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IN THIS ISSUE

This month we are printing a further article in the series on "Modern Methods of Testing Amplifiers". On this occasion Mr. F. Langford-Smith discusses Stability Margin of a Feedback Amplifier. The methods developed by the Radiotronics Laboratory are detailed. The author is well-known as the editor of Radiotron Designers' Handbook: his lucid articles on Audio Amplifiers have been a feature of this journal for many years.

In the May 1956 issue, the 5AS4 data was published. Since that date we have prepared the operating characteristics of the type for both choke and capacitor input circuits — see p. 105.

Nomographs have become an essential to all engineers and designers. The nomograph (or abac) on p. 107 readily enables a designer to determine the necessary conversion factors when the published valve operating conditions are not quite those required. Quite accurate results can be obtained over a ± 30% range.

Your copy of the latest edition of Radiotron Designers' Handbook will be right for accuracy when you tidy up the typographical errors as shown in this issue. Our thanks to the many readers who have pointed out errors and omissions from R.D.H.

The Radiotron 1B3GT half-wave high-voltage e.h.t. rectifier will be featured in most Australian TV receivers. Full valve data is included in this issue together with notes on the installation and applications of the valve.

The senior engineer of A.W.V's Applications Laboratory, Mr. H. Wilshire, has written on a method (developed in the Laboratory) for measuring the filament temperature of the 1B3GT. The control of the filament temperature of this valve is an important factor in ensuring valve reliability: consequently the accuracy of the method of measurement used has been investigated fully in the appendix to the article.

Among the new R.C.A. releases, we have found a number which will be worth watching. For any enquiries for further technical information, contact our Technical Service Department.

Editor .. .. A. J. Gabb, B.Sc., A.M.I.R.E. (Aust.).

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MODERN METHODS OF TESTING AMPLIFIERS

(4) STABILITY MARGIN

By F. LANGFORD-SMITH, B.Sc., B.E., A.M.I.E. (Aust.), S.M.I.R.E. (U.S.A.)
(Amalgamated Wireless Valve Co. Pty. Ltd.)

One of the most important tests to apply to a feedback amplifier is that to measure the stability margin. The stability margin is the increase in feedback which is possible before oscillation occurs.

The method used in the Radiotronics Laboratory is firstly to connect the pre-amplifier to the main amplifier. If the pre-amplifier is not available, a resistor is connected across the input terminals to give the same resistance as that provided by the pre-amplifier. The secondary of the output transformer, duly loaded, is connected to an oscilloscope to indicate any oscillation.

The feedback resistor is gradually decreased in resistance until oscillation just occurs, and then increased until oscillation just ceases.

There are three methods which may be used to measure the stability margin of an amplifier. The first is to measure the feedback at 1000 c/s in decibels under normal conditions, and then with the amplifier just stable; the stability margin is the difference between these two values. The second method is to measure the difference in decibels between the amplifier gain with the amplifier just stable and under normal conditions. The third method, generally used in the Radiotronics Laboratory, is to calculate the amount of feedback in the two cases from the values of the two resistors in the feedback network. Measurements on an amplifier indicated that these three methods agreed within ± 1 db.

The third method is described in detail:

(1) Measure the resistance of the feedback resistor (R_{f1}) in the amplifier. This gives a more accurate result than merely taking the nominal value.

(2) The unbypassed cathode resistor R_k across which the feedback voltage is applied may be taken at its nominal value.

(3) The feedback resistor is open-circuited and replaced by a decade resistance box which is gradually decreased below the nominal value of the feedback resistor until oscillation just begins; it is then increased until oscillation ceases. This gives R_{f2}.

A complication arises when the feedback resistor is shunted either by a capacitor or by a capacitor and resistor in series. In this case the obvious thing to do it to disregard the shunt capacitor which usually has negligible effect at middle frequencies. The stability factor is given by:

$$\text{S.F.} = \frac{R_k / (R_{f2} + R_k)}{R_k / (R_{f1} + R_k)} = \frac{R_{f1} + R_k}{R_{f2} + R_k}$$

where R_{f1} = normal resistance of feedback resistor,
R_{f2} = resistance of feedback resistor to bring the amplifier to the verge of oscillation,
and R_k = impedance "seen" by the feedback resistor.

The Stability Factor may readily be put in decibel form, thus giving the Stability Margin in decibels. A Stability Factor of 10 is the same as a Stability Margin of 20 db.

An alternative method which could be used by those not possessing a suitable resistance box is to shunt the feedback resistor in the amplifier by an external variable resistor having about 10 times the resistance of the feedback resistor. The combined resistance of the feedback resistor in parallel with the variable resistor is then measured as accurately as possible; this gives R_{f2}.

