RADIOTRONICS

AMALGAMATED WIRELESS VALVE CO. PTY. LTD.

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In this issue:—

5-VALVE DUAL-WAVE RECEIVER

Accumulator, Air-Cell or Vibrator Operation

Several designs of battery receivers have been given in previous issues of Radiotronics, but it is now possible to design a circuit which with only minor modifications may be used for operation from an accumulator or an air-cell or a 6 Volt battery and vibrator. The advantages of a common basic design for these three applications is immediately apparent. For simplicity the circuit diagrams have been drawn as two separate diagrams, the first being for 2 Volt battery operation, and the second, which includes the vibrator unit and filter, for 6 Volt operation. Radiotron circuit A56 is a 5-valve dual-wave receiver using valve types 1C4 (R.F.), 1C6 (converter), 1C4 (I.F.), 1K6 (second detector), and 1D4 (output pentode). Since the filament current of these valves together exceed the limit permissible for air-cell operation, the 1D4 may be replaced by type 1F4 so as to bring the filament drain within this limit. This may be done without any other change in the circuit. Type 1F4 draws higher plate and screen currents than the 1D4 and for this reason the 1D4 is to be preferred in receivers operating only from a 2 Volt accumulator.

This circuit incorporates several improvements in fine detail which may not be immediately apparent. In order to enable the receiver to function without overloading, even when situated close to a transmitting station, as may happen in a number of country districts at the present time, a special A.V.C. arrangement has been adopted. The 1C6 converter is operated on fixed bias on both wave bands in order that it may operate under optimum conditions without any difficulties such as are experienced when A.V.C. is applied to this stage, particularly on the short wave band, and also in order to prevent distortion due to overloading. The only two controlled stages are the R.F. and I.F. stages, and it has been found possible to obtain very good results by a very simple method. It is nearly always found that the overloading is most serious in the I.F. stage and if the converter stage is operated on A.V.C. this also tends to overload. The method adopted is to arrange for the R.F. stage to have very rapid A.V.C. action and for the I.F. stage to have a very much less severe action. The result is that the major part of the control is accomplished by the R.F. stage, which, since it operates with smaller grid signal voltages, is therefore capable of giving more effective control without overloading. In order to provide the most effective A.V.C. action, the screen of the 1C4 R.F. stage is connected to the screen of the 1C6 which is effectively a point of fixed voltage since the screen current of the 1C6 is much larger than that of the 1C4 and, being operated on fixed bias, does not change with alteration of signal strength. The 1C4 I.F. stage has a screen supplied by a dropping resistor from B+ which provides a much more remote cut-off and thereby prevents

5—VALVE DUAL-WAVE BATTERY RECEIVER—Continued

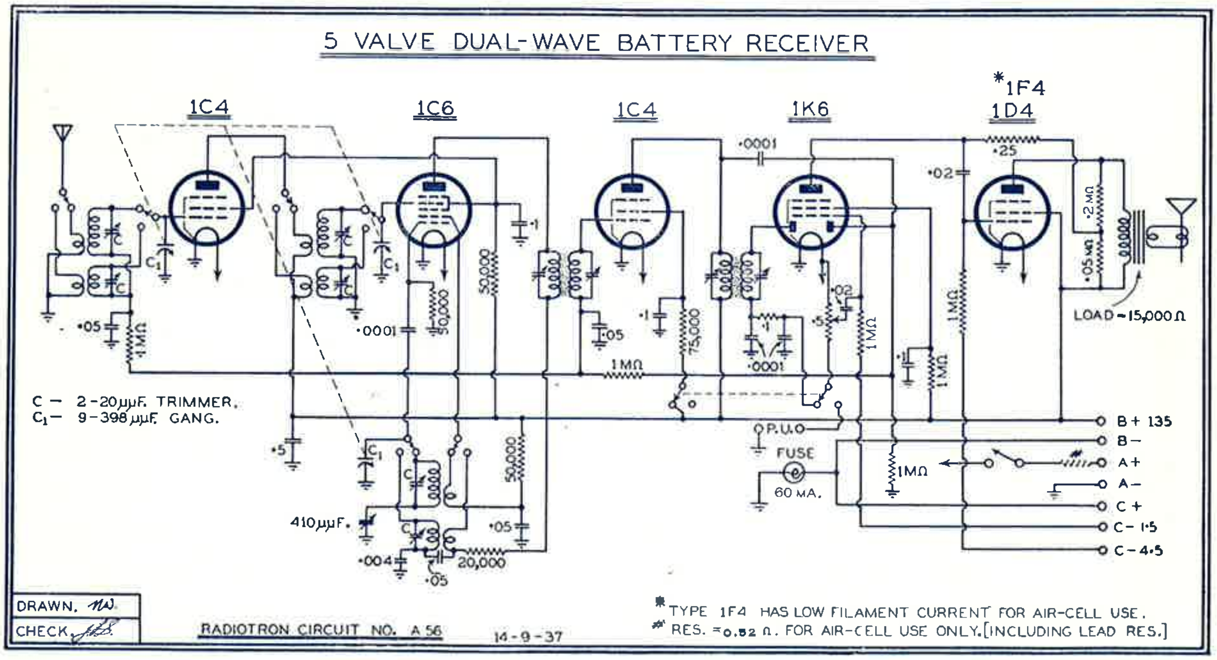
overloading in this stage. In order to obtain the highest possible A.V.C. voltage, the A.V.C. diode is fed directly from the plate of the I.F. valve as in previous Radiotron circuits. The full A.V.C. voltage, as shown in the circuit, should be applied to both controlled stages. Any method of applying a lower A.V.C. voltage to the I.F. stage is more likely to produce distortion than the method shown. This method of operating the I.F. stage also enables excellent uniformity to be obtained from valve to valve in receiver production, due to the self compensating action produced by a series screen dropping resistor together with A.V.C.

