

# Valves at Low Plate Voltages (2)

## Part 2: more power!

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Genuine power valves such as the EL84, EL95, ECL80 and ECL86, and in particular the PL504, do of course offer more power output at low anode voltages than the ECC81 and ECC82 types we discussed in the first part of this series. With the PL504 it is even possible to drive an ordinary low-impedance loudspeaker, using an anode voltage of only 27 V. In this second article we will also be looking at some miniature Russian 'battery valves', which not only operate at low anode voltages, but also demand considerably less heater power.

If, after our initial experiments with ECC81s and ECC82s (or their US equivalents 12AT7 and 12AU7), you have come to the conclusion that our valve headphone amplifier could do with a little more power, then it is time to take a look at some valves which are designed for higher power. Suitable candidates would be output-stage valves such as the EL84 (6BQ5), EL95 (6DL5), ECL80 (6AB8), ECL86 and similar types.

### The EL95

Here we tested a used EL95. The EL95 is a pentode, which means that it has two more grids than a triode. Grid 2 should be connected to the supply voltage, while grid 3 should be connected to ground. Pentodes have a higher gain and lower distortion than triodes. The EL95 is used here with an anode voltage of between 12 V and 24 V. **Figure 1** shows the circuit arrangement for one channel and the pinout of the valve.

The EL95 is relatively economical, drawing a heater current of only 200 mA. Despite

this, we obtain an anode current of 1.3 mA at 12 V and 3.5 mA at 24 V. A respectable power output can be achieved using a suitable transformer. A usable stereo headphone amplifier for low-impedance (32  $\Omega$ )

headphones can be constructed to run from a 12 V supply, for example from an ordinary mains adaptor. The heaters of the two valves should be wired in series to the same 12 V supply used for the anodes.



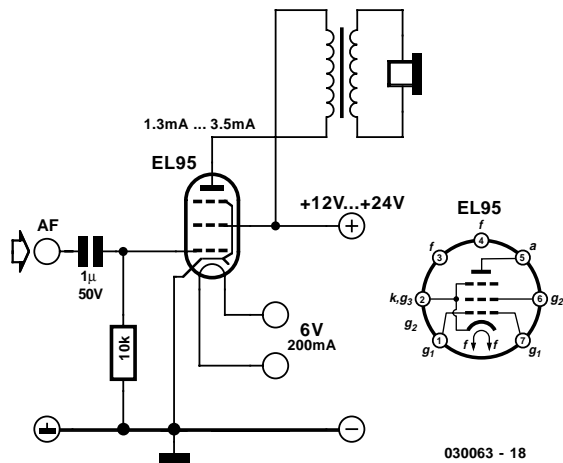


Figure 1. Amplifier using an EL95.

If good sound quality is important then the right transformer must be used. Very small mains transformers have a high winding resistance and saturate too easily. If larger transformers are used, the saturation problem disappears, but the inductance will be lower and so low frequency response will be impaired. A mains transformer can only replace a genuine audio transformer in limited circumstances: in general a custom transformer must be wound for each design of valve output stage, which is of course rather inconvenient.

And so we return to the simplest design and connect the headphones directly in the anode circuit. Experiment shows that this works well with 600 Ω headphones. The question is whether the headphones can tolerate a direct current of 3.5 mA, for example. This corresponds to a

static dissipation of just under 7.5 mW in the quiescent state. The thermal effect of this does not seem excessive, since headphones are typically rated up to 100 mW. A different question is whether the mechanical displacement of the diaphragm will lead to distortion. The direct current is effectively a mechanical pre-tensioning, or 'bias', of the diaphragm, which could, in principle, affect the sound. In practice, however, there is no perceptible disadvantage, and so it seems a sensible idea to construct a headphone amplifier without transformers.

If it is desired to avoid both the use of transformers and a direct current in the headphones, then capacitor coupling can be used (Figure 2). In this case, high-impedance (600 Ω) headphones must be used. The volume is lower than with an ideal out-

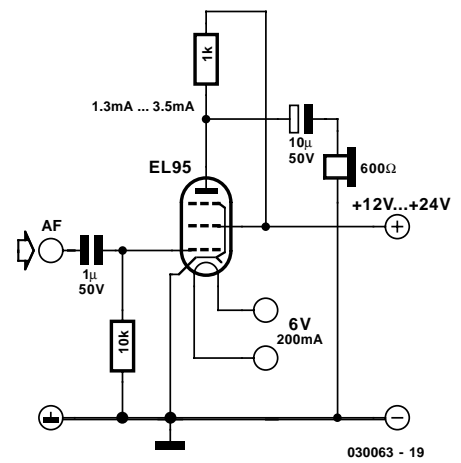


Figure 2. Transformerless headphone amplifier using an EL95.

put transformer, but is entirely adequate for most applications.