The loading of the secondary of the output transformer may be either a loudspeaker or some form of dummy load. For amplifiers which are always used on the same loudspeaker, whether a single, dual or triple unit, the most meaningful test is on loudspeaker load. In other cases the test may be made with various values of resistance, or capacitive, or partially capacitive load.

The usual method of applying a resistive load R_L equal to the nominal impedance of the loudspeaker gives the largest measured Stability Margin, but is hardly a fair test. A more difficult test is to apply

However, it is possible, when copying a prototype with a stability margin of 6 db. on a resistive load,

stability margin is measured on the actual amplifier in question, used on its normal loudspeaker load. However, it is possible, when copying a prototype with a stability margin of 6 db on a resistive load, a capacitance C_L shunted across R_L. For convenience in the following discussion let us assume that the secondary impedance is from 12 to 15 ohms, and the capacitance C_L will be given to correspond. The following are tentatively suggested, on the basis of rather limited experience, as the minimum values of capacitance which should be capable of being shunted across 12 to 15 ohms without oscillation:

1. Single dynamic loudspeaker with short leads . . . . $C_L = 0.05$ μF
2. Dual or triple dynamic unit with constant resistance half-section crossover networks . . . . $C_L = 0.1$ μF
3. Dual or triple dynamic unit with quarter-section cross-over networks $C_L = 0.15$ μF
4. Dynamic woofer with push-pull Lorenz LSH100 electrostatic loudspeakers connected from each plate to earth . . . . $C_L = 0.4$ μF
5. Dynamic woofer with push-pull Körting electrostatic loudspeakers $C_L = 1.4$ μF

In our experience, all amplifiers have reduced Stability Margins as the shunt capacitance is increased up to a certain value (usually less than 0.4 μF) but beyond this point the Stability Margin increases as C_L is increased. Consequently it is no more difficult to get stability with $C_L = 1.4$ μF than it is $C_L = 0.4$ μF.

Minimum stability margin

It is usual to regard 6 decibels as the minimum safe stability margin. This is reasonably safe if the

stability margin is measured on the actual amplifier in question, used on its normal loud speaker load.

to encounter trouble with instability, particularly if the output transformers are not identical or if the second amplifier is used to drive a dual loudspeaker. The writer prefers a minimum stability margin well over 6 db on a resistive load and at least 6 db on the worst likely case with a capacitance shunted across a resistance, as set out in items 1 to 5 above.

Absolutely stable amplifiers

An absolutely stable amplifier is one which is stable no matter what load is connected to the amplifier:

On resistive load — for any value from zero (short-circuit) to infinity (open circuit).

On partially capacitive load — for any value of capacitance from zero to infinity shunted across the normal resistive load.

On purely capacitive load — for any value of capacitance from zero to infinity.

On partially inductive load — with any value of inductance shunted across the normal resistive load.

Measuring frequency of oscillation

When a feedback amplifier oscillates, it usually does so at a very high frequency (often over 100 Kc/s), but it sometimes oscillates at a low frequency (usually less than 10 c/s) and sometimes at both frequencies together.

The method used in the Radiotronics Laboratory for measuring the high frequency is to connect a calibrated oscillator to the horizontal amplifier of a oscilloscope and the output from the amplifier to the vertical amplifier, and to adjust the oscillator until an ellipse is obtained.

Very low frequencies in the vicinity of 1 to 3 c/s, may be measured by counting the beats in a convenient time interval.

Dangers of Exceeding 6V6GT Maximum Ratings

Recently we have had brought to our notice several amplifiers using type 6V6GT valves in which the valve ratings were seriously exceeded. The resulting short valve life was directly caused by faulty or careless design.

Transformer voltages from 365 to 385 volts each side were used, resulting in voltages from plates and screens to cathodes in excess of 315 volts. Since the 6V6GT is rated at 315 volts maximum on the plate and 285 volts on the screen, lower transformer voltages should be used. However, in existing equipment it is possible to make modifications which will very much prolong the life of the output valves.

In amplifiers having two smoothing chokes, the filter could be changed from capacitor input to choke input simply by moving the input capacitor from its original position and placing it in shunt with the final capacitor.

In amplfiers having a single smoothing choke, a suitable resistor (usually 5 watt rating is required) in series with the choke to give the desired voltage of the 6V6GT plates and screens.

ex Nov. '56, P. 145

RADIOTRON 5AS4

FULL WAVE VACUUM RECTIFIER

(Tentative Data)

Since the data was first published on this valve type in the May, 1956, issue of "Radiotronics", further data has been released. There are curves on the operating characteristics, for both capacitor and choke input to filter. In addition, some notes on the operating consideration have been added.