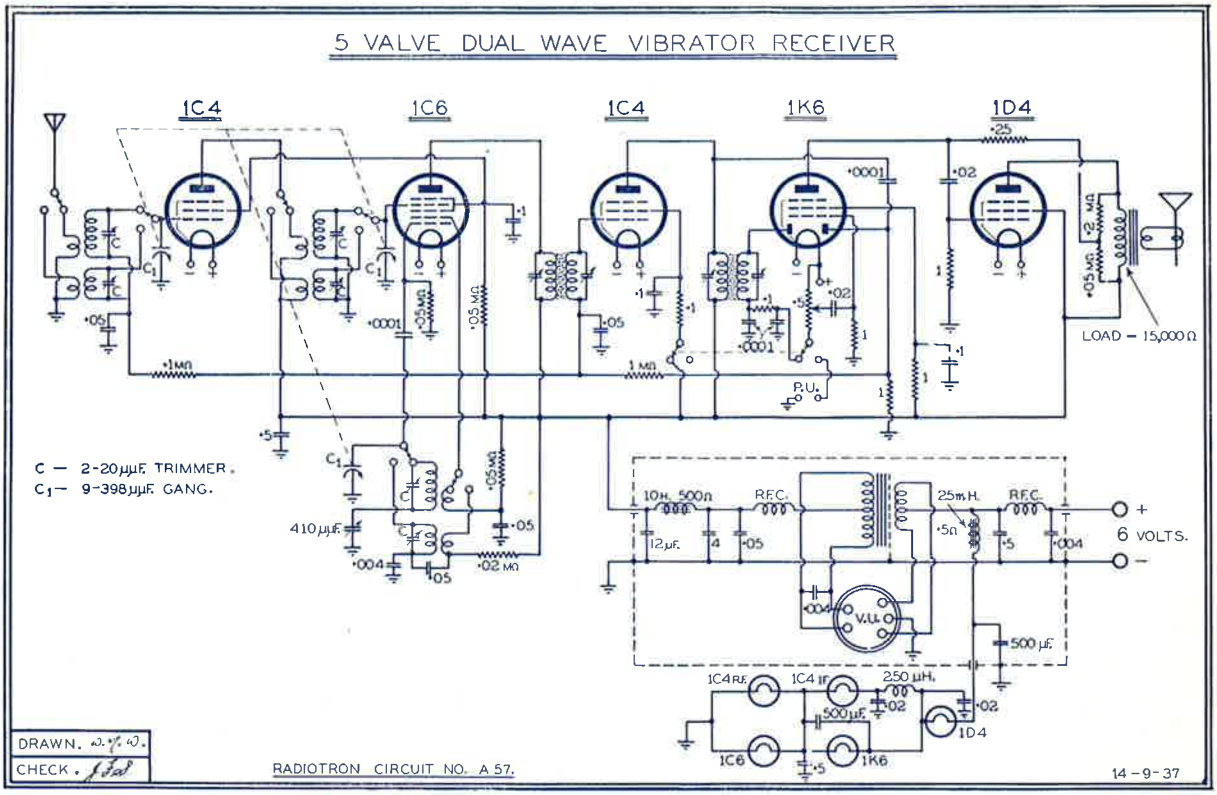
The Radiotron 1C6 is operated under the conditions recommended in Radiotronics 79 and provides very high gain with a complete coverage of the short wave band, even with run down batteries. It will be noticed that the screen dropping resistor is 50,000 ohms in place of 60,000 ohms so as to allow for the additional current drawn by the screen of the 1C4 R.F. valve. Use is made of the padding condenser to obtain additional feedback at the low frequency end of the short wave band and this gives assistance towards maintaining oscillation under all conditions. The coils used in this circuit should be identical with those described in Radiotronics 79 as any less efficient coils will reduce the sensitivity and probably also reduce the strength of oscillation at the low frequency end of the short wave band. Under the conditions specified, the wave range on the short wave band will be from 16 to 51 metres. The padding condenser is shown as .004 μF but some slight adjustment of this capacity may be required with different layouts.

Provision has been made in this circuit for a pick-up to be connected and suitable switching is shown. Due to the low distortion and high power output provided by this circuit, a pick-up can be operated with entire satisfaction. Series inverse feedback has been applied to the 1D4 and an output of approximately .35 Watt is available with 135 Volts B supply. The distortion is less than half that which would be obtained without the use of inverse feedback.

The B battery drain with this receiver using the 1D4 in the output stage will be 15 mA with no signal and 12 mA with a fully modulated strong signal on the broadcast band.

For air-cell operation the 1D4 should be replaced by a 1F4 and the B battery drain will be increased by 3.1 mA as compared with the use of the 1D4. Since an air-cell produces a voltage of considerably more than 2





Volts, it is necessary to employ a dropping resistor so as to protect the filament of the valves. The resistor of 0.52 ohm (including lead resistance) shown in the diagram has been chosen to give the best operation from these particular valves and no change in this resistor should be made.

Vibrator Model

The vibrator receiver is shown in circuit No. A57. This is essentially the same as circuit A56 but it will be noticed that 2 Volts minimum bias is employed on the I.F. stage in place of zero bias, 2 Volts bias on the 1K6 in place of –1.5 Volt and –4 Volts bias on the 1D4 in place of –4.5 Volts in the other circuit. These changes were made necessary by the elimination of the bias battery and all bias voltages are obtained directly from the filament circuit. Since only 4 Volts bias is used on the 1D4, the plate current of this valve will be considerably higher than in the preceding circuit but this will not be of any consequence with the vibrator receiver and the high power output which it will permit is of distinct value. As regards sensitivity and performance in other directions, the two circuits are in all essential respects identical. Both of them can be claimed to be the most up-to-date of their kind at the present time and can be depended upon for excellent reception. A number of fine points have been given particular attention and the result is demonstrated in the improved performance under carefully measured testing conditions.

RADIOTRON RELEASES WATER COOLED VALVES FOR ULTRA HIGH FREQUENCIES

An outstanding forward step in Ultra High Frequency operation has been made in the new Radiotron Water Cooled Valves 887 and 888. These types are capable of operation at the maximum power input of 1200 watts at wavelengths as low as 1.25 metre. An output of 750 watts is obtainable at a wavelength of 5 metres with 3000 volts on the plate. The overall dimensions of these types are remarkably small, being only 7⅛" x 1-11/16" including the water jacket. The two types are identical apart from the amplification factor, which is 10 for the 887 and 30 for the 888.

R.C.A. APPLICATION NOTE ON THE USE OF THE PLATE FAMILY IN VALVE POWER-OUTPUT CALCULATIONS

The set of curves known as a plate family is useful in predicting the performance of a valve under a wide variety of operating conditions. After some experience with the use of plate families, much useful information can be obtained by graphical analyses. For example, a single graphical analysis yields data which can be used to calculate plate dissipation, screen dissipation, power output, and distortion. Additional simple analyses can be used to predict the effects of plate and screen regulation and to indicate the necessary corrections to minimize these effects.

