A 25W OTL Tube Amplifier

Presenting a new output-transformerless circuit with direct coupling to the loudspeaker.

If you have spent $500 or more on 5m or so of exotic loudspeaker cable, have you ever wondered about the 500m of standard copper wire in the output transformers of your tube amplifier? Audio output transformers are large, expensive components that require complicated winding arrangements in order to work properly at high frequencies. They are the prime culprits for the soft bass sound associated with tube amplifiers.

The main causes of this are iron core saturation distortion and the winding inductance which bypasses the loudspeaker at low frequencies. Also, the winding resistance typically wastes 10% of the output power. Hence, a lot of iron and copper are required in order to minimize these problems.

An alternative is the output transformer-less (OTL) tube amplifier. However, this concept is not easy to realize in practice, otherwise there would be more of these around.

AMP OPTIONS

My OTL design offers several solutions. First, in order to protect the loudspeakers in the event of a fault, it needed to be naturally current limiting without using auxiliary protection circuits. Another problem was how to realize a symmetrical output stage when tubes do not come as complementary NPN and PNP pairs as with transistors. One option was to adopt the "circlotron" circuit[1], which was invented by Cecil Hall in 1951, but that precluded the use of natural current limiting and would have greatly complicated the power supply configuration.

Instead, I designed a non-complementary totem-pole output stage using a novel combination of local feedback and current drive in order to achieve good symmetry and cancellation of even harmonics, as confirmed in subsequent measurements. This configuration has more in common with the Futterman circuit[2], except that a long-tailed pair of pentodes is used for the driver stage instead of the concertina phase splitter. The pentodes provide the current drive as well as greater voltage swing than triodes.

A general aim of the design was to have as simple a circuit as possible with a minimal number of components in the signal path as well as push-pull operation throughout (**Fig. 1**). Push-pull amplification not only cancels even harmonic distortion, but also provides good rejection of power supply ripple. In a long-tailed pair, the supply current is virtually DC so that the power supply is effectively removed from the signal path.

Above all, I wanted a stable, reliable design that would not need constant readjusting. To this end, I incorporated ample loop DC feedback, which—after initial adjustment—keeps the offset voltage within 20mV between tube replacements. Similarly, the DC bias needs hardly any adjustment over time.

I know that signal feedback is a controversial issue and there are those who maintain that the ultimate goal should be 0dB. However, zero feedback in this design would result in audible noise and an output impedance of 8Ω, which would severely affect the tonal balance of most loudspeakers. I have applied 26dB of feedback, which is a similar amount to most classic tube designs and sets the output impedance to 0.4Ω for well-controlled bass. However, the advantage of a DIY amplifier is that you can adjust the feedback to suit your own taste. The simplest way to reduce the feedback to 11dB is to omit the cou-

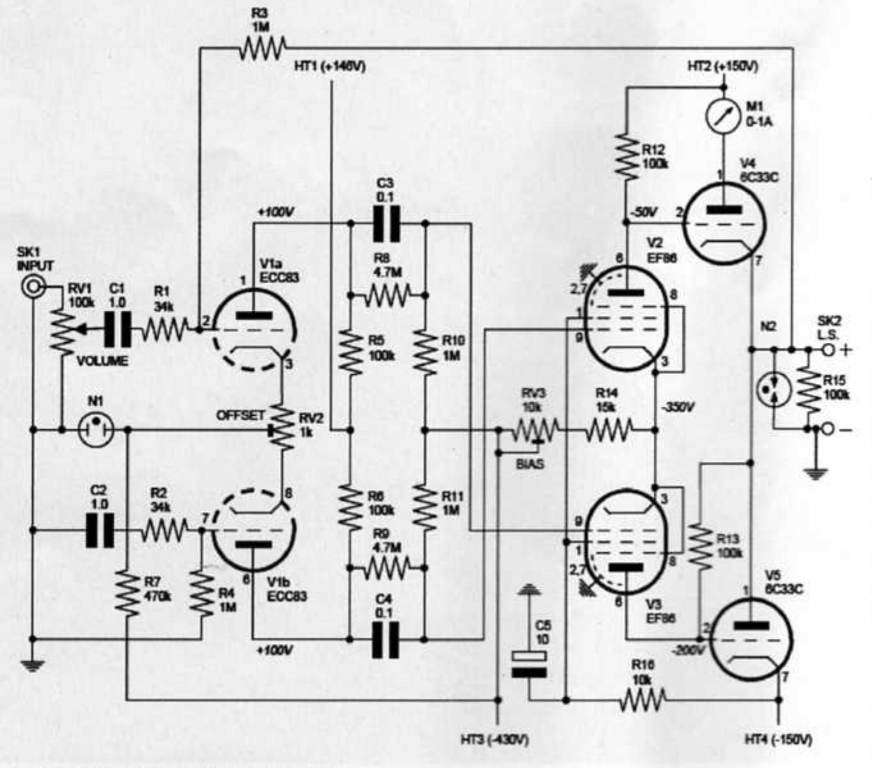

FIGURE 1: 25W amplifier circuit.

Maplin 2W resistors can withstand 500V DC and are an excellent value, especially because they are sold singly. Also, they sound good, having a low noise floor of 1µV/V and low temperature coefficient of 50ppm/°C.

