box using four 15mm long M3 machine screws, with M3 nuts and star lock-washers. Four 6mm long untapped metal spacers are used to provide clearance for the solder joints under the board.

Three lengths of insulated hookup wire are used to connect the power supply outputs to the screw terminals on the preamp board. The preamp board itself is mounted above a 125 x 62mm piece of 1mm thick aluminium sheet, which is identical to the alternative metal lid sold with some UB3 boxes. The dimensions of the plate are shown in Fig.13.

The aluminium plate supports the preamp PC board as well as providing shielding between it and the power supply board. The preamp board is spaced above the plate using six 6mm-long untapped metal spacers.

It's attached to the plate initially using two 12mm long M3 machine screws with M3 nuts and star lock-washers, passing through the centre holes on each long side of the board. Then when the plate is placed in the top of the box, the four 4G x 15mm self-tappers supplied with the box are passed through the four corner holes (and the remaining four spacers), to hold the board and plate assembly together as well as firmly in the box.

Note that the three lengths of hookup wire used to connect the power supply to the preamp board are brought out through an 8mm hole in the metal plate, with a grommet to protect the insulation from chafing.

Where To Buy A Kit

A complete kit of parts for this design is available from Jaycar Electronics for $89.95. In addition, Jaycar will be selling a kit for preamplifier board only (includes the preamp PC board, all parts and the valve) for $59.95. Note: copyright of the PC boards associated with this design are owned by Jaycar Electronics.

Checkout & adjustment

Before you fit the preamp board assembly into the top of the box, it's a good idea to check that everything is working and also to adjust the HT voltage output via trimpot VR1.

Do this by first plugging your 12AX7 valve into the preamp socket. Make sure you orientate the valve correctly, using the gap between pins 1 and 9 as a guide. Also push the pins into the socket clips gently, so they don't bend and possibly crack the glass envelope.

Now set trimpot VR1 to its mid position and then connect a DMM (set to a range such as 0-400V DC) across the HT terminals of either the power supply or preamp boards. After this, connect the power input of the power supply board to either a 12-15V DC plugpack (500mA or better) or a 12V battery, depending on the power source you're planning to use for the preamp.

A few seconds after you connect the power, you should see the heaters of the valve begin glowing as they heat up. At the same time the DMM reading should rise up to 260V or thereabouts, as the DC-DC converter output builds up. If the voltage rises higher than 260V or lower than 250V, adjust trimpot VR1 to bring it back to 260V. That's the only adjustment you may need to make.

If you want to make sure that the preamp circuit is working correctly, carefully disconnect the DMM from the HT supply **(don't touch the probes or clips, because 260V DC can give you a nasty shock!)** and use it to measure the plate voltage on each section of the 12AX7. You can measure these voltages at the plate ends of each 100kΩ 1W plate load resistor, with the DMM's negative lead connected to the preamp's earth. You should measure about +160V on each plate.

You can also measure the voltage across each 1kΩ cathode resistor, with the DMM now set to a lower DC range.

