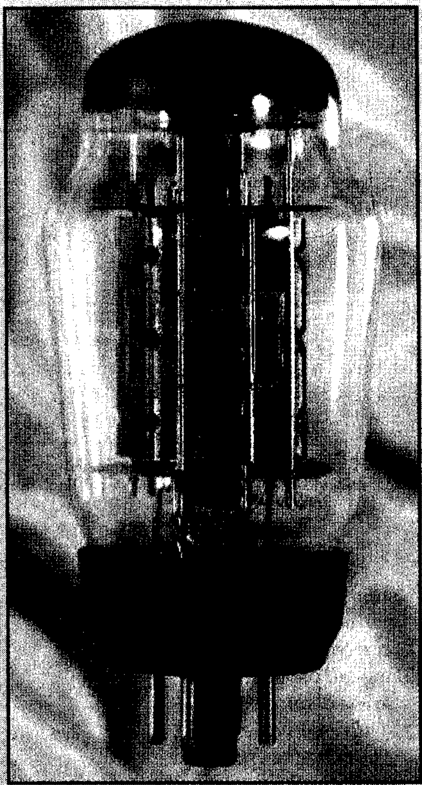
DC-coupled valve power



Coupling capacitors and output transformer greatly simplify valve power amplifier design, but they both degrade linearity. Because of the inherently high impedance of valves, eliminating the output transformer is difficult. Numerous single-ended designs without coupling capacitors have appeared in the past, but there have been few DC-coupled push-pull amplifiers like this one from Kees Heuvelman and Wim de Haan.

This article was prepared by Wim de Haan, Kees Brakenhoff and Kees Heuvelman. The idea for the amplifier came from Kees Heuvelman.

Throughout the years I have seen many valve circuits. I have seen single-ended designs without coupling capacitors, but I have never seen a push-pull design that was DC coupled.

I believe that coupling capacitors have a major influence on the overall sound quality of an amplifier. The goal here was to produce a relatively simple push-pull valve amplifier using an output transformer, but without any coupling capacitors.

Valve amplifiers have appeared without an output transformer. But the benefits of transformerless designs are are outweighed by their high complexity and high component count.

We have found that single-ended designs are affected by speaker choice so we produced this DC-coupled amplifier using an ECC85 and EL84s in push-pull.

Design goals, amplifier No 1

The goal of this amplifier project was to design an amplifier with a low component count that was DC coupled throughout. It also had to be low cost and relatively easy to build.

Figure 1 shows the complete amplifier. Because one of the design goals was low component count, we had to come up with a simple input stage. A long-tail pair was chosen.

An ECC85 is used for its low impedance in combination with a relative high amplification factor. The low impedance is important because the valve has to work with a relatively low plate voltage. We have found the ECC85 to perform well in audio applications. It is also widely available and inexpensive.

For the output stage, we chose the EL84. It is also inexpensive and widely available. In push-pull mode, it can deliver over 10W.

Most valve amplifiers use a common-cathode circuit directly coupled to a long-tailed pair as driver stage. We thought, "why not skip the common cathode and find a way to couple the long-tail pair directly to the EL84 push-pull output circuit?" After all, the ECC85 can provide enough gain.

The EL84 needs –11V of bias for 40mA at 300V plate voltage. Thus, we had to find a way to couple the long-tail pair and the output stage in such a way that the 11V bias voltage remained.

Our power supply provides +390V. Knowing this allows the anode voltage of the ECC85 to be calculated. Maximum plate voltage of the EL84 is 300V, so cathode voltage has to be something like +85V. This is derived from,

$$V_{cath}=V_{psu}-(V_{plate}+V_{transformer}).$$

Now that the cathode voltage of the EL84 is known, it is easy to determine the plate voltage of the ECC85. As the cathode voltage is +85V, this has to be +74V in order to maintain the –11V bias voltage. The screen grid voltage should be 85V–11V=74V.

A transistor is used as a current source, setting current for the ECC85. Because of the high values of the cathode resistors, the EL84s automatically find the correct operating point.

The current source also makes the amplifier more stable via DC feedback by means of the two 120kΩ resistors. These resistors apply some correction for current differences in the EL84s by setting the voltage at the base of the transistor. This correction feature is not essential, but it works fine with the current source used.

