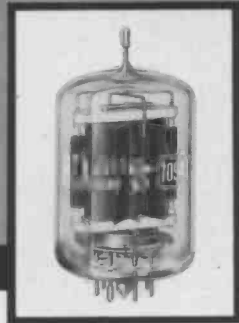




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DETERMINATION OF TYPICAL OPERATING CONDITIONS

For RCA Tubes Used as Linear RF Power Amplifiers

Part I

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During the past few years, ham interest in single-sideband transmission has been on a continual upswing. As a result, numerous articles have been published on the theory and construction of linear triode and tetrode amplifiers. While these articles have discussed classes of tube operation and compared grid-drive to cathode-drive circuits, only a handful provided design information for adapting tube manufacturers' data to available components or to the amateur's specific requirements.

Included among the "selected few" was an article by A. P. Sweet, which appeared in the December, 1954, issue of HAM TIPS. It presented such information in the form of step-by-step calculations for use in converting published maximum ratings to typical operating conditions.

Now, six years later, having recognized the need to bring this design information up to date, HAM TIPS is pleased to offer here Part I of a two-part article prepared by W3FAL. This first part extends the calculations to include cathode-drive (grounded-grid) operation of tetrodes and triodes in class AB₁ service.

In the next issue, Part II will cover the procedure for calculating typical operating conditions for class B operation of triodes or triode-connected tetrodes in a cathode-drive circuit.

Sample calculations are based on published data and curves for the RCA-7094 power tetrode. Also included is a chart which lists maximum ratings and typical operating conditions for several widely used RCA power tubes.

Class AB₁ Operation of Tetrodes (Grid-Drive Circuit)

When it is desirable to operate tubes at conditions other than those given in the published data, typical operating conditions can be calculated from the maximum ratings and characteristic curves. The calculations required for class AB₁ operation of a tetrode in grid-drive

service are given below. This procedure may be adapted to triode tube types by eliminating the terms E_{c2} , I_{c2} , i'_{c2} , and SI from the calculations.

(1) Make sure that E_b is within maximum ratings. (E_b is one of 21 symbols defined on page 2.)

(2) On the average plate-characteristics

curves, select a point near the "knee" of the curve for zero control-grid voltage; record i'_b and e_{bmin} . From the average screen-grid characteristics curves, determine i'_{c2} for this point; record E_{c2} for the curves used.

(3) Calculate I_{bms} : $I_{bms} = i'_b/3$.

(4) Calculate PD: $PD = (I_{bms}/4) (E_b + 3 e_{bmin})$.

(5) Calculate SI: $SI = E_{c2} i'_{c2}/4$.

(6) Calculate PI: $PI = E_b I_{bms}$.

(7) Check the values obtained in steps 3 through 6 to determine whether they are within tube ratings. If either I_{bms} , PI, or PD is out of ratings, select a point slightly lower than the original point on the knee of the curve for zero control-grid voltage and recalculate steps

2 through 6. If only SI is out of ratings, select a point slightly higher on the knee. If SI and either I_{bms} , PI, or PD are out of ratings, select a lower value of i'_b (either in the negative-control-grid region or at a lower screen-grid voltage) and repeat steps 2 through 6.

(8) Calculate PO: $PO = PI - PD$.

(9) Calculate I_{bo} : $I_{bo} = I_{bms}/5$.

(10) Determine E_{c1} from the plate-characteristics curves as the control-grid voltage at which the plate voltage is E_b and the plate current is I_{bo} .

(11) Calculate E'_g : $E'_g = |E_{c1}| + e_{cm}$. This value of E'_g is equal to the absolute value of E_{c1} (the straight lines around this term indicate that its plus or minus sign may be ignored) plus the algebraic value of e_{cm} (include the sign). If the point selected in step 2 was on the curve for zero control-grid voltage, then e_{cm} is equal to zero and $E'_g = |E_{c1}|$.

(12) Calculate I_{c2} : $I_{c2} = i'_{c2}/4$.

(13) Calculate DP: $DP = E'_g i'_{c1}/4$. (For AB_1 operation, i'_{c1} equals zero; therefore, DP is also zero.) This value of DP does not include rf tube and circuit losses. The power available from the driver, therefore, should be at least 10 times this value in grid-drive operation. Because AB_1 tube driving power is zero, determine the approximate driver-output requirements from published AB_2 typical operating conditions at approximately the same E'_g and operating frequency.