Because a plate family represents the average of a large number of valves, it should not be used to predict the performance of a particular valve under given operating conditions when high accuracy is desired. When the results of a graphical analysis which includes the use of a plate family is to be verified by test, a representative number of valves should be used. This Note describes several useful graphical methods for predicting the performance of single-valve amplifiers when grid current does not flow during any portion of the input-voltage cycle. A later Note will describe graphical methods for predicting the performance of push-pull amplifiers.

The Load Line

When the voltage across a resistor R_1 of constant value is varied throughout a given range, the relation between current through the resistor and voltage across it is a straight line, as shown in Fig. 1. Given the straight-line relationship, it is evident that R_1 is constant and is equal to e/i at any point. When the applied voltage is adjusted to a value E and the current is reduced to the value i by means of a series resistor R_2, the voltage drop across R_2, is $(E—e)$, because the sum of the voltage drops across R_1 and R_2 equals E. This condition is represented by the diagram in Fig. 2. The straight line connecting points O and E is the voltage-current characteristic of R_2 using the point E as the origin. Thus

$$R_2 = (E—e)/i = \cot b.$$

The values of the resistors need not be constant in order to represent their voltage-current characteristics on a diagram. In Fig. 3, for example, the voltage-current characteristics of R_3 and of R_4 are functions of the applied voltage. When the resistors are connected in series across an applied voltage E_1, the value of the current is i_1, the voltage drop across R_3 is e, and the voltage drop across R_4 is $(E_1—e)$. The value of the current and the voltage across each resistor is determined by the point of intersection (O) of the two curves. The a-c value of R_3 at the point O is $\cot a'$, where a' is the angle between the voltage axis and the tangent to the curve at point O; the value of R_4 at this same point is $\cot b'$. The d-c resistances of R_3 and R_4 at point O are e/i_1 and $(E_1—e)/i_1$, respectively.

The curve R_3 in Fig. 3 may represent the plate-voltage vs. plate-current characteristics of a valve for a given value of grid voltage. A number of such curves, each corresponding to a different value of grid voltage, constitute a plate family. A typical plate family for a pentode is shown in Fig. 4A. Because each curve represents a voltage-current characteristic of the valve, the intersection of any curve in the family with a line representing a load resistance connected in series with the plate circuit determines a point of operation.

When a voltage E is applied to the plate of a pentode through a load resistance R, the plate current varies with bias in accordance with the interesctions of the "load line" R and the grid-bias curves. The relation between grid-voltage and plate current is shown by

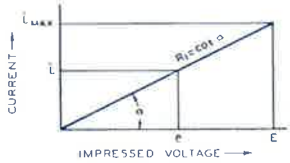


FIG. 1

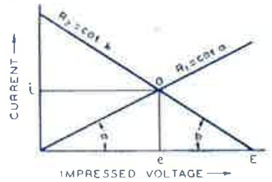


FIG. 2

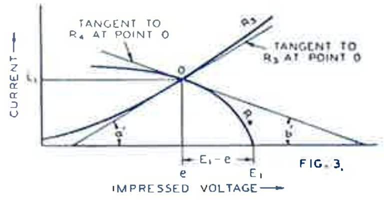


FIG. 3

curve *R* in Fig. 4B. For a zero-signal bias of —15 volts, the operating point is *O*, the voltage at the plate is e_0 = 250 volts, and the plate current is 105 ma. It is seen that when an alternating voltage having a peak value of 15 volts is applied to the grid of the valve, the plate voltage falls to a minimum value e_{min} = 50 volts and rises to a maximum value e_{max} = 395 volts; the corresponding plate-current change is $(i_{max} - i_{min})$ = 205 — 30 = 175 *ma.*

When the B-supply voltage *E* is applied to the plate through a choke of negligible resistance, the operating point is *O'* for a bias of —15 volts. A reduction of the B-supply voltage to the value of e_0 = 250 volts shifts the

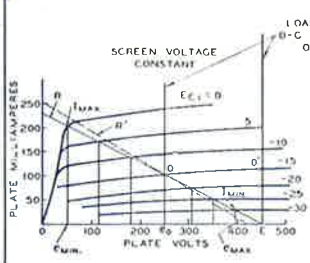


FIG. 4A

FIG. 4B

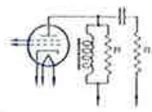


FIG. 4C

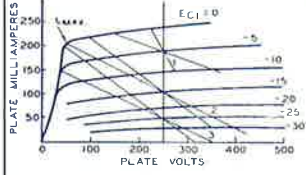


FIG. 5A

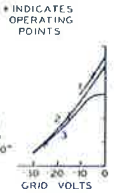


FIG. 5B

CURVE No.	GRID VOLTS	POWER* OUTPUT WATTS	LOAD OHMS
1	-5	0.55	555
2	-15	7.7	2000
3	-25	4.1	1325

*AT GRID-CURRENT POINT

FIG. 5C

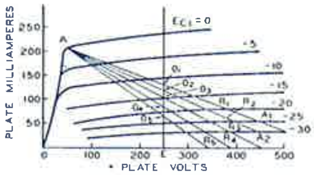


FIG. 6A

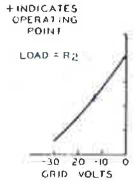


FIG. 6B

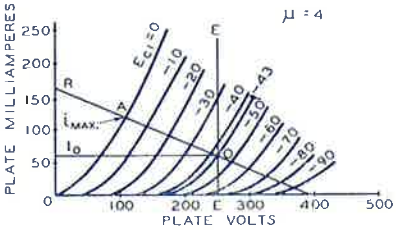


FIG. 7

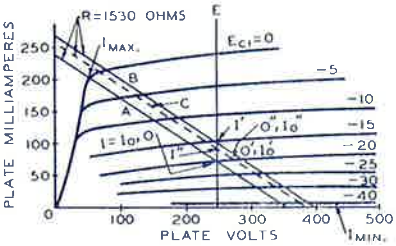


FIG. 8A

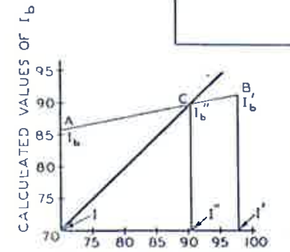
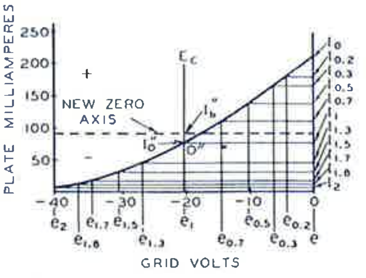