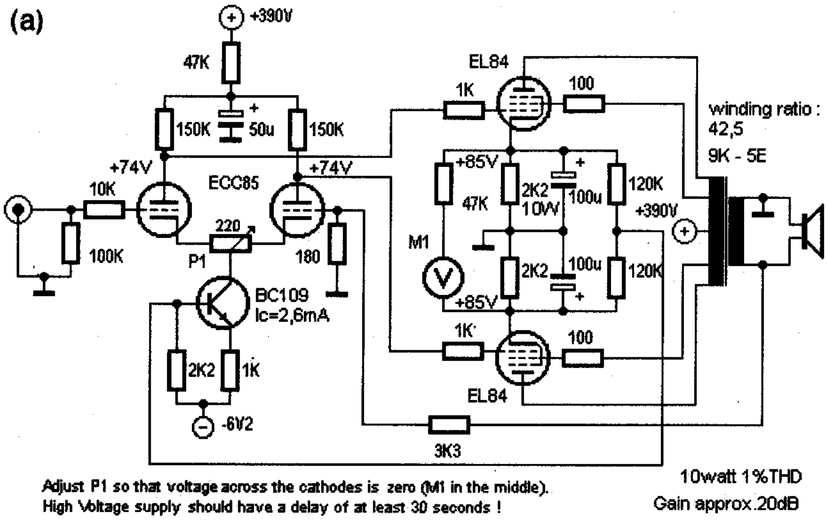
A negative supply is needed for the current source. We chose –6.2V for convenience, using the heater winding and zener diode to produce it. If you use 12V and modify the current source as shown in Fig. **1b)**, you can remove feedback and the amplifier will be very stable.

Using a cascode as a current source with a LED forming the reference should improve the current source even further. In this alternative, Fig. **1c)**, the DC feedback is again superfluous.

Potentiometer P_1 is 220Ω and is added to correct imbalance in the output stage. We used a voltmeter made from a small 50μA-0-50μA meter for adjustment. If the needle of this meter is in the middle, balance is good.

Adjustment for imbalance is not critical. A difference in the cathode voltages of 2.2V will result in a current imbalance of only 1mA. This is because of the large DC current feedback of the large cathode resistors.

Adjustment should be made 20 seconds after power-up and again after 15 minutes



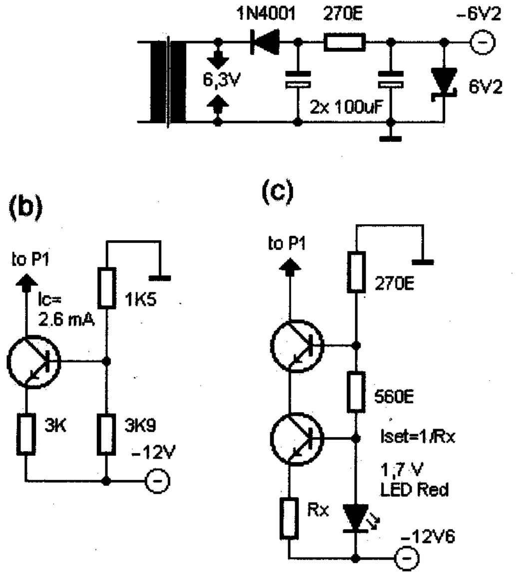
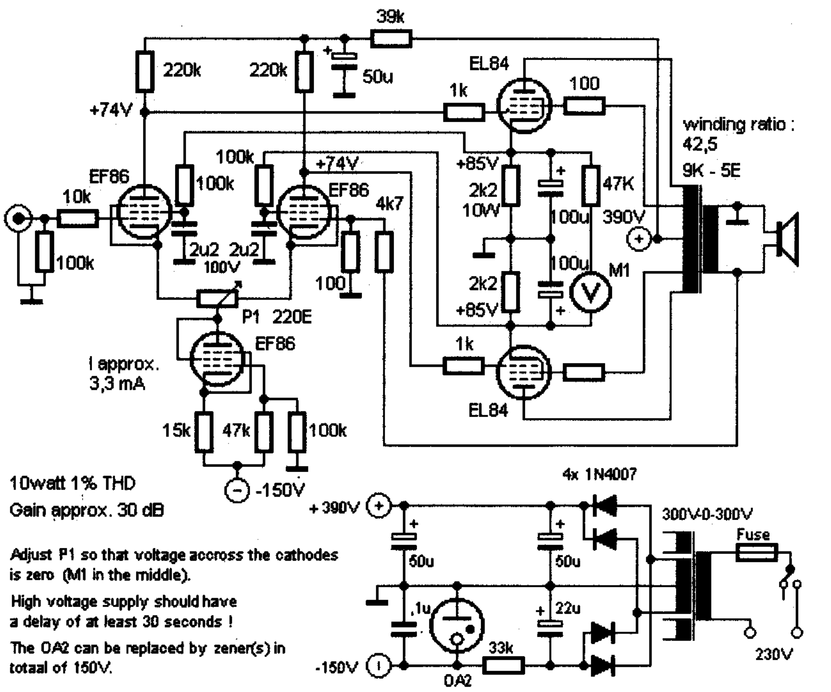


Fig. 1. Three-valve audio power amplifier using a transistor current source in the long-tail pair cathode. Insets b) and c) show alternative ways of forming the current source. In the original design, –6.2V was chosen as the source supply rail due to the convenience of the 6.3V heater winding.



or so. In this way the balance of the output stage remain stable over a very long period.