### Class A amplifier using a PL504

Can we do a little more? What about using a PL504 in a small class A loudspeaker amplifier? The PL504 is a physically large valve with a Magnoval base, which was used in the line output stages of television sets. Its heater requires 300 mA at 27 V. It therefore makes sense to use an anode voltage of 27 V also. In its intended application in the line output stage the valve had to operate at anode currents in excess of 500 mA, and of course this means that we can also expect good performance at lower voltages.

An experiment using 27 V produces an anode current of 33 mA. That is already more than (according to its data sheet) the EL95 can deliver at 250 V — we will certainly be able to build a very useful loudspeaker amplifier using a PL504 at 27 V. A reasonably large transformer will be needed for good results. The impedance connected to the valve should be around 800 Ω. The circuit was tested using a large mains transformer with a 230 V primary and a 24 V secondary, having a turns ratio of around 10:1 and hence an impedance ratio of around 100:1. An 8 Ω loudspeaker is then just right, since the valve will see 800 Ω. An oscilloscope can be used to check that the valve is suitable. If, when the amplifier is driven into limiting both positive and negative half-cycles are clipped to an approximately equal degree, then the circuit is optimally arranged.

In use, this amplifier (Figure 3) delivers plenty of volume and a pleasant sound. The anode power dissipation is around 1 W, as would be expected. The 27 V supply voltage is a little inconvenient: an experiment was tried using 24 V. The lower heater power does

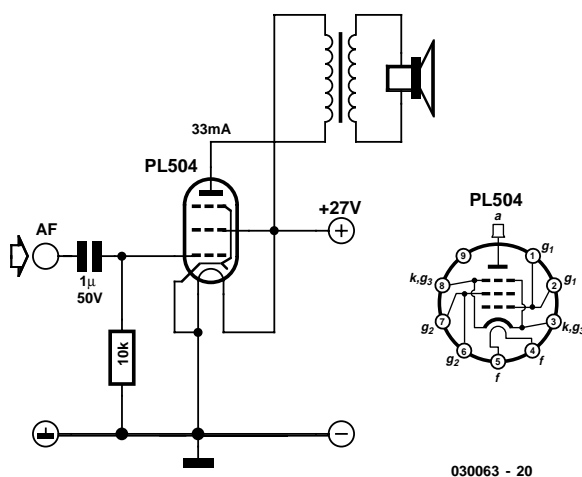


Figure 3. Loudspeaker amplifier using a PL504.

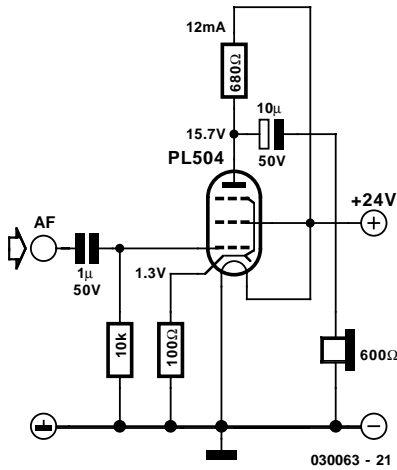


Figure 4. Headphone output stage running on 24 V.

not appear to have any ill effect; the anode current falls to 25 mA and there is practically no effect on the sound.

### PL504 headphone amplifier

When building a headphone amplifier, the PL504 has plenty of spare capacity to allow RC coupling to be used at the output. A cathode resistor of 100 Ω provides a grid bias voltage of -1.3 V. At the same time, distortion is reduced due to negative feedback. A 680 Ω resistor in the anode connection allows the amplified signal to be coupled out of the circuit. In this circuit (Figure 4) only about half of the amplified signal current flows through the headphones, the other half flowing through the anode resistor. With an anode current of 12 mA we can put up with this loss.

