

Fig. 2. Conventional plate characteristic for triode-connected 807 (solid lines) and cathode-follower characteristic (dotted lines).

polarity is defined as positive in the direction from ground to cathode and that the plate of the tube is at ground potential for a.c. voltages. The plate-to-cathode voltage is therefore negative as far as the defined voltages are concerned. If the plate voltages on the plate family characteristics (which are, of course, plate-to-cathode voltages) are taken as negative for the feedback conditions of the cathode follower, these characteristics can be used to create a new set of curves valid for cathode-follower operation.

The grid-to-cathode voltage, e_g , is the difference between the input voltage e_i and the feedback or cathode voltage $e_f = e_o$.

$$e_g = e_i - e_o$$

From this relation it is seen that at $e_g = 0$ the value of e_i must be equal to that of e_o . If points along the $e_g = 0$ curve are taken at different values of e_o (which are the plate-voltage ordinates on the graph) the value of e_i at each point will be exactly equal to the plate voltage ordinate at that point. For example, at the intersection of the $e_g = 0$ curve and "plate volts" = 300 volts on the 807 characteristic (Point A) the value of e_i is -300 volts (negative since e_o values were defined as negative). In like fashion, the value of e_i at the intersection of the $e_g = 0$ curve and the 200 volts ordinate is -200 volts (Point B). Similarly, the intersection of $e_g = -10$ volts and the 300 volts ordinate represents -310 volts (Point C), since

$$e_i = e_g + e_o \\ -310 = -10 + (-300)$$

If a number of points thus plotted representing a fixed value of e_i (such as $e_i = -300$ volts) are connected, a curve for this value of input voltage is constructed. Continuation of this process for different values of e_i permits the construction of the equivalent cathode-follower characteristic for the tube. Although this may appear a lengthy process, it is

actually the work of only five minutes or so to construct an equivalent cathode follower characteristic, depending upon the number of curves desired. The 807 cathode-follower characteristics are shown in dotted lines on the original graph. Note that (1) the lines are much steeper, representing a tube of much lower plate resistance, and (2) the distance that represented an input of 5 volts on the original characteristic represents an input of approximately 50 volts on the cathode-follower characteristic, showing a reduction in μ to one tenth of the original value. Construction for other percentages of feedback in plate-loaded amplifiers can be made in a similar manner.² Note that the figures on the parameter curves represent values of e_i and not e_g for the feedback characteristic.

It is fairly evident that quiescent conditions will be designed on the basis of

² Albert Preisman, "Graphical Constructions for Vacuum Tube Circuits," New York: McGraw-Hill Book Co., 1943, pp 226-231.

the original curves. The bias point Q is chosen, for example, at a plate voltage of 300 volts and a bias of -25 volts. This value gives a quiescent plate current of 50 ma, and the bias resistor, if cathode bias is used, is calculated in the usual manner. It is less evident that the point of grid current has not been changed—i.e., it is not given by the locus curve of $e_i = 0$ of the cathode-follower characteristic. It is still given by the original grid current curve, that for $e_g = 0$. This is because grid current is drawn when the grid-cathode voltage e_g is positive, and e_i does not represent this voltage in a negative-voltage-feedback amplifier. Thus it is seen that the available plate-voltage swing (or correctly, the cathode-voltage swing) without current has not been increased, as might have been expected from preliminary inspection of the new curves.

Impedance Matching

The method of proper impedance matching in the cathode-follower output stage is also not immediately discernible from the new curves. For any system, the maximum power output is obtained when the load impedance equals the generator impedance. For the cathode follower

$$Z_i = Z_o = r_p / (\mu + 1)$$

It is customary in vacuum tube impedance matching, however, to base the relationships on the concept of maximum power with a prescribed amount of distortion. For triode tubes, to a first approximation, the optimum load is twice the plate resistance of the tube. For a cathode follower (or any inverse feedback amplifier), the optimum load is also twice the plate resistance, *not* of the equivalent tube, however, but of the original, unaltered tube, i.e., the optimum load is not changed by feedback. The validity of this relation between load and

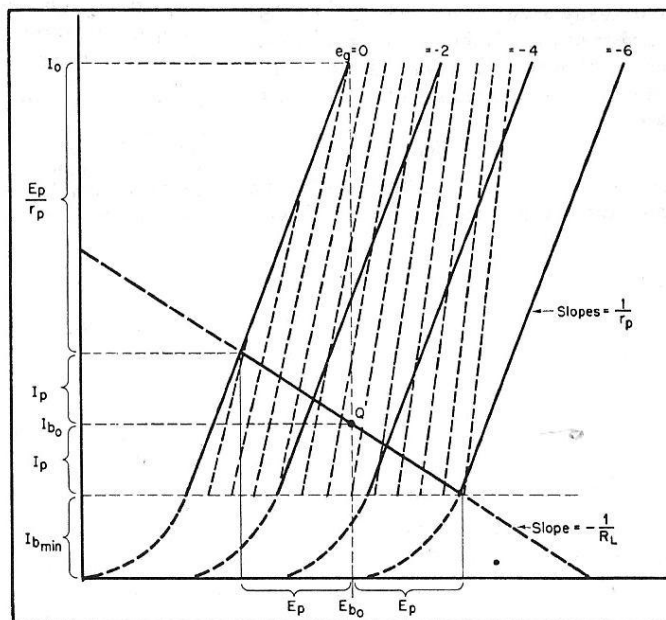


Fig. 3. Idealized plate and cathode-follower characteristics for a triode.