FIG. 8B



$e_0 = 0$
$e_{0.2} = -0.2\,E_c$
$e_{0.3} = -0.3\,E_c$
$e_{0.5} = -0.5\,E_c$
$e_{0.7} = -0.7\,E_c$
$e_1 = -E_c$
$e_{1.3} = -1.3\,E_c$
$e_{1.5} = -1.5\,E_c$
$e_{1.7} = -1.7\,E_c$
$e_{1.8} = -1.8\,E_c$
$e_2 = -2\,E_c$

FIG. 9

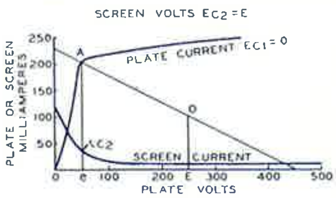
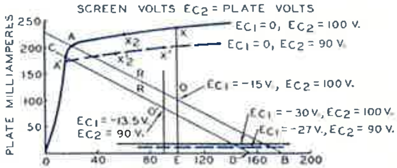


FIG. 10



PEAK INPUT SIGNAL FOR E_{C2} = 100 VOLTS IS 15 VOLTS
PEAK INPUT SIGNAL FOR E_{C2} = 90 VOLTS IS 13.5 VOLTS

FIG. 11A

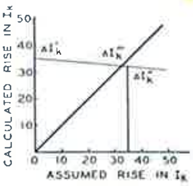


FIG. 11B

operating point to O. When the choke is shunted by a resistance R, operation with a-c signals takes place along the load line R, provided the reactance of the choke is much greater than the value of R. Thus, when the load consists of a choke shunted by a resistance R, the valve operates as though a series resistance R is connected in the plate circuit and the B-supply voltage is increased by an amount $(E - e_0)$. When a second resistor R_1 is shunted across R through a condenser of low reactance, as shown in Fig. 4C, the zero-signal operating point is O; it is determined only by the intersection of the d-c load line and the operating-bias curve. The a-c operating line is then determined by a new load line, R', which passes through O and has a value $RR_1/(R + R_1)$. In an output-valve circuit, however, $R' = R$ when the d-c resistance of the choke can be neglected.

Determining Power Output When Distortion is Negligible

In the practical use of a plate family for output-valve calculations, the load line R is drawn through the point determined by the plate voltage E and zero-signal plate current or zero-signal bias. When an alternating voltage is applied to the grid, the plate-current varies between i_{max} and i_{min}, the plate voltage varies between e_{min} and e_{max}, and the voltage across R varies between $(E - e_{min})$ and $(e_{max} - E)$. The alternating power in R is the product of the alternating voltage across R and the alternating current through R. In this example, the peak value of the alternating component of the plate current is

$$\frac{i_{max.} - i_{min.}}{2};$$

the peak value of the alternating component of the voltage across R is

$$\frac{(E - e_{min.}) + (e_{max.} - E)}{2}$$

$$= \frac{e_{max.} - e_{min.}}{2}.$$

Thus, the peak power is

$$\frac{(i_{max.} - i_{min.})\,(e_{max.} - e_{min.})}{4};$$

the average power, P, as indicated by a wattmeter, is

$$P = \frac{(i_{max.} - i_{min.})\,(e_{max.} - e_{min.})}{8}.$$

This expression for power is independent of valve type; it gives good accuracy only when the distortion is nominal.

Optimum Load for Pentodes

An output valve should be operated for highest power output at minimum distortion. To satisfy this condition, plot the grid-voltage vs. plate-current characteristics for a number of load resistances and biases from the plate family, as shown in Figs. 5A and 5B; a computation of approximate power output for each operating condition should also be made, as illustrated in Fig. 5C. It is assumed that grid current does not flow during any portion of the input-voltage cycle.

For zero plate-circuit distortion, the dynamic characteristic should be a straight line over the operating range; for high efficiency, the power output should be a maximum. The curves in Fig. 5 show that a bias of —15 volts and a load (No. 2) of 2000 ohms represent a good operating condition, provided plate and screen dissipations are not exceeded. It should be noted that the load line representing 2000 ohms passes through the knee of the zero-bias characteristic and through an operating point determined by approximately $i_{max}/2$. That this load and operating point are suitable can be predicted by an inspection of Fig. 5A; a reduction in the value of R causes a nearly proportional decrease in the plate-voltage swing with no appreciable change in plate current; an increase in the value of R causes a large decrease in i_{max} and a small increase in plate-voltage swing. From these considerations, several short-cuts can be used to obtain quickly a satisfactory value of load and bias.

Determining Optimum Load for Pentodes

In Fig. 6A, from a point A which is just above the knee of the zero-bias characteristic, draw load lines to the plate-voltage axis; these lines should surround an operating point whose coordinates are $(E, i_{max}/2)$. Along any load line, say R_2, measure the distance AO_2; lay off an equal distance O_2A_2 along R_2. For optimum operation, the change in bias from A *to* O_2 should nearly equal the change in bias from O_2 to A_2. The value of the load, R, is:

$$R = \frac{e_{max.} - e_{min.}}{i_{max.} - i_{min.}}.$$

It is well at this time to determine the change in power output with load by means of equation (1), because it may be desirable in some cases to obtain high power at the expense of increased distortion. When the knee of the zero-bias characteristic is not well-defined, several points should be used, in turn, until the proper one is found. The results should be checked by actual test, using a reasonable number of valves. It may be necessary to increase the bias above the value determined by this test in order to satisfy plate- and screen-dissipation requirements.

Optimum Load for Triodes

The method shown in Fig. 5 for determining the proper load and bias is independent of the characteristics of the valve type. Because the plate characteristics of a triode do not have "knees" at negative control-grid biases, the use of approximate relations which serve to reduce the number of trials is advisable.

