Loudspeaker Damping as a Function of the Plate Resistance of the Power Output Tube

DONOVAN V. GEPPERT

Logical reasoning is applied to the problem of choosing between triodes and pentodes or tetrodes to obtain low output impedance and the resulting high damping factor.

A MISCONCEPTION appears to be common with regard to the effect of the dynamic plate resistance of a tube driving a loudspeaker on the "damping" properties of the tube. It is apparently considered a general rule that the lower the plate resistance of the output tube the greater the amount of speaker damping. The 2A3, with a relatively low plate resistance of 800 ohms, has long been considered the tube *par excellence* for driving a loudspeaker. Recently the 6AS7, with a plate resistance of only 200 ohms, has made its appearance in the output stage of amplifiers designed to feed loudspeakers. Carried to its logical end, we would eventually use output tubes having zero plate resistance and, naturally, zero amplification since

$$\mu = r_P g_m$$

Is there any real justification for this apparent race towards an infinitesimal plate resistance? It will be shown that there actually does exist a practical advantage in using triodes over beam tetrodes or pentodes, as far as speaker damping is concerned, but there is practically *no* advantage of one triode over another. Also it will be shown that the advantage of triodes over beam tetrodes and pentodes does not lie in the fact that they have lower values of plate resistance as such, but that for the values of load impedance commonly chosen on the basis of allowable distortion, the impedance reflected into the secondary of the output transformer is inherently lower for triodes than for pentodes or beam tetrodes.

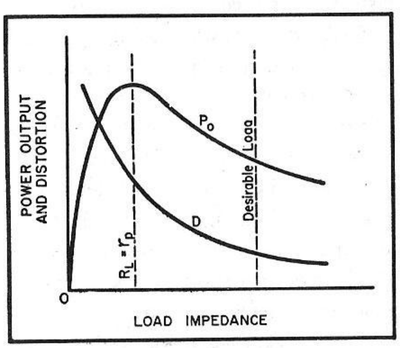

Fig. 1. Power output and distortion vs. load impedance for a typical single-ended triode power amplifier.

Consider the curves in *Fig.* 1 which show the variation in power output and harmonic distortion for a single-ended triode amplifier. For Class A linear operation, maximum power output occurs when the equivalent load impedance reflected into the primary of the output transformer equals the dynamic plate resistance of the tube. This is shown by the dotted line marked $R_L = r_P$ in *Fig.* 1. However, a more desirable load from the standpoint of distortion is a value somewhat higher than the plate resistance of the tube. A load impedance equal to twice the plate resistance of the tube is frequently stated as being an optimum value. In actual practice, values between two and four times the plate resistance are used to advantage.

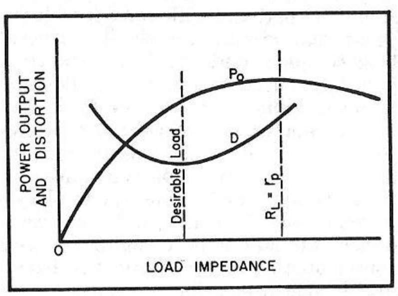

Fig. 2. Power output and distortion vs. load impedance for a typical single-ended pentode power amplifier.

Pentode Curves

The corresponding curves for a pentode or beam tetrode are given in *Fig.* 2. In this case a desirable load is one giving a minimum harmonic distortion which inevitably occurs at a load impedance lower than the plate resistance of the tube. Hence, for typical triodes, loads *greater* than the plate resistance are used, whereas for typical pentodes or beam tetrodes, loads *less* than the plate resistance are used.

Refer now to *Fig.* 3. For operation over the linear portion of the tube's characteristics, the series equivalent circuit can be used to replace the tube as far as a.c. computations are concerned.

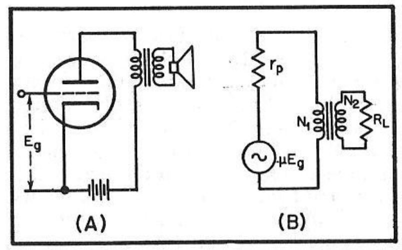

Fig. 3. (A), left, actual circuit and (B) right, equivalent circuit for Class A linear single-ended power amplifier.

If the output transformer has a turns ratio of N_1/N_2 and is considered to be perfect, the impedance reflected into the primary is $\left(\frac{N_1}{N_2}\right)^2 R_L$ and the impedance reflected into the secondary is $\left(\frac{N_2}{N_1}\right)^2 r_P$. In other words the impedances can be referred to either side. The ratio of load impedance to plate resistance is the same on either side. In the case of triodes, it has been shown that the ratio of load impedance to plate resistance is always made *greater* than one and generally two or three to one. Therefore the equivalent generator internal impedance is about one-half or one-third of the load impedance. But for pentodes, the ratio of load impedance to plate resistance is always made *less* than one, and the equivalent generator internal impedance is therefore greater than the load impedance. Consequently, triodes reflect a lower impedance into the secondary than tetrodes or beam pentodes, not because of their lower plate resistance, but because the values of load impedance dictated by distortion considerations make it so.

As to the relative merit of different triode tubes, it should be obvious that as long as the same ratio of load impedance to plate resistance is used, there is no difference whatever in the amount of speaker damping. As an example, consider a hypothetical tube having a plate resistance of 1000 ohms and a desirable load of 2500 ohms. To feed a 10-ohm loudspeaker requires a turns ratio of