TECHNICAL BULLETIN No. 94   23rd JANUARY, 1939

In this issue:—

RADIOTRON 810
125 WATTS PLATE DISSIPATION

Radiotron 810 is a triode suitable for transmitting purposes, having a plate dissipation of 125 watts. It is intermediate in size between types 805 and 806. The amplification factor of the 810 is 35, which also is intermediate between those of the 805 (very high) and the 806 (12.6). The maximum plate voltage for plate-modulated conditions is 1600 volts, and for all other conditions 2000 volts. The filament operates at 10 volts 4.5 amperes, and is shielded at each end so as to conserve input power by eliminating bulb bombardment and stray electrons. The plate is brought out to a cap at the top, and the grid to a cap at the side of the bulb, thereby giving excellent H-F operation. The output obtainable under typical operating conditions with maximum plate voltage in each case is:—

Class B Audio (2 Valves)	590 Watts
Class B Linear R.F.	60 Watts
Class C Grid-Modulated	60 Watts
Class C Plate-Modulated	250 Watts
Class C Telegraphy	375 Watts

Bulb	T20
Base	Jumbo 4-Large Pin
Maximum Length	9-1/16"
Maximum Diameter	2-9/16"
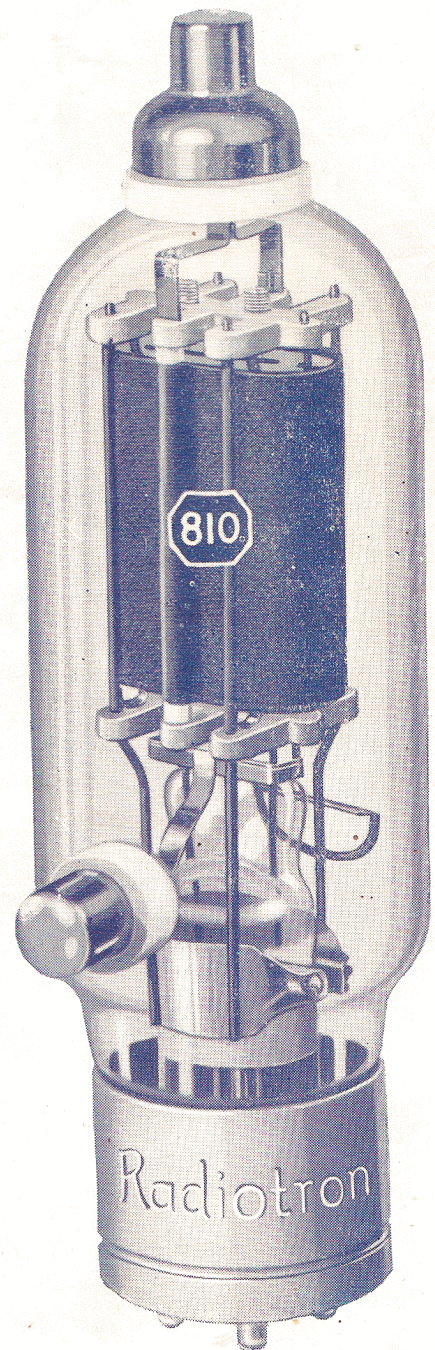
RADIOTRON 1616
HALF WAVE VACUUM RECTIFIER

Radiotron 1616 is a high vacuum, half wave rectifier of the coated filament type. It is quick-heating and is particularly useful in high-voltage devices where plate and filament voltages are applied simultaneously under full load conditions. In single phase circuits, full wave rectification is obtained by using two of these types, and the R.M.S. voltage should not exceed 3900 volts plate to plate. The maximum D.C. voltage is therefore 0.9×1950 or 1750 volts with choke input. At full load this voltage will not drop by more than 90 volts due to the valve drop alone, but voltage drop in the transformer and filter must also be considered.

Radiotron 1616 may be used with either choke or condenser input filters, but with the latter the capacitance of the input condenser must be low enough to limit the peak and surge currents to the valve ratings.