Consider the typical triode plate family shown in Fig. 7. The proper load line *R* intersects the operating-bias curve at point *O* and the $E_{c1} = 0$ curve at point *A*. The following relations may be used as guides; final values should be obtained by the methods described for Fig. 5.

$$\text{Zero-Signal Bias} = \frac{0{\cdot}675\ E}{\mu}$$

$$i_{max.} = 2\ I_o.$$

Compensating for Rise in D-C Plate Current

When the change in plate current due to rectification in the plate circuit is appreciable, the load line should be shifted from its zero-signal position for improved accuracy in calculating power output and distortion at full output. Consider the plate family shown in Fig. 8A. The load line *A* is drawn through the zero-signal operating point *O*. Calculate the change in plate current using point *O* as the operating point; this change is designated $\triangle I_b$ at full output.

$$\triangle I_b = \frac{i_{max.} + i_{min.} - 2\ I_o}{4} = 16{\cdot}25\text{ ma.} \quad (2)$$

When $\triangle I_b$ is positive, the d-c plate current at full output is greater than I_o; when $\triangle I_b$ is negative, the d-c plate current at full output is less than I_o. In this problem, $\triangle I_b$ is positive. Now, shift the load line to another, arbitrarily chosen, position B. With *O′* as the operating point, obtain another value of calculated plate-current rise $\triangle I_b'$.

$$\triangle I_b' = \frac{210 + 5 - 150}{4} = 16{\cdot}75\text{ ma.}$$

A very good approximation to the actual position of the load line is determined from these values of $\triangle I_b$ and $\triangle I_b'$ in the following manner. The plate current at the original operating point *O* is $I_o = 70$ *ma.*; $\triangle I_b$ for this condition is 16.25 *ma.* Then, $I_b = I_o + \triangle I_b = 86.25$ *ma.*; this condition is represented by point *A* in Fig. 8B. For the line B, a calculated value of $I_b' = I_o' + \triangle I_b' = 75 + 16.75 = 91.75$ *ma.* is obtained for a value of *I′* of 97.5 *ma.* This condition is designated by point B in Fig. 8B. Points A and B are connected by a straight line. From the origin, draw another straight line inclined 45 degrees. The point of intersection C of these two lines is a very good approximation to the actual measured value of full-signal plate current I_b''. The final location of the load line (line C) is then determined by the plate voltage and the calculated value of I_b''.

The ordinate of Fig. 8B represents calculated values of full-signal plate current determined from the operating points *O* and *O′*, respectively; the abscissa represents the plate current determined by a load line and the zero-signal plate voltage. For the example of Figs. 8A and 8B, the actual rise in plate current, as read by a d-c meter, is $I_b'' - I_o = 20$ *ma.*

Determination of Distortion and Power Output

The distortion in a single-valve amplifier can be determined from a plate family and a corrected load line. As a first step in calculating distortion, determine the rise in d-c plate current and draw the load line through the proper operating point. Then plot the relation between grid voltage and plate current, as shown in Fig. 9; this curve was plotted from the plate family and corrected load line of Fig. 8A.

The full-signal plate current is I_b''. The value of plate current corresponding to I_b'' is used as a new plate-current axis from which currents in the harmonic analysis are measured. Thus, the actual value of I_o'' is 75 ma.; its value in the harmonic analysis is —15 ma. All values of plate current below the new plate-current axis are negative in the harmonic analysis.

The abscissa of Fig. 9 is divided into ten parts; ordinates are erected from each point of division to the plotted curve, as shown. In terms of the zero-signal bias E_c, these points are 0, $-0.2E_c$, $-0.3E_c$, $-0.5E_c$, $-0.7E_c$, $-E_c$, $-1.3E_c$, $-1.5E_c$, $-1.7E_c$, $-1.8E_c$, $-2E_c$. The value of the current at each of these points is designated by I_o, $I_{0{\cdot}2}$, $I_{0{\cdot}3}$, etc. Designating the fundamental component of the plate current as H_1, and the harmonic components of plate current as H_2, H_3, H_4, and H_5, we have

$$H_2 = \frac{I_o + I_2 - 2\ I_1}{4}$$

$$H_3 = \frac{2\,I_{0\cdot5} + I_2 - I_o - 2\,I_{1\cdot5}}{6}$$

$$H_4 = \frac{I_o + 2\,I_1 + I_2 - 2\,I_{0\cdot3} - 2\,I_{1\cdot7}}{8}$$

$$H_5 = \frac{2\,I_{0\cdot7} + I_o + 2\,I_{1\cdot8} - 2\,I_{0\cdot2} - I_{1\cdot3} - I_2}{10}$$

$$H_1 = \frac{I_o - I_2}{2} + H_3 - H_5.$$

Because H_1 is the fundamental component of the plate current, the power, P, due to the fundamental, is :—

$$P = \frac{H_1^2\ R}{2}.$$

Plate and Screen Dissipation in Tetrodes and Pentodes

The power dissipated in the screen circuit is added to the power in the plate to obtain the total B-supply input power. With full-signal input, the power delivered to the plate circuit is the product of the full-signal plate-supply voltage and the full-signal d-c plate current. The power dissipated by the plate in heat is the difference between the power supplied to the plate circuit and the power supplied to the load.

Screen dissipation increases with load resistance. In order to visualize this relation, assume that the sum of the screen and plate current is independent of plate voltage for zero control-grid bias or for a negative value of it. A decrease in plate voltage causes a certain decrease in plate current; it is assumed that the screen current rises by an equal amount. Hence, when the screen-grid valve operates with a load which intersects the zero-bias characteristic below the knee, the screen current rises to high values during low-plate voltage excursions of the output voltage. This action produces a rise in the d-c value of screen current with signal. Therefore, the screen dissipation with full-signal input may be several times the zero-signal value. To reduce screen dissipation, the load should always be chosen so that it passes through the knee of the zero-bias characteristic.

Increasing the applied signal voltage to a value higher than that for which the load is designed also increases screen dissipation. For this reason, it may be advisable to use a value of load which is slightly less than the optimum value. This precaution has another advantage, which is especially important at high audio frequencies. The impedance of a loudspeaker increases with frequency. When the load is adjusted for the proper value at 400 cycles, the load is usually too high at 2000 cycles; thus, a screen-dissipation limit may be exceeded at 2000 cycles even though operation is normal at 400 cycles. The use of a load which passes through the zero-bias characteristic somewhat above the knee is desirable for these reasons.