Operating Considerations.

Even occasional "hot-switching" with capacitor-input circuits permits the flow of plate current having magnitudes which can adversely affect tube life and reliability. If capacitor-input circuits are to be used, it is essential that the tube be protected against the possible adverse effects of "hot-switching".

The valve can be protected by circuits designed to incorporate sufficient plate-supply resistance, to limit the maximum peak current for plate to 4.6 amperes during the initial cycles of "hot-switching" operation. The minimum value of this resistance may be determined from Rating Chart 2 (Radiotronics, May, 1956). If the transformer windings do not provide this minimum value of resistance, then additional d.c. series resistance is required. The value of this d.c. resistance, R_A, may be determined from the relationship shown in the legend for Rating Chart 3.

For applications in which "hot-switching" is required, choke-input circuits are recommended. Such circuits limit the hot-switching current to a value no higher than that of the peak plate current.

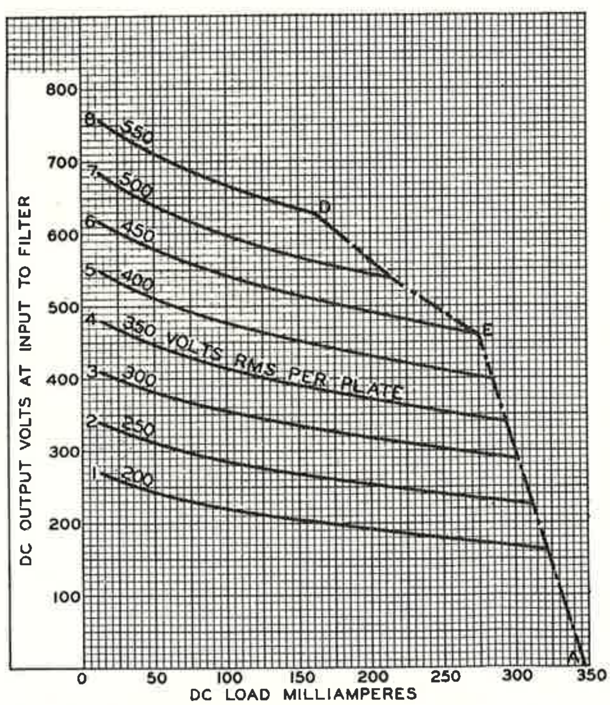


Fig. 1. *Operation Characteristics.* Full-wave circuit, ***capacitor input to filter*** = 40 μF.

Total effective plate-supply impedance per plate

Curve	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Ohms	*11*	*11*	*20*	*36*	*52*	*67*	*82*	*97*

Note: Current end-voltage boundary line "DEA" is the same as shown on rating chart 1.

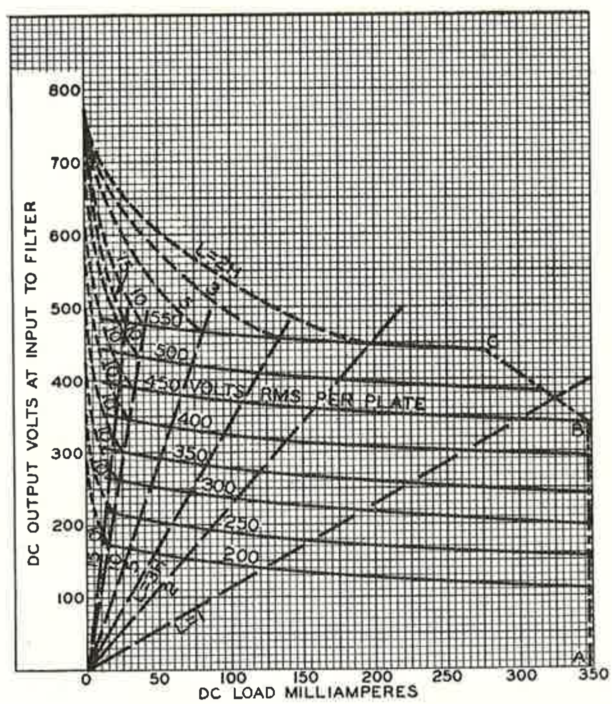


Fig. 2. *Operation Characteristics.* Full-wave circuit, ***choke input to filter.***

Solid-line curves — chokes of indefinite inductance.

Long-dash lines — boundary lines for choke sizes as shown.

Short-dash curves — regulation curves for representative choke sizes.

Note: Current and voltage boundary line "CBA" is the same as shown on rating chart 1.

R.C.A. Application Note AN-164*.