The characteristics of Radiotron 1616 somewhat resemble those of Radiotron 836 except that the latter has an indirectly heated cathode and is comparatively slow-heating.

Radiotron 1616.

Filament (A.C.)*	2.5 Volts 5 Amps
Peak Inverse Voltage	5500 (max.) Volts
Peak Plate Current	0.8 (max.) Amp.
Surge Current**	2.5 (max.) Amp.
Average Plate Current	0.13 (max.) Amp.
Bulb	T-16
Cap	Medium Metal
Base	Medium 4 Pin Bayonet
Overall Length	6-11/16"
Overall Diameter	2-1/16"

*Voltage tolerance ± 5%.
**Equipment should be designed so that this value is not exceeded during switching operation.

THIRD HARMONIC DISTORTION
GRAPHICAL METHOD FOR PUSH-PULL AMPLIFIERS

A very simple graphical method of calculating the third harmonic distortion of a Push-Pull amplifier is here given. From the plate $(E_p I_p)$ characteristic and loadline construct a dynamic characteristic (A) as shown in Fig. 1, in which the horizontal axis represents A.C. grid voltage and the vertical axis A.C. plate current. Draw the straight line B joining the ends of the dynamic characteristic (and therefore passing through the origin) and measure the vertical difference between A and B at half the peak grid voltage. This difference is shown as I_{diff} in Fig. 1.

Since the amplifier is in push-pull there will, with proper matching and symmetry, be no second harmonic, and the third will be the principal harmonic. The percentage of third harmonic will be

$$\frac{\frac{2}{3} I_{diff} \times 100}{I_{peak} - \frac{2}{3} I_{diff}}$$

If the percentage of third harmonic is small, a convenient approximation is

$$3\text{rd Harmonic } \% = \frac{\frac{2}{3} I_{diff} \times 100}{I_{peak}} \text{ approx.}$$

The accuracy of these expressions is only very slightly affected by normal percentages of fifth and higher odd harmonics.

This method was described in Radiotronics 80, Page 79, but an error was made in equation (9), which should be corrected to read as above.
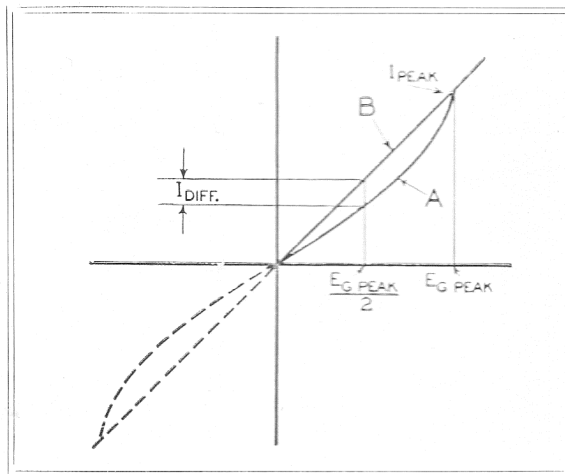

Fig. 1.   *Graphical Determination of Distortion.*

Curve A = Dynamic characteristic.
Curve B = Ideal straight line.
As the dynamic line is symmetrical about the origin, only half is shown.

GRID LEAK BIAS OPERATION OF
HIGH MU TRIODE VALVES

The advantage of using self-bias with high mu valves was explained in a previous Bulletin (Radiotronics 87).

Tests have been carried out recently in the laboratory of Amalgamated Wireless Valve Co. Pty. Ltd. on Radiotron type 6B6-G (75) with a new form of self-bias which has several advantages over the older form using a cathode resistor and condenser. It consists in connecting the cathode directly to earth and increasing the grid resistor from one megohm to at least five or ten megohms as shown in Fig. 2.

Although it would appear that the valve is operating at zero bias it is biased due to the contact potential of the grid which causes grid current to flow at approximately −0.75 volt.

When a high value of grid leak is used the grid current flowing produces a negative voltage on the grid which is sufficient to allow the valve to excite a 6F6-G (42) to full output without excessive distortion.