The curves of Fig. 10 consist of a zero-bias plate characteristic and a zero-bias screen characteristic. This screen-current curve is the only one required for the determination of full-signal screen dissipation. Draw in the corrected load line, as previously described. Project point A on the plate-voltage axis to e, as shown in Fig. 10. The projecting line intersects the zero-bias screen curve at i_{c2}. The full-signal screen current is then approximately $(i_{c2}/4) + (i_0/2)$, where i_0 is the zero-signal screen current at normal bias; the full-signal screen dissipation is $E\ [(i_{c2}/4) + (i_0/_2)]$. It is evident from an inspection of Fig. 10 that the screen current rises rapidly with increasing load resistance.

Effects of Plate and Screen Regulation

When the internal resistances of plate- and screen-supply sources are high, plate and screen voltages decrease with increasing power output. It is possible to determine approximate full-signal plate and screen voltages when the value of the internal resistance of the B-supply unit is known.

Consider the zero-bias characteristics of a pentode, shown in Fig. 11A; assume that plate and screen voltages are equal and that they are obtained from the same power-supply unit. Draw the corrected load line AB through point O and determine the rise in cathode (plate plus screen) current $(\triangle I_K')$, as previously described. The product of the increment in cathode current and the value of the internal resistance of the B-supply source is the approximate decrease in plate and screen voltage, $\triangle E_b$ and $\triangle E_{c2}$, respectively. The zero-bias characteristic of Fig. 11A should now be redrawn to correspond to the new screen voltage $E_{c2}' = E_{c2} - \triangle E_{c2}$. The load for this new value of screen voltage is represented by CD; the new operating point is now 0′. Calculate the rise in cathode current using CD as the load; a new value $\triangle I_K''$ is obtained. A good approximate value for the final cathode-current rise $(\triangle I_K''')$ is obtained by the method described in Fig. 11B. The product of the full-signal cathode current I_K''' and the internal resistance of the B-supply source determines the final operating point and the new location of the plate family.

The change in location of a plate characteristic and an operating point for a change in screen voltage can be found. Consider the point X on the zero-bias characteristic at which the plate voltage equals the screen voltage (Fig. 11A). The plate current corresponding to point X is 235 milliamperes. If the screen voltage is reduced to 90 volts, for example, the value of the plate current at the corresponding point on the new zero-bias characteristic is approximately $235 \times (90/100)^{3/2} = 235 \times 0.854 = 200$ milliamperes; the corresponding plate voltage at which this point occurs is 90 volts. Hence, the new location of X is at X′. By a similar computation, the point X_2 shifts to X_2' and the point A shifts to A'. The operating point O located at $E = 100$ volts, $I_b = 100$ ma., $E_{c1} = -15$ volts, shifts to O' located at $E = 0.9 \times 100 = 90$ volts, $I_b = 0.854 \times 100 = 85.4$ ma., $E_{c1} = 0.9 \times 15 = -13.5$ volts. By proceeding in this manner the $E_{c1} = -27$ volt curve, which is necessary for the determination of $\Delta I_b''$, can be obtained from the given $E_{c1} = -30$ volt curve.

The proper negative bias and peak input signal with 100 volts on the screen is 15 volts; the proper negative bias and peak input signal with 90 volts on the screen is 0.9 x 15 = 13.5 volts. Thus, one effect of power-supply resistance is to reduce the value of input signal required for full output: a second effect, as shown by Fig. 11A, is to reduce the power output with full-signal input. An increase in the value of load resistance may be necessary in order that the load line intersect the new zero-bias characteristic at the knee.

The effect of power-supply resistance is small when the output valve is a triode, because the load is usually adjusted for a small rise in d-c plate current with signal.

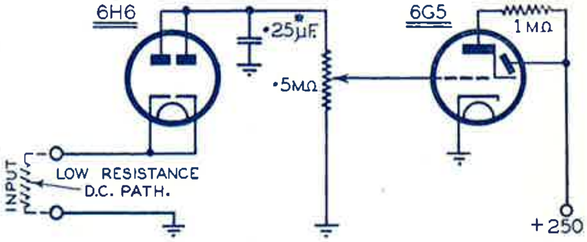
Conclusion

The analyses described in this Note are useful in determining with fair accuracy the operating conditions of single-valve power-output amplifiers. The analyses are also useful in determining the operation of a valve under given conditions. Although first approximations are accurate enough for most purposes, some second approximations are given for higher accuracy. Whenever possible, the results of the analyses should be checked by measurements with a reasonable number of valves.

LEVEL INDICATOR USING RADIOTRON 6G5

In public address systems and studio amplifiers where the output is not directly audible to the operator, a level indicating device is necessary. This usually takes the form of a copper oxide rectifier type voltmeter connected across the output of the amplifier at some suitable point.

A highly satisfactory type of level indicator may be made by using a Radiotron 6G5 Magic Eye. The deflection of the 6G5 follows approximately a logarithmic law and will thus indicate proportionally to the output level in dB. One Radiotron 6H6 is used as a diode rectifier with a load consisting of a 0.5 megohm potentiometer. This is shunted by a 0.25 μF filter condenser which gives a time constant suitable for most applications, but which may be varied over wide limits while still giving a clear shadow on the target of the 6G5. The voltage required to close the eye is approximately 25V. RMS input to the 6H6.



* ADJUSTED TO GIVE SUITABLE TIME CONSTANT WITH LOAD RESISTOR USED

The source of audio frequency voltage should have a reasonably low resistance D.C. path compared with 0.5 megohm. If a low impedance line is used to supply the speakers, the indicator may be placed across this line. The 0.5 megohm potentiometer can be calibrated in dB. or in any other suitable units but the potentiometer should preferably be one in which the resistance is proportional to the rotation.

In operation, adjustment is made so that the shadow area on the target becomes zero at a convenient level, which may be the point of overload or of full modulation. When this level is exceeded there will be overlapping of the 6G5 and a bright line will appear on the target, this being the danger signal.

PUSH-PULL TRIODE AMPLIFIERS

The first part of this article was given in Radiotronics 79, Pages 64-67, and it gave the theoretical basis on which the following Graphical Application is built. In this article a very simple method for the determination of working conditions of push-pull triode amplifiers is described.