(14) Calculate R_p : $R_p = E_b/1.7 I_{bms}$.

* * *

Example—The following example illustrates the calculation of typical operating conditions for class AB_1 tetrode operation of the RCA-7094 in a grid-drive circuit:

(1) The maximum plate voltage rating is 2000 volts.

(2) From the plate-characteristics curves shown in Figure 1 ($E_{c2} = 350$ volts), select a point PI on the knee of the curve for zero control-grid voltage. At this point, i'_b is 0.650 ampere and e_{bmin} is 300 volts. At the corresponding point on the grid-characteristics curves shown in Figure 2, i'_{c2} is equal to 0.085 ampere.

(3) $I_{bms} = i'_b/3 = 0.217$ ampere.

(4) $PD = (I_{bms}/4) (E_b + 3 e_{bmin}) = (0.217/4) [2000 + 3 (300)] = 157$ watts.

(5) $SI = E_{c2} i'_{c2}/4 = (350) (0.085)/4 = 7.4$ watts.

(6) $PI = E_b I_{bms} = (2000) (0.217) = 434$ watts.

E_b	DC plate voltage (with respect to cathode)
e_{bmin}	Minimum plate voltage necessary to produce the required peak current (from the characteristics curves)
E_{c2}	DC screen-grid voltage
E_{c1}	DC control-grid voltage
e_{cm}	Maximum control-grid drive voltage needed to obtain the required peak plate current at a given minimum plate voltage
E'_g	Peak value of control-grid voltage swing
I_{bms}	Maximum signal, dc plate current
I_{bo}	Zero-signal, dc plate current
i'_b	Instantaneous peak plate current
I_{c1}	Maximum-signal, dc control-grid current
I_{c2}	Maximum-signal, dc screen-grid current
i'_{c1}	Instantaneous peak control-grid current
i'_{c2}	Instantaneous peak screen-grid current
PD	Plate dissipation at maximum signal
PD ₀	Plate dissipation at zero signal
PI	Plate power input at maximum signal
PO	Power output at maximum signal
P _{ft}	Feed-through power at maximum signal (cathode-drive operation)
DP	Driving power at maximum signal
SI	Screen-grid input at maximum signal
R_p	Effective rf plate-load resistance

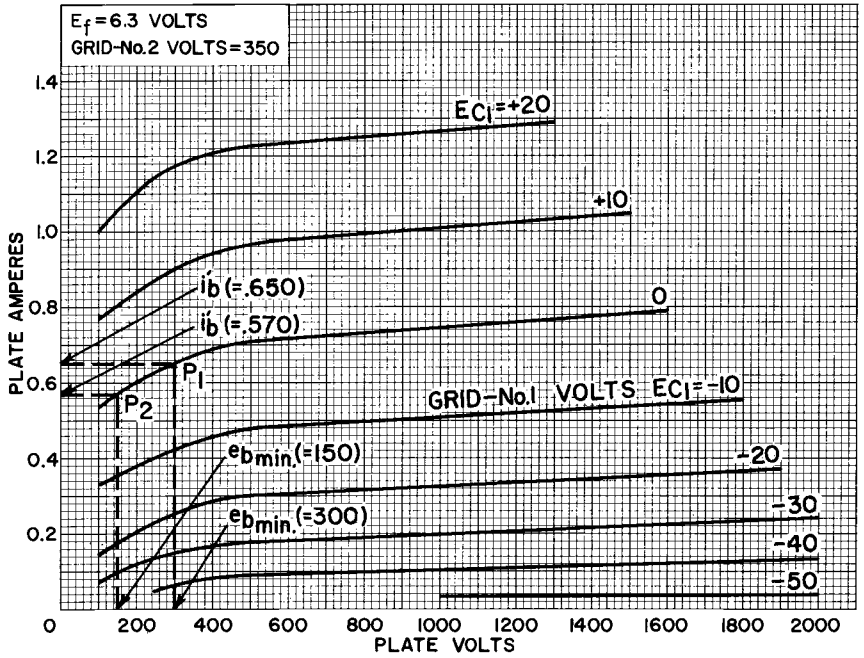


Figure 1: Typical plate characteristics of type 7094.

(7) Because both PD and PI are above the maximum ratings for the 7094, a lower value of i'_b must be used. Select a point P2 below the original point on the knee of the curve for

zero control-grid voltage and recalculate steps 2 through 6.