Tests carried out on an average sample of Radiotron 6B6-G (75) gave the following results:—

In each case:
Plate Supply Volts . = 250 Volts
Plate Load .... = .25 Megohm
Following Grid Leak = 1.0 Megohm

(3) The distortion is slightly less than with cathode bias.
(4) There is a saving of both bias resistor and by-pass condenser.
(5) There is better uniformity from valve to valve.

One disadvantage which is immediately apparent is that delayed A.V.C. is not possible by ordinary means. It is felt that this is not serious, for by returning the diode load to some negative point delayed A.V.C. may still
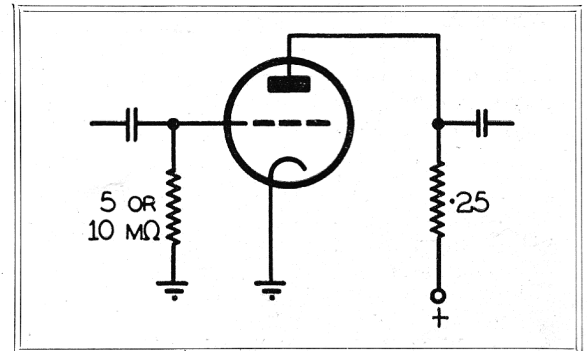

Fig. 2.   *Method of grid leak bias operation of high mu triode valves.*

Input.	Cathode Bias. 5000 Ohms + 25μF.		Zero Bias. 5 Megohm Grid Leak.		Zero Bias. 10 Megohm Grid Leak.	
	Output R.M.S.	Distortion	Output R.M.S.	Distortion	Output R.M.S.	Distortion
.05V	2.7V	4.5%	3.1V	4.2%	3.1V	4.5%
.1V	5.7V	3.1%	6.45V	3.0%	6.5V	3.0%
.2V	10.2V	2.8%	12.0V	2.6%	12.4V	2.5%
.3V	16.2V	2.8%	18.0V	2.5%	19.0V	2.6%
.4V	21.8V	3.3%	23.2V	2.6%	24.6V	2.6%
.5V	26.6V	4.2%	27.0V	3.8%	28.4V	3.5%
.6V	29.4V	5.8%	29.4V	5.5%	31.0V	4.8%

The above tests were also carried out with grid leaks of 15 and 1 megohm resistance. With 15 megohms no appreciable improvement was shown over the figures for 10 megohms, whilst with 1 megohm the distortion was too high to be tolerable.

Summarizing the above results the scheme has the following advantages over the normal self-bias method:—

(1) The A.C. load resistance on the preceding valve is increased, being approximately half the resistance of the grid leak, and thus in case of a diode load allows a higher percentage of modulation to be handled without distortion.

(2) The gain with small inputs is slightly higher than with cathode bias.

be obtained, and at the same time this does away with the need for cathode bias resistors in the controlled stages, further simplifying the receiver.

A further disadvantage is that due to the flow of a small amount of grid current which varies over the input cycle, the load on the preceding valve is of a variable nature. This, however, is not serious when a 5 or 10 megohm grid leak is used, as the highest load which is likely to precede a 6B6-G is 0.5 megohm and the shunting effect on this is negligible.

It will be seen from the tabulated results that it is preferable to use 10 megohms for the grid leak, if satisfactory resistors of this value are available commercially.

THE EFFECT OF SHUNT CAPACITANCES

It is sometimes necessary to calculate the effect of a shunt capacitance across a load resistor (Fig. 3). The effect on the frequency response depends on the type of valve used. **If V is a triode** with a plate resistance R_p, and C represents the total effective capacitance across the load R_L, the following method may be adopted.

