The Quad II

The Quad II is an unusual design, which at first sight does not look too promising, but works because the design is synergetic.

In this design, not only has the phase splitter been combined with the driver stage, but it has also been combined with the input stage. In order to achieve the necessary gain, pentodes have been used. Output resistance is therefore high, as is input noise. To make matters worse, a variant of the see-saw phase splitter has been used. The output stage has local feedback, requiring increased drive voltage. See Fig. 6.26.

The output stage is a pair of KT66 beam tetrodes with anode and cathode loads split in the ratio 9.375:1. The cathode connection therefore provides little drive to the loudspeaker and may be considered to be series feedback

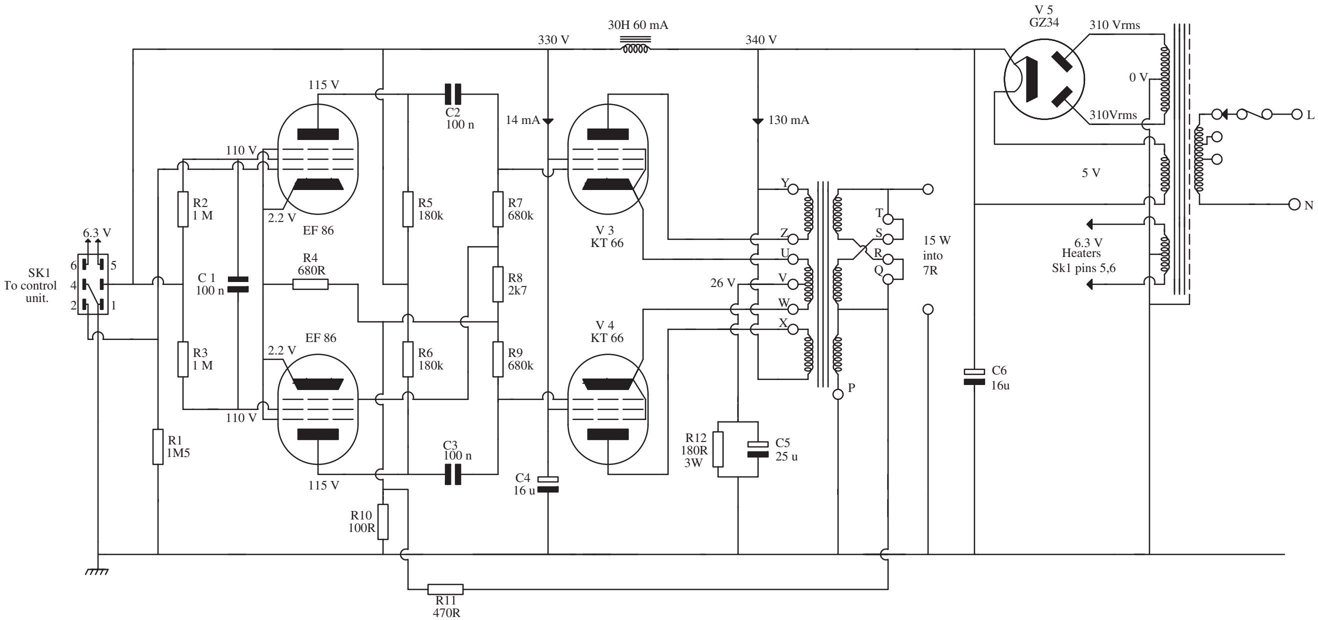

Fig. 6.26 *Quad II (by kind permission of Quad Electroacoustics Ltd)*

from the output transformer. However, the cathode current in the output transformer is the sum of the anode and g_2 currents, and it was found that this summation reduced 3rd harmonic distortion by a further 8 dB over that due to the negative feedback.[9]

The effect of this feedback on output resistance is the opposite to what might be intuitively expected.[10] If we simply leave a cathode resistor unbypassed, then this generates series feedback which increases r_a, whereas the transformer coupled feedback *reduces* r_a. This can easily be explained if we apply a short circuit as a load. Clearly, the output stage will be unable to drive any voltage into this load, but conversely, there will be no feedback signal applied to the cathodes. The grids will then be driven by the full input signal, rather than the input signal minus the feedback, so the output stage will be driven harder as it attempts to maintain its voltage into a short circuit. This action is directly equivalent to reducing output resistance, and the new value of output resistance can be found using the normal feedback equation.

The transformer primaries are equivalent to 3 kΩ anode to anode. With tetrodes, this low value of anode load results in a reduction of 3rd harmonic distortion, and an increase in 2nd harmonic, which is then cancelled by push–pull action in the output transformer (assuming that the output valves are perfectly matched).

The automatic bias is shared, so there is no provision for balancing anode current, and we can expect an increase in distortion at low frequencies due to saturation of the transformer core. Curiously, the cathode resistor was only rated at 3 W, yet it dissipates 3.8 W. If your Quad II distorts, a burnt-out cathode bias resistor may well be the cause.

Even with pentodes, there is not a great deal of gain from the driver circuitry, and input sensitivity is low; 1.4 V for full output. This is an excellent choice of input sensitivity for a power amplifier, as not only does it guarantee impeccable noise performance (even from a pentode), but it means that the input is far less susceptible to hum and noise from input cables or heater circuitry. The Quad II was only beaten in signal to noise performance by the Williamson, which was quieter because it had a triode input stage.

Despite being a variant of the see-saw phase splitter, the phase splitter/input stage does not rely on feedback for balance, and its operation is quite elegant. The output valves *must* each have a grid leak resistor, so instead of applying additional loading to the driver valves, a tapping is taken from one of these to provide the input for V_2. In theory, if this tapping has an attenuation equal to the gain of V_2, then the output of the phase splitter is balanced. Because of component variation, this will not always be true, so the cathodes of the two valves are tied together to improve balance.

Pentode stages have output resistance $\approx R_L$. Since R_L for the Quad input/phase splitter/driver is 180 kΩ, this would appear to be very poor at driving the ≈30 pF input capacitance of the output stage, resulting in a cut-off of ≈30 kHz. However, apart from the output transformer, this is the only HF cut-off in the circuit, and it is therefore not a problem. Each output valve requires a swing of $\approx 80\,V_{pk-pk}$, which is easily provided, because pentodes can approach 0 V more closely than triodes, and also because *LC* filtering was used on the HT line, rather than *RC* filtering, thus increasing the available HT. The *LC* filtered HT supply also feeds g_2 of the output valves, which has the valuable advantage of reducing hum, since the anode current of a tetrode or pentode is far more dependent on g_2 voltage than anode voltage.

Pentodes need to have g_2 decoupled to ground. Instead of each EF86 having a capacitor to ground, a single capacitor is connected between g_2 of the two valves. This has three advantages:

- If we had two individual capacitors, they would effectively be in series, with a centre tap to ground. Since each valve is connected to an equal but opposite signal, the centre tap would be at ground potential even if it were disconnected from ground. Therefore, we could cheerfully disconnect the centre tap from ground, leaving two capacitors in series that can be replaced by a single capacitor of half the value.
- Since this one capacitor is connected between two points of equal potential, it doesn't need the full voltage rating to ground. However, it is as well to consider the effect of fault conditions when determining the voltage rating, so this is not a great advantage.
- Connecting g_2 of each valve together at AC helps maintain balance in the same way as commoning the cathodes.

Although substituting one stage that combines the functions of input, phase splitter, and driver does not achieve the linearity of purpose designed stages, it achieves better linearity than the Mullard circuit because less gain is demanded from it.

With only a simple driver circuit and output stage within the feedback loop, the elegant Quad II has no stability problems.