This headphone amplifier can be constructed without difficulty, since there is no need to find a suitable output transformer. The circuit has a pleasant sound and plenty of volume. If you can find two PL504s, consider yourself lucky; alternatively, there is the EL504 which has a heater voltage of 6.3 V at a current of 1.3 A. This is practically the same valve, but with a different heater. And of course there are many other power pentodes around which similar circuits can be designed.

### Low-voltage valves from Russia

The 1SH24B, 1SH29B and 1P24B (Figure 5) are tiny battery valves from the former Soviet Union. These valves are still available in large quantities and can be obtained very cheaply. They have wire connections that can be soldered directly, and so special sockets are not required. A characteristic of these valves is the directly heated cathode: in other words,

the heater is also the cathode. This has an impact on the circuit design, since it makes it difficult to wire heaters in series.

Most valves have a concentric construction, but these are rather different. In the centre is a thin heater element which forms the directly-heated cathode; in the case of the 1SH19B and 1P24B there are two cathodes. All the other electrodes take the form of plates or wires arranged parallel to the cathode. This makes for a very robust and efficient valve.

The 1SH24B (high frequency pentode) has a heater current of just 13 mA at 1.2 V — a marvel of efficiency. The 1SH29B (universal pentode with  $P_a = 1.2$  W) has a heater current of 64 mA at 1.2 V or 32 mA at 2.4 V.

Initial experiments with the 1SH29B show that it has very useful properties: at  $U_a = U_{g2} = 40$  V the

anode current is 3 mA, grid 1 being held at the same voltage as the negative heater terminal. The transconductance is about 1 mA/V. The valve also works at lower voltages, but the anode current and transconductance fall off sharply. Even at an anode voltage of 12 V the characteristics are better than those of the ECC81.

Still better is the 1P24B (power pentode with  $P_a = 4$  W). The 'P' might stand for 'power', and this tiny valve certainly has that. It needs a relatively high heater current of around 240 mA at 1.2 V, but in return we get very useful results even at an anode voltage of zero. With a grid voltage of zero we obtain an anode current of 2 mA and a transconductance of 1.5 mA/V. The valve is therefore particularly suitable for use in a small headphone amplifier. Figure 6 shows a tested circuit for use with high-impedance headphones.

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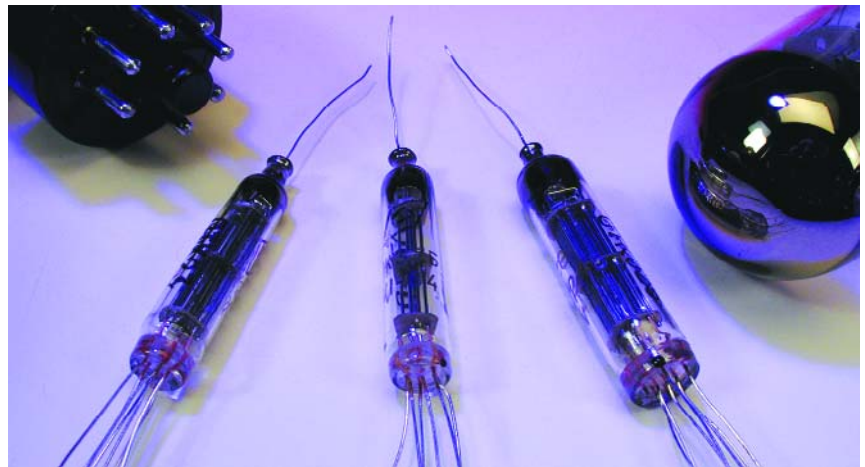


Figure 5. The 1SH24B, 1SH29B and 1P24B.

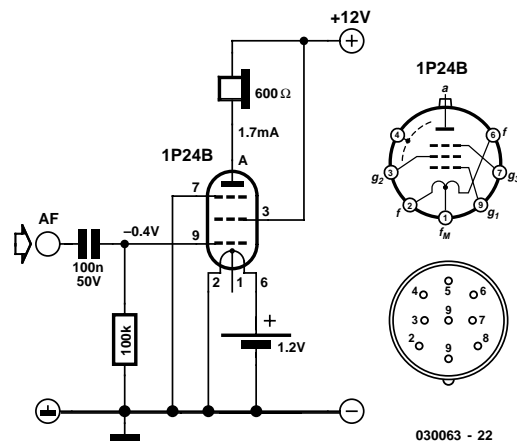


Figure 6. Audio amplifier using a 1P24B.