

a high 25W anode dissipation. It also fits into a standard octal relay socket and is relatively cheap. Reasons for the solid state driver will become apparent as the article progresses, but first it will be useful to get to grips with some output stage basics.

The simplest form of valve output stage is the single-ended class-A triode, Fig. 1a). Because valves have limited current handling capacity and rather large internal resistance, anode drive is applied to the loudspeaker through an impedance matching transformer. This system works fine but its maximum theoretical efficiency is only 50%. Usually because of the anode characteristics practical efficiency is more often in the region of 25%. If I had been writing this article a couple of years ago, I could have said that single ended triode output stages were a thing of the past. However audio 'purists' have resurrected them. If you have the money and inclination you can purchase one particular triode amplifier for a cool £30,000.

Valve output stages

The conventional valve output stage is shown in Fig 1b) where for simplicity the valves are shown as triodes. Output is fed from the valve

anodes to the output transformer primary. The centre tap of this winding is connected to the positive supply.

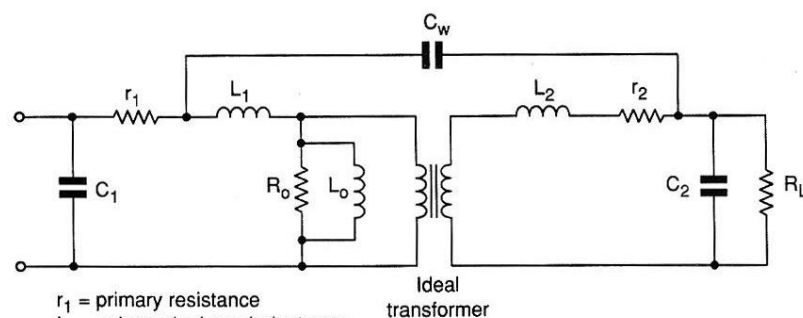
When equal and antiphase input signals are applied to the valve grids, push-pull operation is obtained. As with solid state designs the operating class is decided by bias current.

This push-pull stage has the usual advantages of cancelling even-harmonic distortion and increased power output. In addition hum voltages at the anodes cancel, producing an inherently high power supply ripple rejection.

Using EL34s in this type of circuit, it is possible to get outputs in the 20-50W range with reasonable ht voltages. However, the main problem with valve output stages is the output transformer – particularly in terms of frequency response.

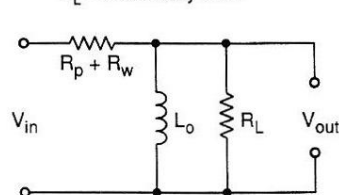
A real transformer, as opposed to a theoretical model, requires considerable primary inductance for good bass. Similarly at the high end, leakage inductance and winding capacitance limit response.

A modelled real transformer is shown in Fig. 2. Figure 2a) shows an equivalent circuit at low frequencies. Here primary inductance forms a high-pass filter with the valve's anode impedance. Clearly, the greater the inductance

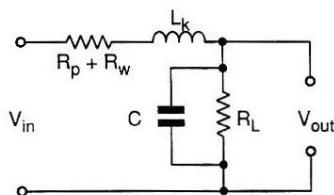


r_1 = primary resistance
 L_1 = primary leakage inductance
 r_2 = resistance of secondary
 L_2 = equivalent secondary leakage
 R_o = equivalent core loss resistance
 L_o = primary inductance
 C_1, C_2 = equivalent lumped capacitance of primary and secondary
 C_w = interwinding capacitance
 R_L = secondary load

Fig. 2. Model of the output transformer, above. For good bass, the transformer requires significant primary inductance. Low and high-frequency equivalents are shown below in a) and b) respectively.



R_p = anode resistance
 R_w = winding resistance
 L_o = primary inductance
 R_L = secondary load x turns ratio squared
 a) low frequency equivalent circuit



L_k = leakage inductance
 C = winding capacitance
 b) high frequency equivalent circuit

Components

Resistors 1%, 0.5W metal film unless indicated

R_1	56k	[2]
$R_{2/5}$	10k	[4]
$R_{3/4}$	1k8	[4]
$R_{12/13}$	68k	[4]
$R_{6/9}$	80k	[4]
$R_{7/8}$	220k	[4]
R_{10}	470R, 3W ww	[2]
R_{11}	8k8	[2]
$R_{14/15}$	470R, 1W	[4]
R_{16}	1k, 1W	[2]

Capacitors

$C_{1,2}$	100nF, 1000V WKG polyprop	[4]
C_3	100μF, 100V	[2]
C_4	220μF, 25V	[2]
$C_{5,6}$	470μF, 400V	[2]
$C_{7,8}$	1000μF, 63V	[4]

Active devices

A_1/A_2	TL072	[2]
V_1/V_2	EL34	[4]
$T_{1,2}$	2SC2547E	[4]
$D_{1,2}$	1N4001	[4]
BR_1	W08	[1]

Wound components

T_1	Output transformer 20:1 ratio, centre tapped. Primary inductance >8H, Leakage inductance <10mH	[2]
T_2	Mains, 240V prim. 280V, 700mA second. 6-0-6V 4A second.	[1]

Transformer availability

Three transformers especially wound for this design have been produced by Antrim Transformers. The set is available to UK readers for £99.99 plus £8 postage – fully inclusive of VAT. Antrim Transformers Ltd is at 25 Randalstown Road, Antrim, Co Antrim, BT41 4LD, tel. 018494 28734, fax 018494 68745. Overseas readers should contact Antrim for export details. Readers who already have the mains transformer can obtain the output pair for £79.50 plus £8 postage, again inclusive of VAT.

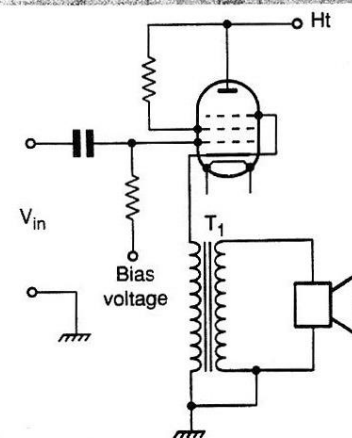


Fig. 3. Valve equivalent of the emitter follower. Putting the transformer in the cathode improves performance but driving the circuit needs a prohibitively large supply rail.