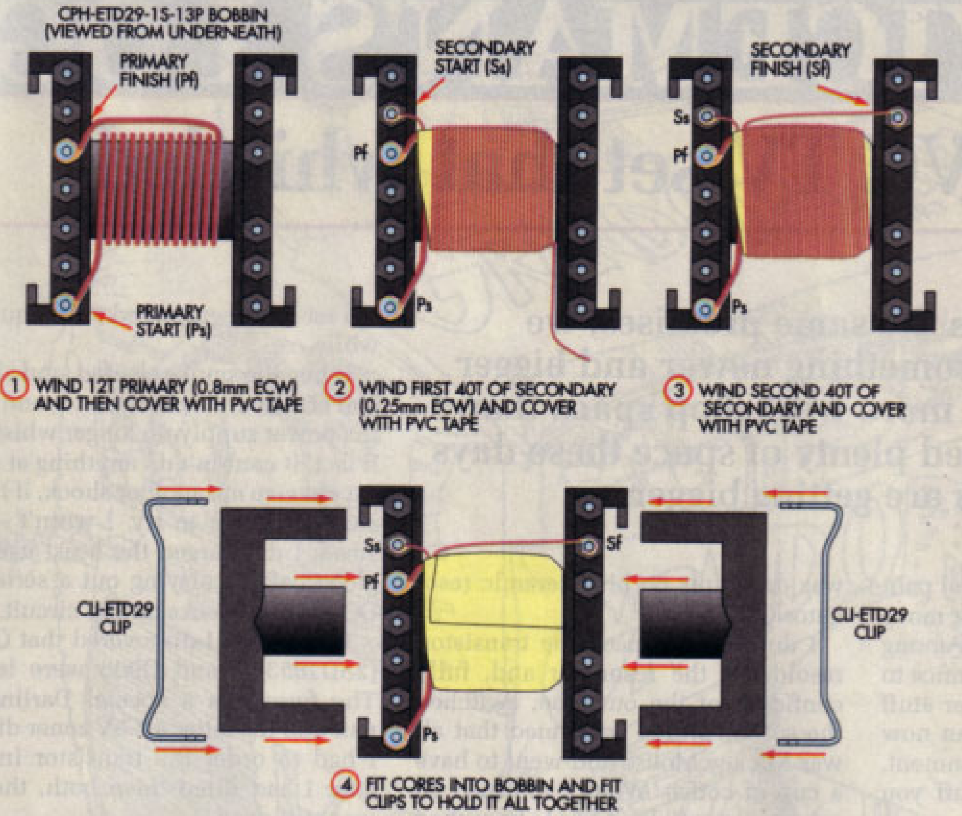
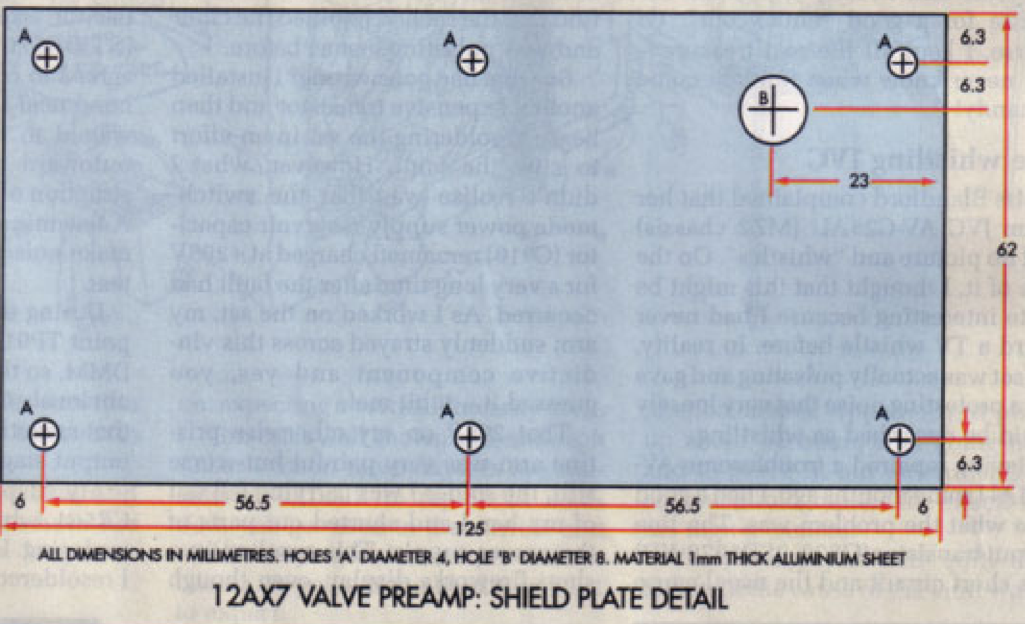


Fig.12: these diagrams show how the converter transformer is wound. The primary is wound on first, followed by two layers of the secondary.

Fig.13: this diagram shows the dimensions of the metal shield plate.



You should find about 1V DC across each one, verifying that each section of the 12AX7 is drawing about 1mA of plate-cathode current.

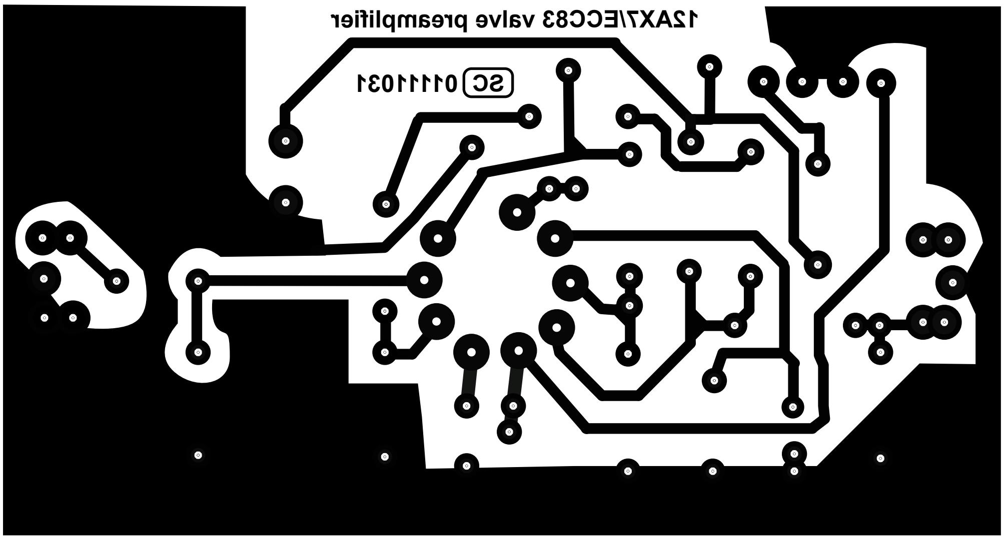
If all these voltages seem OK, your preamp should be working correctly.

High voltage protection

Now that you've checked all the voltages, it remains to provide a some protection against accidental electric shock. **Since the HT voltage is around +250V, it is possible to get a bad shock if you simultaneously touch the plate resistors and the earthed RCA connectors.**

With that in mind, we strongly suggest you put a generous coating of silicone sealant over the two 100kΩ 1W resistors, the 8.2kΩ resistor and the HT connection on the screw terminal block (be sure to cover both the top and the side entry point).

Now all that should remain is connecting its input to the pickup of a guitar or other instrument and its output to your power amplifier, recorder or mixing desk. Then you can hear for yourself what "valve sound" actually sounds like. **SC**



PCB ready for transfer