Overall feedback is accomplished by the 3.3kΩ resistor, the 5Ω transformer winding and the negative input of the long-tail pair. Total gain of the amplifier is approximately 20dB while overall feedback is approximately 6dB.

Transformer alternatives

The Amplimo VDV8020 toroidal output transformer would be the perfect choice as output transformer. The primary impedance of this toroidal transformer is 8kΩ and ultra-linear taps are provided. Frequency response is exceptional with –3dB points at 2Hz and 134kHz.

An extremely high coupling factor, very low leakage inductances and low internal capacitances have achieved this. There are no conflicting resonances below 100kHz. This performance is achieved through the use of multi-sectioned windings together with special combinations of series and parallel connections. The multi-segment secondary winding has a 5Ω impedance, contrived to be suitable for both 4Ω and 8Ω loudspeakers.

In 1993, Amplimo was the first company in the world to supply toroidal output transformers with a quality factor greater than 290 000. This factor is synonymous with frequency range.

Other suitable transformers are the Hammond 1608 or 1650F (USA), the BorderPatrol OTTP-610 (England), the Sowter U004, U064, UA23 or U082 (England).

A vintage Unitran 9U13 is used as output transformer throughout this project. This Dutch transformer is made back in the sixties. Unitran manufactured some fine transformers.

All transformers mentioned are still in production, except for the Unitran.

Amplifier 1 in summary

This amplifier circuit has no coupling capacitors, it works well and it is very stable.

As is common with DC-coupled valve amplifiers, the heater filaments must be up to temperature before the HT is applied to the circuit. This means a power-up delay of at least 30s.

Cathode capacitors on the output valves ensure that AC signals cannot feed back to the input stage through the current source transistor.

We designed this amplifier to give good performance yet remain simple. One area that could possibly benefit from a little extra complexity is the current source.

The suggested circuit works only with output valves biased fully in Class A. If for any reason the power supply voltage rises by, say 10%, then the output valves will be automatically overloaded.

In a recent design, we used a regulated DC power supply for the driver stage. This makes the circuit more flexible.

Amplifier design 2

We designed a second DC-coupled amplifier using three EF86s and EL84s in push-pull. Shown in **Fig. 2**, this circuit provides even better stability.

To enhance stability, the current source incorporates an EF86 pentode and the long-tail pair uses two more EF86s. Stability is improved because the DC differences in the output stage taken from the cathodes of the EL84s are fed to the screen grids of the EF86s of the long-tail

Fig. 2. Stability is improved by replacing the dual triode with two EF86 pentodes and using the same pentode as the active device in the current source.

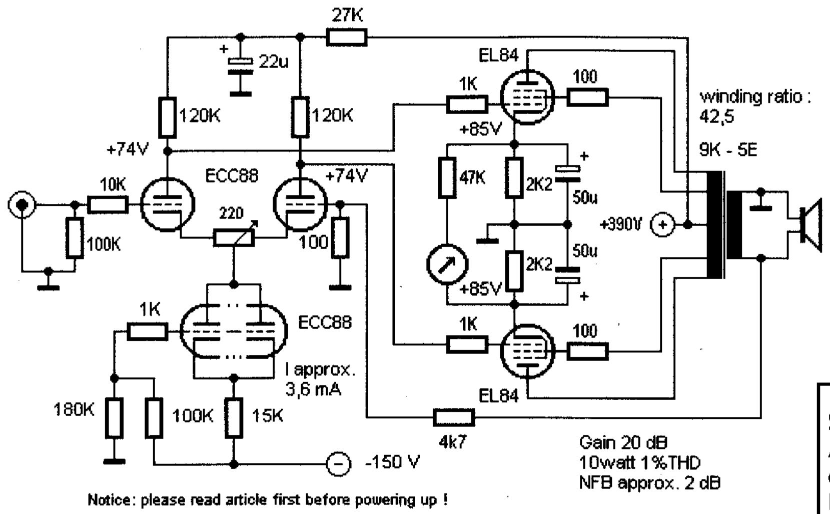


Fig. 3. Practical realisation of design 3, which provides good stability and an easy-to-implement circuit. Two ECC88 double triodes are used at the input.

pair. In this way each output valve has its own DC regulation, regulated by its associated EF86.