The impedance of C and R_L in parallel is Z where

$$Z = \frac{R_L X_c}{\sqrt{(R_L^2 + X_c^2)}}$$

Where X_c = reactance of C = $\dfrac{1}{2\pi f C}$

If now the ratio X_c/R_L is called A, the impedance may be written

$$Z = \frac{R_L A}{\sqrt{(1 + A^2)}}$$

or

$$\frac{Z}{R_L} = \frac{A}{\sqrt{(1 + A^2)}} = B \text{ (say)}$$

If now M = gain with load R_L
and M' = gain with load Z

$$\frac{M'}{M} = \frac{B(R_L + R_p)}{BR_L + R_p}$$

Using this as a basis, a table has been prepared showing the value of M'/M for various conditions. In order to simplify the table, the values are shown for selected values of R_L/R_p. R_p is of course taken **under working conditions** and in all cases will be higher than the published value. The true value may be determined from the published curves, or an approximation may be taken. It is found that as R_L is increased in a resistance loaded amplifier, R_p also increases. For most general purpose triodes a value of R_L/R_p equal to 5 is fairly accurate. For high-mu triodes a value of 2 is fairly satisfactory.
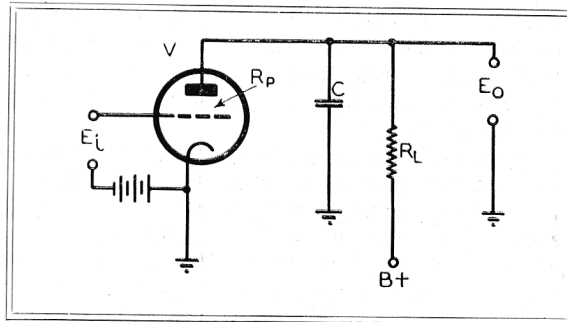

Fig. 3. *Typical plate circuit of a valve showing a shunt capacitance C across the load resistor R_L.*

The treatment for **pentodes** is different since the plate resistance is very much greater than the load resistance. As an approximation

$$M = g_m . R_L$$

where g_m = mutual conductance of V under working conditions.

The amplification with pentodes is therefore directly proportional to R_L (or Z) and

$$\frac{M'}{M} = \frac{Z}{R_L} = B$$

Special cases in which high accuracy is required should be calculated directly.

TABLE.

Gain with capacitive shunt as a fraction of gain without shunt.

$\dfrac{X_c}{R_L}$	M'/M			
	$R_L/R_p = 10$	$R_L/R_p = 5$*	$R_L/R_p = 2$**	Pentodes
.05	.36	.24	.14	.05
.10	.55	.40	.25	.10
.20	.73	.55	.42	.20
.30	.82	.71	.55	.29
.40	.87	.78	.64	.37
.50	.90	.83	.71	.45
.60	.92	.865	.76	.52
.80	.95	.91	.83	.63
1.0	.965	.935	.88	.71
2.0	.99	.980	.963	.90
5.0	.998	.996	.994	.98
10.0	.9995	.9991	.9983	.995
20.0	.9999	.9998	.9996	.999

*Suitable for most general purpose triodes.   **Suitable for most high-mu triodes.

NEW "PARALLEL FEED-BACK" CIRCUIT
NEGATIVE FEEDBACK WITH RESISTANCE COUPLING

The "Series Feedback" circuit described and applied in many previous issues of Radiotronics has been very widely adopted with excellent results. A new form of "Parallel Feedback" with certain good features has recently been described in an R.C.A. Application Note. The fundamental circuit is shown in Fig. 4, and at first sight may appear very similar to the "Series" circuit. There are, however, important differences in operation.

Only two resistors (R_1 and R_3) are used in the parallel circuit, as compared with three in the series circuit, the plate resistor of V_1, as such, being omitted and its place taken by a suitable choice of values for R_1 and R_3. There is thus a slight economy in the parallel circuit.

When a normal percentage of feedback is employed either circuit may be used satisfactorily. The parallel circuit has a peculiar characteristic in that at a certain high feedback factor, infinite attenuation (i.e., zero gain) occurs. This, however, should not normally be encountered.