PART 2. — GRAPHICAL APPLICATION

To find the correct operating conditions for any pair of triodes, for a specified plate voltage, it is necessary to *find the plate current at zero bias and 0·6 of the supply voltage*. From this the output and load may be calculated. As it has been decided that each valve shall just cut off on negative input voltage peaks, the cut-off grid voltage is found for $E_p = (E_b + E) = 1{\cdot}4E_b$. One half of this may be taken as the bias, and the working point for one valve fixed on the E_p I_p family at $e_p = E_b$. A composite family should be drawn for the two valves and a load line having the slope $-\dfrac{R_L}{4}$ drawn through the composite working point ($E_p = E_b$, $i_{p1} = i_{p2} = 0$), and the two peak currents (zero bias on each valve).

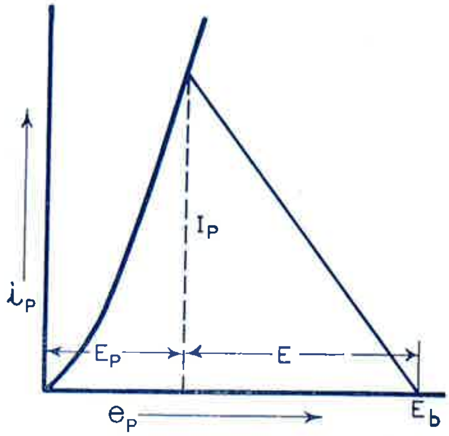


Fig. 4—Determination of working constants for maximum power output.
i_p = plate current.
I_p = peak plate current.
e_p = plate voltage.
E_p = minimum plate voltage.
E = peak (negative) output voltage.
E_b = plate supply voltage.

By plotting i_o *against* e_i a dynamic characteristic may be drawn as in fig. 3. By adding instead of subtracting the plate currents of each valve, i_t may be plotted in terms of e_i, as in curve B, fig. 3. To find the mean plate current, a curve $i_t = F\ (e_i\ sin\ pt)$ may be drawn by projection, (fig. 3, curves C and D). By counting the squares under the curve, or by averaging ordinates, the mean total current may assessed for maximum (or any other) output.

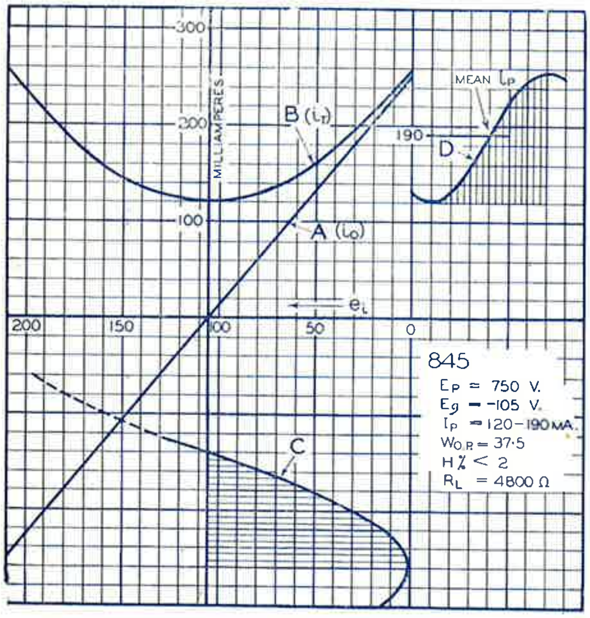


Fig. 3—Dynamic characteristics of push-pull 845's.
Curve A — signal output current (dynamic) — i_o.
Curve B — total plate current — i_t.
Curve C — sine wave signal input voltage.
Curve D — total periodic plate current.

The linearity of the dynamic line is the criterion of distortion, and the percentage of third harmonic may be computed* by measuring the ordinate

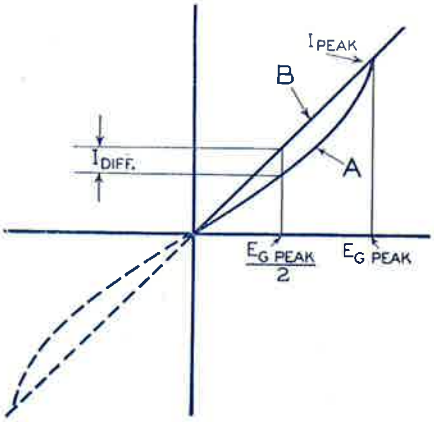


Fig. 5—Graphical determination of distortion.
Curve A = dynamic characteristic.
Curve B = ideal straight line.
As the dynamic line is symmetrical about the origin, only one half is shown.

difference between a chord and the curve at $e_i = \frac{1}{2}$ *peak* e_i, the percentage of third harmonics

$$H_3\% = \frac{33{\cdot}3\,i_{diff}}{i_{peak}} \quad \ldots\ldots\text{(Fig. 5)}\ldots\ldots(9)$$

If self bias is to be used, it is necessary to calculate the power input to each plate at zero signal input. Quite frequently it is found that the plate dissipation exceeds the maximum allowable. The load resistance must then be increased until the required bias at maximum signal requires a bias resistor high enough to keep the valve working within its ratings. If the mean maximum signal plate current is taken as half the sum of the total peak and total zero signal current (for two valves) an approximate curve for mean plate current (maximum) against grid voltage may be drawn. If the I_P E_g static curve for two valves is drawn on the same sheet (fig. 6), and a straight line drawn through the origin and the maximum plate current for the plate voltage under consideration, its slope will be the required cathode resistance, and it will intersect the mean current line at the required bias. The required load may be fixed and the dynamic operation studied from a composite family.

At the applied voltage (1000V.) in fig. 6, it is found that the 845 valve would have been overloaded seriously at zero input if self bias were employed with the operating conditions for maximum possible output. The cathode resistance has been chosen, therefore, to limit the dissipation at zero input to the maximum rating (75W. per plate).

It should be noted that while the total plate *input* at maximum signal may far exceed the figure for the maximum allowable dissipation of the valves, the actual power consumed by the valves themselves is the difference between the input power and the power output to the load. When self bias is used, the bias is reduced as the signal input is diminished, because the plate current is itself reduced. Quite frequently it is found that a stage may be working well within its rating at maximum output, but due to the bias reduction at zero input the dissipation may rise dangerously. That is why the load has to be increased to reduce the power output (and input) when self bias is used. The distortion also, is found generally to be greater.