Using the EF86, the long-tail pair has a higher output impedance. This tends to cause a problem with high frequencies if no feedback is used. However, gain is high so more feedback can be applied to overcome this problem.

Square waves fed into this amplifier come out fine. Overall feedback is approximately 10dB.

Good stability, simpler circuit – design 3

We tried replacing the three EF86s with two ECC88s, **Fig. 3**. Stability was just as good. After 36 hours of continuous operation, the voltage across the cathode resistors of the EL84s changed only 0.3V.

Only 2dB feedback is used here. Current for the long-tail pair can be set by changing the 100kΩ resistor connected to the negative supply. It is approximately,

$$\left(150\frac{100k}{100k+180k}\right)\div 15k$$

or about 3.6mA. This configuration should also work with ECC85s.

Amplifier design 4

Figure 4 shows a practical DC-coupled design using an ECC85, a current source and two additional potentiometers. These pots are there to allow current and the high voltage of the input stage to be adjusted.

Current of the ECC85 is set to half that of ECC88. The other section of the ECC88 is used in the plus section of the power supply, in this way the voltage of the input stage is adjustable.

The grid of the ECC88 is controlled by the resistor divider between the negative rail and ground. Using the potentiometer, the high voltage can be easily set to approximate 206V.

The current source should be set to approximately 1.7mA. Bear in mind that the current source should be adjusted in so that the anode voltage of the ECC85 reads +74V. ■

Specifications, amplifier design 4

All measurements were made using a Hammond 1608 output transformer, a Tesla JJ ECC88, Tesla JJ EL84s, an RFT ECC85.

Output power at 1% distortion	11.9W
Sensitivity for 10W output power	700mV
Noise/hum related to 1W	78dB
Frequency response @ 1W	10Hz-72kHz, –3dB
Distortion at 10W @ 1kHz	0.55%
Distortion at 10 W @ 30kHz	2.35%
Distortion at 10 W @ 45Hz	2.7%
Damping 4Ω @ 100Hz	4x
Damping 4Ω @ 10kHz	5.3x

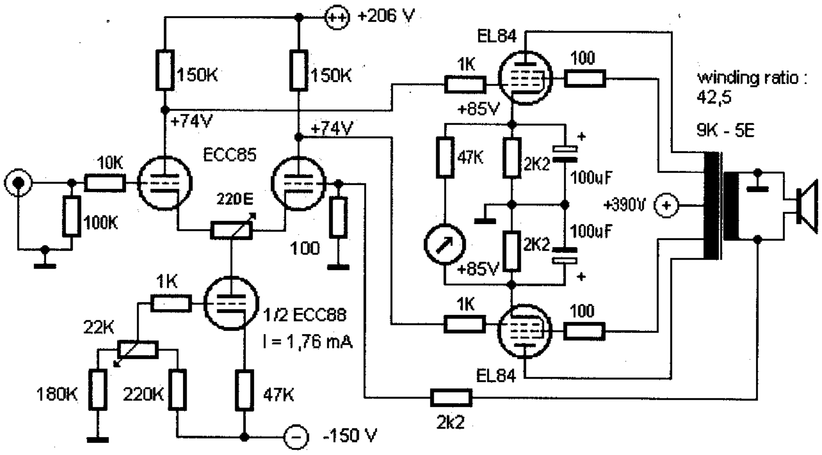
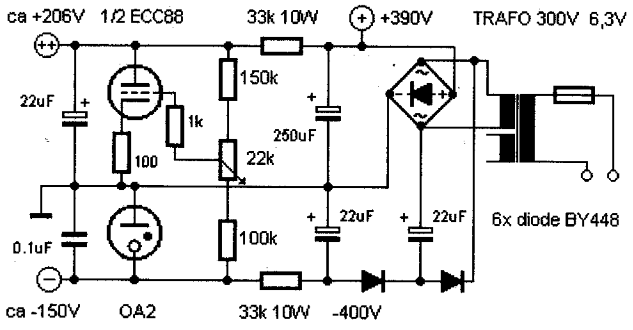


Fig.4. Of the four designs, this one is the most practical. It provides good stability and is easy to adjust.



Power supply for amplifier design 4 with a simple triode shunt regulator on the positive supply and a neon shunt stabiliser for the –150V rail.