As with the series circuit, the plate resistance of the preceding valve acts as a shunt on the feedback network. The feedback factor with Fig. 4 is β

$$\text{where} \quad \beta = \frac{R}{R + R_3} \quad - - - - - - \quad (1)$$

$$\text{and} \quad R = \frac{1}{\dfrac{1}{r_{p1}} + \dfrac{1}{R_1} + \dfrac{1}{R_2}}$$

neglecting the reactance of the coupling condenser.

When V_1 is a pentode, r_{p1} will be very high compared with R_1 and R_2 and may be neglected to a first approximation, and then

$$\beta = \frac{1}{\dfrac{R_3}{R_2} + \dfrac{R_3}{R_1} + 1} \quad - - - - - \quad (2)$$

For example, if $R_3 = 0.5$ megohm, $R_2 = 0.5$ megohm and $R_1 = 0.1$ megohm, β will be 0.14 (or 14%) approximately.

Certain problems arise in this type of circuit when a triode is used for V_1. Apart from the effect of r_{p1} in reducing the effective feedback (see Eqn. 1), there is also the loss of gain which is generally more apparent in the case of the triode, due to its less initial gain. A still more serious defect with the triode is the possibility of serious distortion in V_1 due to a low A.C. load resistance. The A.C. load on V_1 is the parallel combination of R_1, R_2 and a fictitious resistor $R_3/(1 + M_2)$ where M_2 is the gain of V_2. With a triode valve this low A.C. load resistance may reduce the plate current to zero during part of the cycle and cause serious distortion.

Nevertheless it is quite possible to use a suitable triode valve for V_1 provided that the feedback factor is small. Type 6B6-G (75) is not regarded as suitable for this application due to the restricted grid swing, but type 6Q7-G may be used with the following typical values:—

$$R_1 = 0.25 \text{ megohm}$$
$$R_2 = 0.25 \text{ megohm}$$
$$\text{and} \quad R_3 = 1.25 \text{ to } 2.25 \text{ megohms.}$$

It will be understood that even when the 6Q7-G is used in this manner, the total harmonic distortion is greater than with a pentode under similar conditions, due to the unavoidable distortion in the 6Q7-G which partially offsets the reduction of distortion in V_2.

When a pentode (6J7-G or 6B8-G) is used for V_1 the full advantages of a high feedback factor are obtainable, and this arrangement is much to be preferred to the triode arrangement.

Fig. 4. *Circuit arrangement of new form of "Parallel Feedback," with Resistance Coupling.*
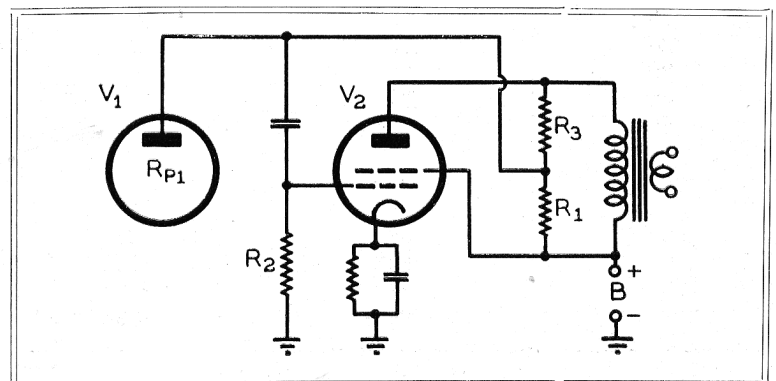
1.4 VOLT SERIES
FILAMENT VOLTAGE LIMITS

The 1.4 volt series of valves recently announced in Radiotronics is intended for operation from a dry cell filament supply. The full voltage of a new dry cell will not do any harm to the filaments, since the valves have been designed for this service. The lower voltage limit will, however, depend largely upon the design of the receiver, and whether the coverage includes the broadcast band only or with the addition of a short-wave band.