You will observe from **Photo 2** that the layout is a little cramped; I recommend using a larger chassis than the 12″ × 9″ × 3″ one that I used. The amplifier produces quite a lot of heat and ideally the tubes should have more space around them for air to circulate. There should also be good ventilation underneath the chassis.

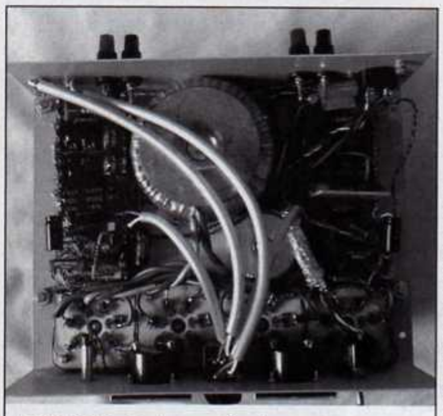

PHOTO 2: Underneath view.

While the retro style toggle switch on the front may look nice, the routing of the wires to it proved somewhat problematic. Notice the aluminum foil that I had to wrap around them to shield the sensitive input stage from the mains frequency radiation plus high frequency harmonics. This is exacerbated by the fact that the current only flows during short pulses while the rectifier diodes are conducting. If possible, fit a rotary mains switch near the back with a long extension spindle or use a relay. I used tag strips throughout because this is a prototype and I knew from experience that design revisions would be likely. Connecting components directly to the tube sockets is generally a good

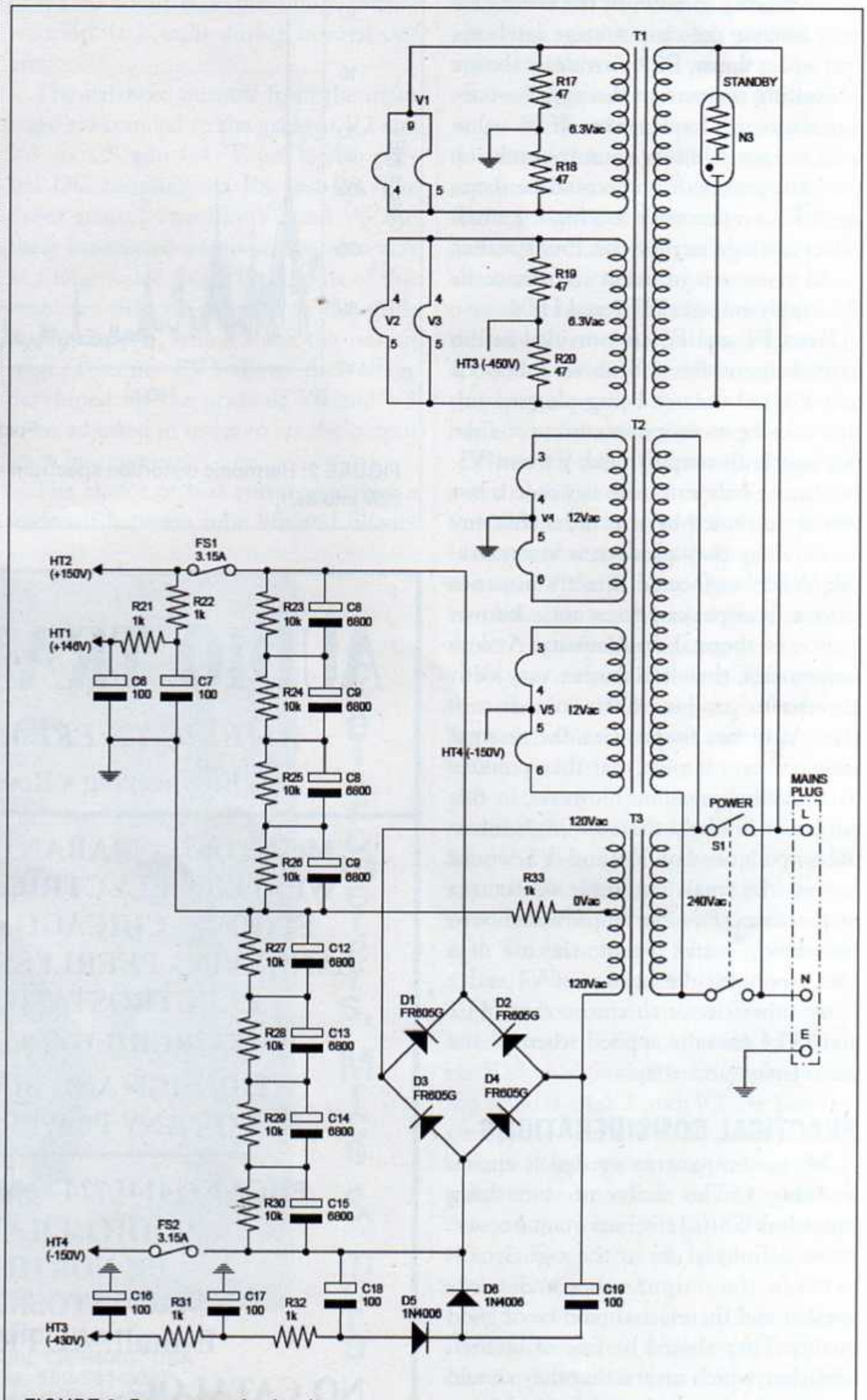

FIGURE 3: Power supply circuit.