A Power Tube Figure of Merit

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The author presents a simple method of evaluating power output tubes which takes into account most of the factors which are of importance in any tube application.

It is customary to define figures of merit in order to have a numerical means of examining how well a specific job is being done. Such figures of merit as the "Q" of a tuned circuit or the gain-bandwith product of an amplifier stage are typical examples. This article attempts to define a figure of merit for power output tubes used in home amplifiers, and to compare on this basis the tubes commonly used for this application.

The following characteristics of power tubes are evaluated in the figure of merit: power output, driving voltage, distortion, and internal impedance. Other factors such as cost and ease of eliminating hum, for example, do not appear in the figure of merit, and must be taken into account separately.

Since amplifiers for serious home use are almost without exception, push pull in operation, the evaluation of the figure of merit is in every case for two push-pull tubes. Also since home amplifiers are considered, only A and AB_1 operation are tabulated.

The value of the figure of merit is given by:

$$F = \frac{P\ (100 - D)}{R_L\ E_G}$$

where

F = Figure of Merit
P = power output in watts
D = distortion at rated output
R_L = load impedance in thousand ohms
E_G = peak grid driving volts.

The available power appears in the numerator of the figure of merit; thus a larger amount of power results in a larger or more desirable figure of merit.

Conversely the peak grid driving voltage and the load impedance, which is a function of the internal impedance, appear in the denominator. Thus, the figure of merit is an index of the power available as modified by other factors which make the use of the tube more or less desirable. The larger the figure of merit the better is the tube.

A number of values for commonly used tubes is given in Table I.

The calculations for the 2A3 family show a marked preference for the use of fixed bias. However the choice of bias method must depend on the decision of the designer as to the return for the extra trouble of providing fixed bias.

Within this group of tubes are many differences which are not reflected in the common figures of merit. The 2A3, while a standby for almost a generation, suffers from the need of a special filament voltage and old fashioned socket requirements. The six-volt equivalent—the 6A3—has almost been completely replaced by the 6B4G and 6A5G. Of these, the latter with its unipotential cathode brought out to a separate pin, is the more modern and probably more preferable tube.

The 6AS7G suffers because of the extremely high driving voltages required. The other triodes listed with their somewhat better figures of merit include those types whose use is becoming more and more popular.

Of particular interest is the triode-connected 6AR6, which in this evaluation seems to be a very desirable tube for future exploitation.

Beam-power tubes in general, with their modest drive requirements and good power sensitivity, average a bit better than triodes. It is significant to note the high figure of merit obtained by class A 6L6's which are very commonly used.

Non-beam-power pentodes which are less modern compare rather poorly with beam power tubes. Class A 6L6's at 10.5 watts output have a figure of merit of 1.75. The figure of merit of class A 6K6's at 9.8 watts is only 1.54.

If operation into AB_2 is allowed the figure of merit increases markedly, although this increase is attended with greatly increased difficulties of driving power, power supply requirements, etc. Fixed-bias 6L6's with 47 watts of output power have a figure of merit of 16.82. Similarly connected KT66's yield a value of 11.9.

It must be remembered that the Tube-Manual figures used to derive these values assume among other things, 100 per cent efficiency of the output transformer and perfect regulation of the power supply. The first condition will not effect the value of a comparison. The second condition however, will affect the validity of a comparison between class A and AB_1 operation if the regulation of the power supply is not perfect. From this point of view, when using a conventional power supply, class A operation, with its smaller current variations with signal, is distinctly advantageous, although schemes to regulate the screens of beam power tubes in class AB_1 do much to decrease the advantage of class A operation.

All reference to the triode *vs.* beam-power controversy has been purposely omitted. The figures do not show any clear advantage for either type. It is felt that this is a realistic representation of the situation. The high power sensitivity of beam power tubes makes the application of larger amounts of negative feedback easier, which makes up for the higher generator impedance of this type of tube.

It is interesting to note the correlation between high figures of merit and popularity of application. The use of this figure of merit enables a numerical comparison of the desirability of various tubes under consideration for a given amplifier. If it is desired to evaluate new tube types or other operating points, the calculations to obtain a figure of merit are straightforward and easy. Thus it is a simple matter to keep the table of figures of merit up to date.

TABLE I

Figure of Merit

Triodes	Class	Bias	Voltage	Power (watts)	Figure of Merit
2A3-6B4 etc.	AB1	Self	300	10	1.22
2A3-6B4 etc.	AB1	Fixed	300	15	3.94
6AS7G	A	Self	250	13	0.83
6AS7G	A	Self	200	11	1.47
300A	A	Self	450	35.6	4.90
KT66	AB1	Self	250	4.5	4.42
KT66	AB1	Self	450	14.5	4.38
807-1614	AB1	Self	400	15	5.40
6AR6	A	Self	400	20	14.5
Beam Power Tubes	**Class**	**Bias**	**Voltage**	**Power (watts)**	**Figure of Merit**
6V6	AB1	Self	285	14	4.45
6V6-6AQ5	AB1	Self	250	10	3.17
KT66	AB1	Self	250	17	11.30
KT66	AB1	Self	450	30	5.05
6L6-5881	A	Self	270	18.5	9.06
6L6-5881	A	Fixed	270	17.5	9.80
6L6-5881	AB1	Self	360	24.5	4.58
6L6-5881	AB1	Fixed	360	26.5	8.78

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