Tests have been conducted in our laboratory under typical operating conditions in order to determine the lower voltage limit for the converter valve 1A7-G. Unfortunately the number of valves available at the time was not sufficient to enable true average values to be settled. The tests showed

(1) That under the best conditions operation of a sort could be obtained down to 0.85 volt on the broadcast band and 1.0 volt on the shortwave band **with specially selected valves.**

(2) That with the weakest valve (one which has already had a fair service life) the oscillator ceased oscillating at about 1.2 volt on the filament on both broadcast and shortwave bands.

It therefore appears that with a typical new valve reasonable operation may be expected down to about 1.1 volt on the broadcast band and 1.2 volt on the shortwave band. Nevertheless difficulty may be experienced in maintaining oscillation down to these voltage limits with valves which are slightly weak either initially or due to a few hundred hours life.

These results are obviously dependent upon the conditions of operation, and particularly on the coil design, and are only given as an indication of what may be obtained under certain conditions. It is interesting to note that the valve manufacturers' filament voltage rating is 1.4 volt $\pm$ 10%, that is from 1.26 to 1.54 volt. No valve guarantee extends beyond these limits.

Example (Triode case).

R_p = 20,000 ohms under working conditions.

R_L = 100,000 ohms (i.e., R_L/R_p = 5).

C = .0002μF.

f = 10,000 c/s.

$$X_c = \frac{10^6}{2\pi \times 10,000 \times .0002} = 79,500 \text{ ohms.}$$

$$\therefore \frac{X_c}{R_L} = \frac{79,500}{100,000} = 0.795$$

Referring to the table, the nearest value of X_c/R_L is 0.8, and the column for R_L/R_p = 5 gives a value of M'/M = 0.91. The output voltage is therefore 91% of that at middle frequencies (400 c/s).

If the valve had been a pentode, the output voltage would have been 63% of that at 400 c/s.

RADIOTRON NEWS

Radiotron 6U5 is intended to supersede type 6G5, both types having identical electrical characteristics, but the 6U5 having a tubular (straight sided) bulb. As soon as present stocks of type 6G5 are exhausted, all orders for type 6G5 will be filled with type 6U5. At a later date type 6U5 will be branded 6U5/6G5 (see below).

Radiotron 6U5/6G5 will be identical to the existing type 6U5, the addition "6G5" signifying that it is also a replacement for type 6G5.

Radiotron 6SA7 is a "single-ended" metal Pentagrid Converter.

Radiotron 6SC7 is a "single-ended" metal Twin Triode with common cathode intended primarily for phase inverter service.

Both Radiotrons 6SA7 and 6SC7 are additions to the single-ended metal series announced in Radiotronics 92. Further information on these types will be given at a later date.

A series of three filament type "Acorn" valves has been announced, the filaments being intended for operation from a single dry cell.

Radiotron 957 is a triode "Acorn" having a 1.4V 50 mA. filament.

Radiotron 958 is a larger triode "Acorn" having a 1.4V 100 mA. filament.

Radiotron 959 is a sharp cut-off pentode "Acorn" with a 1.4V 50 mA. filament.

Further information on these types will be given at a later date.

RADIOTRON 1C7-G
HIGH FREQUENCY OPERATION

The zero bias conditions of operation for Radiotron 1C7-G (or 1C6) are perfectly satisfactory on the broadcast band and on the 16-51 metre short-wave band provided that suitable coils are used. There is some difficulty, however, in obtaining satisfactory operation with a similar arrangement at 13 metres, and it is suggested that one of the following methods be considered:—

(1) With conditions as for standard zero bias operation except that the oscillator grid-leak is returned to the positive end of the filament.

(2) With conditions as for standard "—3 volts bias" operation, or

(3) With conditions as for standard zero bias operation except that full voltage is applied to the anode grid, and the screen voltage is increased by decreasing the resistance of the dropping resistor.

None of these devices is to be preferred on the broadcast band, but in certain circumstances a compromise may have to be made. Methods (1) and (3) result in a decrease of plate resistance, method (3) also being accompanied by a considerable increase in B battery drain. Method (2) results in a decrease of conversion conductance.