At the new point, i'_b is 0.570 ampere and e_{bmin} is 150 volts. At this point on the grid-

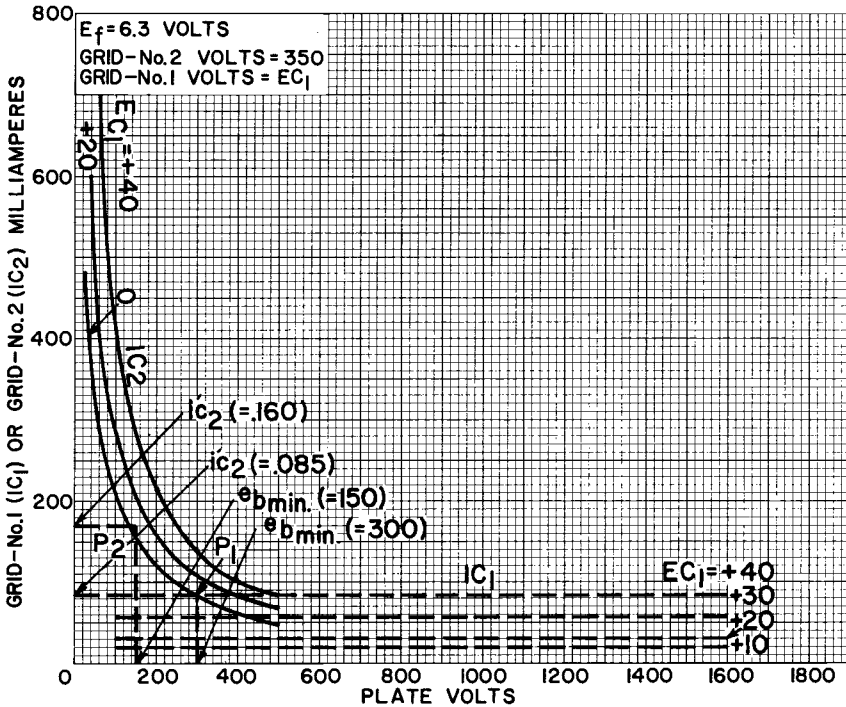


Figure 2: Typical characteristics for type 7094.

characteristics curves, i'_{c2} is 0.160 ampere.

$$I_{bms} = 0.570/3 = 0.190 \text{ ampere.}$$

$$PD = (0.190/4) [2000 + 3 (150)] = 116 \text{ watts.}$$

$$SI = (350) (0.160)/4 = 14 \text{ watts.}$$

$$PI = (2000) (0.190) = 380 \text{ watts.}$$

All values in steps 3 through 6 are now within maximum ratings, and the calculations may be continued.

$$(8) PO = PI - PD = 380 - 116 = 264 \text{ watts.}$$

$$(9) I_{bo} = I_{bms}/5 = 0.190/5 = 0.038 \text{ ampere.}$$

(10) E_{c1} can now be determined from the plate-characteristics curves as the control-grid voltage at which the plate voltage is 2000 volts and the plate current is 0.038 ampere; $E_{c1} = -50$ volts.

$$(11) E'_g = |E_{c1}| + e_{cm} = 50 + 0 = 50 \text{ volts.}$$

$$(12) I_{c2} = i'_{c2}/4 = 0.160/4 = 0.040 \text{ ampere.}$$

$$(13) DP = E'_g i'_{c1}/2 = (60) (0)/2 = 0.$$

A suitable value of driving power can be

determined from Table I. For the 7094 in ICAS AB₁ service, a typical value of 4 watts is listed.

$$(14) R_p = E_b/1.7 I_{bms} = 2000/(1.7 \times 0.190) = 6200 \text{ ohms.}$$

* * *

Table I shows the maximum ratings and typical operating conditions for several popular RCA tubes in linear rf amplifier service for single-sideband, suppressed-carrier service.

It should be remembered that the typical operating conditions shown by the manufacturer (or calculated by the preceding methods) are only approximate. Minor adjustments are usually made in actual operation by slight variation of the control-grid bias or screen-grid voltage. In linear rf amplifier circuits for single-sideband, suppressed-carrier transmission, it is particularly important to check the actual operating conditions when the transmitter is first set up to assure that linear operation within the maximum tube ratings is being obtained.

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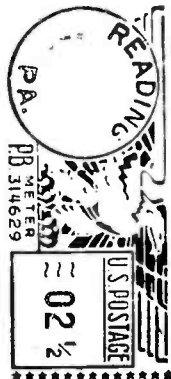
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