The methods outlined have been found to be in close agreement with practical results. A table of operating conditions for triode amplifiers has been published as a loose leaf for the Radiotron data book.

*Hutcheson—Electronics, January, 1936.

NEW RADIOTRON RELEASES

1608: 20 Watt Dissipation High Efficiency Triode, filament 2.5V. 2.5A, amplification factor 20, maximum plate voltage 425, maximum plate current 95 mA, medium 4 pin ceramic base. Dimensions similar to 801. Typical output 18 Watts (plate modulated), 27 Watts (telegraphy). Australian nett price, £1/15/-.

1609: Pentode for use in Battery operated Pre-amplifiers, filament 1.1V. 0.25A, plate voltage 135 maximum, low microphonic construction, small 5 pin base. Australian nett price, 17/6.

1610: Crystal Oscillator Pentode, filament 2.5V. 1.75A, maximum plate voltage 400, maximum plate dissipation 6W., typical output 5 watts, medium 5 pin base. Australian nett price, £1.

914: 9″ Electrostatic Cathode Ray Tube with medium persistence (greenish) screen. Australian nett price, £58.

921: Phototube (Gaseous Type). This new phototube of the gas-filled type has a short double-ended construction which eliminates the conventional base and provides a long insulating path between electrodes. This construction offers features of compactness and convenience in circuit arrangement. Because the 921 has high sensitivity to red light and infrared radiation, it is particularly well adapted for use with the readily available incandescent lamp as a light source. Australian nett price, 17/6.

922: Phototube (Vacuum Type). Similar in construction to the Radiotron 921, the 922 is a sensitive phototube of the vacuum type hav-

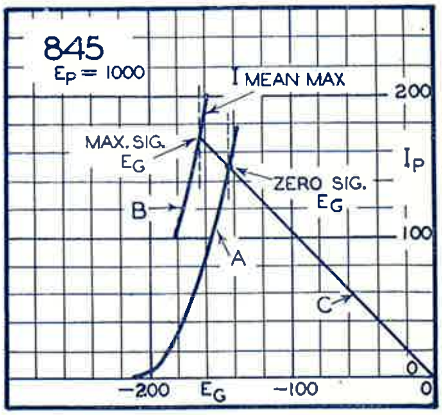


Fig. 6—Self bias operations: Type 845, E_p = 1,000V.
Curve A — I_p, E_g, zero signal (two valves).
Curve B — I_p, E_g, maximum signal (two valves).
The slope of the line C determines the value of the bias resistor.

ing high internal resistance and low leakage current between electrodes. The 921 is, therefore, especially suited for space-limited applications where the use of a high resistance load is desirable to give maximum circuit sensitivity. The large spectral response of the 922 in the infra-red region makes this type particularly useful where tungsten-filament lamps are employed as light sources. Australian nett price, 17/6.

923: Phototube (Gaseous Type). This new phototube is similar mechanically and electrically to Radiotron 918 but has a shorter overall length. Australian nett price, £1/1/-.

RADIOTRON 1603

Pentode for Microphone Amplifiers

For special applications where a very low degree of microphonicity is desirable, Radiotron 1603 (Australian price 20/- nett) is to be recommended. This valve is very similar in dimensions and in electrical characteristics to the well-known 6C6, and may be applied in an identical manner. As a resistance coupled amplifier Radiotron 1603 should be operated as shown for the 6C6 in the table on page 41 of Radiotronics 76. The 1603 is designed particularly as a low-level microphone amplifier.

RADIOTRON 302 BARRETTER

The Radiotron 302 Barretter which was announced in Radiotronics 79 has already met with a ready response and it is being used by a number of manufacturers in their new models. The Australian price of the 302, which was inadvertently omitted from the announcement, is 14/6. This Barretter is rated at 0.3A with a voltage drop across the barretter of from 112 to 195 volts, and it is therefore suitable for A.C./D.C. or D.C. receivers operating from 200 to 260 volt mains.

It is desirable to arrange so that the voltage drop across the barretter is in the region of 165 to 170 volts with nominal mains voltages so that the fullest protection is secured in the case of fluctuating voltages. With a 240 volt supply the voltage drop in the heaters should therefore be somewhere about 70-75 volts. This is provided by a 25Z5 rectifier and 43 power pentode together with earlier stages as shown in Circuit E51, described in Radiotronics 79.

The 302 is fitted with a standard "Edison screw" base in conformity with the larger current regulators (876 and 886) which are fitted with the larger "Mogul Screw" base. *The screw base gives more rigid mounting than a valve base, and prevents the barretter from coming loose from the socket during transport.*

REDUCED PRICES

Transmitting and Miscellaneous Types

A reduction has been made in the Australian nett prices of many types of Radiotron Valves, among which are the following popular types:—

Type	Description	New Nett Price
6P6	10 Watt Pentode ..	12 6
800	35 Watt H.F. triode ..	£4 0 0
801	20 Watt H.F. triode ..	£1 15 0
802	10 Watt Pentode ..	£1 15 0
804	40 Watt Pentode ..	£6 10 0
807	21 Watt Tetrode ..	£2 0 0
808	50 Watt H.F. Triode ..	£4 0 0
830B	60 Watt Triode ..	£4 5 0
834	50 Watt U.H.F. Triode ..	£5 10 0
864	Low microphonic Triode .	15 0
866	Mercury vapour Rectifier	£1 0 0
866A	Mercury vapour Rectifier	£1 15 0
868	Photo-tube	£1 10 0
878	Half wave Rectifier ..	£4 10 0
879	Half wave Rectifier ..	£1 5 0
885	Gas Triode	£1 0 0
905	5" Cathode Ray Tube ..	£18 0 0
906	3" Cathode Ray Tube ..	£6 10 0
913	1" Cathode Ray Tube ..	£1 15 0
956	Acorn R.F. Pentode (Super-Control ..	£2 0 0
1603*	Low microphonic Pentode	£1 0 0
1608*	20 Watt Triode	£1 15 0
1609*	Low microphonic Pentode	17 6
1610*	Crystal oscillator Pentode	£1 0 0

* New types described elsewhere in this issue.

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