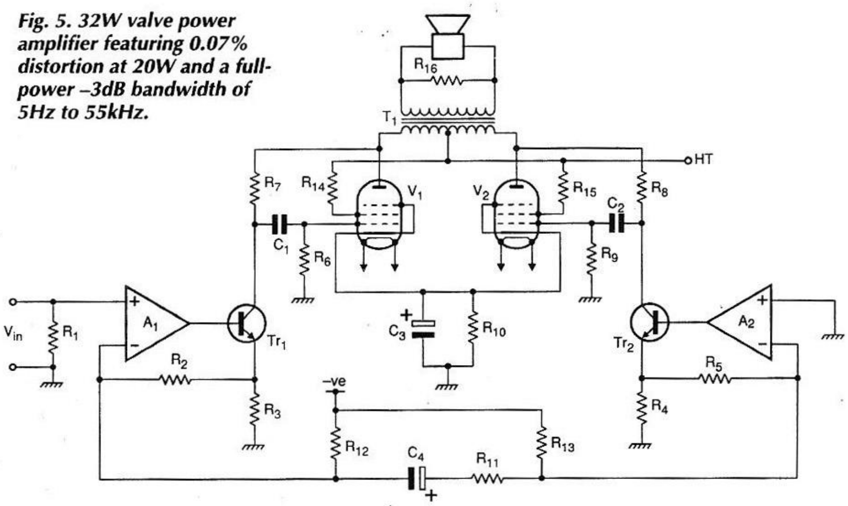
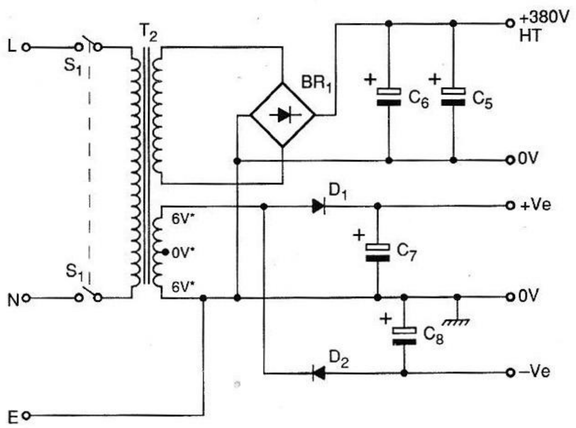


Fig. 5. 32W valve power amplifier featuring 0.07% distortion at 20W and a full-power –3dB bandwidth of 5Hz to 55kHz.



Being entirely balanced, the amplifier effectively cancels out ripple, simplifying design of the power supply. Voltage for the op-amps is derived from the transformer heater windings. For stereo, two heaters connect to each 6V winding.

the signal fed back) is almost unity. As the transconductance amplifier can also be made with unity gain a very well-behaved circuit is obtained.

In the present circuit the transimpedance amplifier is replaced by the valve. A transistor in the feedback loop of an *TL072* op-amp is the basis of the transconductance amplifier. Across the audio band the circuit gives an output impedance greater than 10MΩ.

Required voltage gain can be achieved by altering the transconductance ratio R_2 – both transconductance and transimpedance amplifiers have unity voltage gain. A well balanced push-pull output from the driving circuitry is also required to drive the push-pull output stage. This can easily be obtained by linking inverting inputs of the op-amps via a resistor and dc blocking capacitor.

Unfortunately a valve driver – though possible – is very difficult to design. An *EF86* pentode valve is a possibility but the only way of obtaining the requisite high impedance drive is to use low operating current. High current drive is required from this stage since impedance seen at the output valves grid is low due to feedback employed.

Figure 5 shows the amplifier's complete circuit. Input signals are fed across R_1 to the non-inverting input of A_1 which sets input impedance. Op-amp A_1 in conjunction with Tr_1 form a transconductance amplifier as discussed previously. Feedback is taken from emitter resistor R_3 to the inverting input via R_6. Resistors $R_{12,13}$ connect to the supply rail and provides bias for $Tr_{1,2}$ setting the quiescent current of the stage.

Output current from the collector of Tr_1 feeds into R_7 which connects in shunt between the anode and grid circuit of V_1. Capacitor C_1 isolates the valve from the dc level present at Tr_1 collector and R_6 returns the grid to ground. At ac, R_7 and R_6 appear as a parallel load to Tr_1. This impedance is effectively reduced by around 9.2 times by the valve gains.

Biasing of the output stage is effected by R_{10}, shunted at ac by C_3. Screen grids are also biased by R_{14} and R_{15}.

Both circuit halves are identical. Phase splitting is produced by coupling inverting inputs of A_1 and A_2 together via R_{11} and dc blocking capacitor C_4. This results in two antiphase equal amplitude signals at the emitters of Tr_1 and Tr_2 to drive the output stage.

Output voltages from V_1 and V_2 are applied to the primary coil of T_1 while ht is applied to the valves through the centre tap. Audio output signals are taken from the secondary coil of T_1 and applied to the loudspeaker. Resistor R_{16} keeps the output stage under control in the absence of a suitable load.

Because of heavy negative feedback within the circuit, overall feedback around the output transformer was found unnecessary. However, for those who like to experiment, feedback can be taken from the output side of the output transformer to the non-inverting input of A_2. If this is tried, R_{11} should be reduced to increase open-loop gain

Implementation

Building this design is straightforward. I used a readily available chassis and tagstrips. For the heater wiring, 5A loudspeaker cable is ideal. It should be laid close to the chassis but need not be twisted together as in low-level valve circuitry.

Potentially lethal voltages are present on capacitors C_5 and C_6 and all ht lines, and there is of course live mains around the transformer primary circuit. Always power up the amplifier with the *EL34*s *in situ* and make sure that the heaters heat up before turning off again. As long as the valves are in circuit and conducting, they will discharge the decoupling capacitors rapidly after turn off. If they are not installed, high voltage will linger for hours – sometimes days.

The amplifier requires no setting up. Provided it is wired correctly the circuit will operate first time.

Conclusion

Was it worth the effort? Yes, I certainly think so. The prototype gives out 32W continuous per channel with a full power bandwidth of 5Hz to 55kHz, –3dB. Measured thd at 1kHz and 20W output is 0.07% while output impedance is a mere 0.6Ω – minuscule by valve amplifier standards.

Mainly though, the amplifier excels at driving awkward loads and can suffer short circuits on the output without complaint. Last, but by no means least, it was fun to design. ■