CONVERSION FACTORS FOR VALVE CHARACTERISTICS

This Note describes a method for determining the approximate characteristics of an electron valve when all the electrode voltages are changed in the same proportion from the published or measured values. Conversion factors for the principal characteristics are given in a nomograph which is easy to use and provides direct reading. Although these conversion factors have been available in curve form for some time, the nomograph is more convenient to use than the log-log curves.

The conversion factors obtained from the nomograph are applicable to triodes, tetrodes, pentodes, and beam power valves when the plate voltage, grid-No. 1 voltage, and grid-No. 2 voltage are changed simultaneously by the same factor. They may be used for any class of valve operation (class A, AB_1, AB_2, B, or C).

Conversion Factor Nomograph.

The nomograph shown in Fig. 1 may be used to determine the proper value for each conversion factor for a specified relationship (F_e) between published or measured values (E_{pub}) and desired values (E_{des}) of operating voltage. Conversion factors for resistance and transconductance (F_r and F_{gm}) are plotted on the scale at the extreme left of the nomograph, and conversion factors for current and power output (F_i and F_p) on the scale at the extreme right. The dashed lines on the nomograph indicate the correct procedure for determining these factors when it is desired to reduce the operating electrode voltage from 250 to 200 volts. The basis of the conversion factors and the formulas for determining each factor as a function of the change in operating voltages are given in the Appendix.

Use of Nomograph Conversion Factors.

An example of how the Conversion Factor Nomograph may be used to determine the characteristics of an electron valve when the operating voltages are changed in the same proportion follows:

The published characteristics for a typical pentode are:

Plate Voltage	250	volts
Grid-No. 2 Voltage	250	volts
Grid-No. 1 Voltage	—15	volts
Plate Current	30	mA
Grid-No. 2 Current	6	mA
Plate Resistance (approx.) ..	0.13	megohm
Transconductance	2000	μmhos
Load Resistance	10000	ohms
Total Harmonic Distortion ..	10	%
Max.-Signal Power Output ..	2.5	watts
Maximum-Signal Power Output	2.5	watts

* Printed with acknowledgments to R.C.A.

If it is desired to determine the characteristics of this valve for a plate voltage of 200 volts, the voltage conversion factor, F_e, is equal to 200/250 or 0.8. The following values for the other conversion factors are obtained from the nomograph:

Current Conversion Factor (F_i) 0.72
Resistance Conversion Factor (F_r) 1.12
Transconductance Conversion Factor (F_{gm}) 0.89
Power-Output Conversion Factor (F_p) .. 0.57

By the use of these factors, the following characteristics values at a plate voltage of 200 volts are obtained from the published characteristics:

Plate Voltage = 200 volts
Grid-No. 2 Voltage = 0.8 x 250 = 200 volts
Grid-No. 1 Voltage = 0.8 x –15 = –12 volts
Plate Current = 0.72 x 30 = 21.6 mA
Grid-No. 2 Current = 0.72 x 6 = 4.3 mA
Plate Resistance = 1.12 x 0.13 = 0.15 megohm
Transconductance = 0.89 x 200 = 1780 μmhos
Load Resistance = 1.12 x 10000 = 11200 ohms
Total Harmonic Distortion remains unchanged at 10%
Maximum-Signal Power Output = 0.57 x 2.5 = 1.42 watts

Comparison of Nomograph with Measured Values.

Two sets of laboratory measurements were made to determine the relative accuracy obtained by the use of conversion-factor values given by the nomograph. The valves tested were the Radiotron-6BH6 sharp-cutoff pentode (tested under class A_1 amplifier conditions) and the Radiotron-6146 beam power valve (tested under class C telegraphy conditions). Comparative data for these types are given in Tables I and II, respectively.

Limitations.

Because this method for conversion of characteristics is necessarily an approximation, progressively greater errors will be introduced as the voltage conversion factor ($F_e = E_{des}/E_{pub}$) departs from unity. In general, it may be assumed that results obtained will be approximately correct when the value of F_e is between 0.7 and 1.5. When F_e is extended beyond these limits (down to 0.5 or up to 2.0), the accuracy becomes considerably reduced and the results obtained can serve only as a rough approximation.

It should be noted that this method does not take into account the effects of contact potential or secondary emission in electron valves. Contact potential, however, may safely be neglected for most applications because its effects are noticeable only at very low grid-No. 1 voltages. Secondary emission may occur in conventional tetrodes at low plate voltages. For such valves, therefore, the use of conversion factors should be limited to regions of the plate characteristic in which the plate voltage is greater than the grid-No. 2 voltage. For beam power valves, the regions of both low plate currents and low plate voltages should also be avoided.

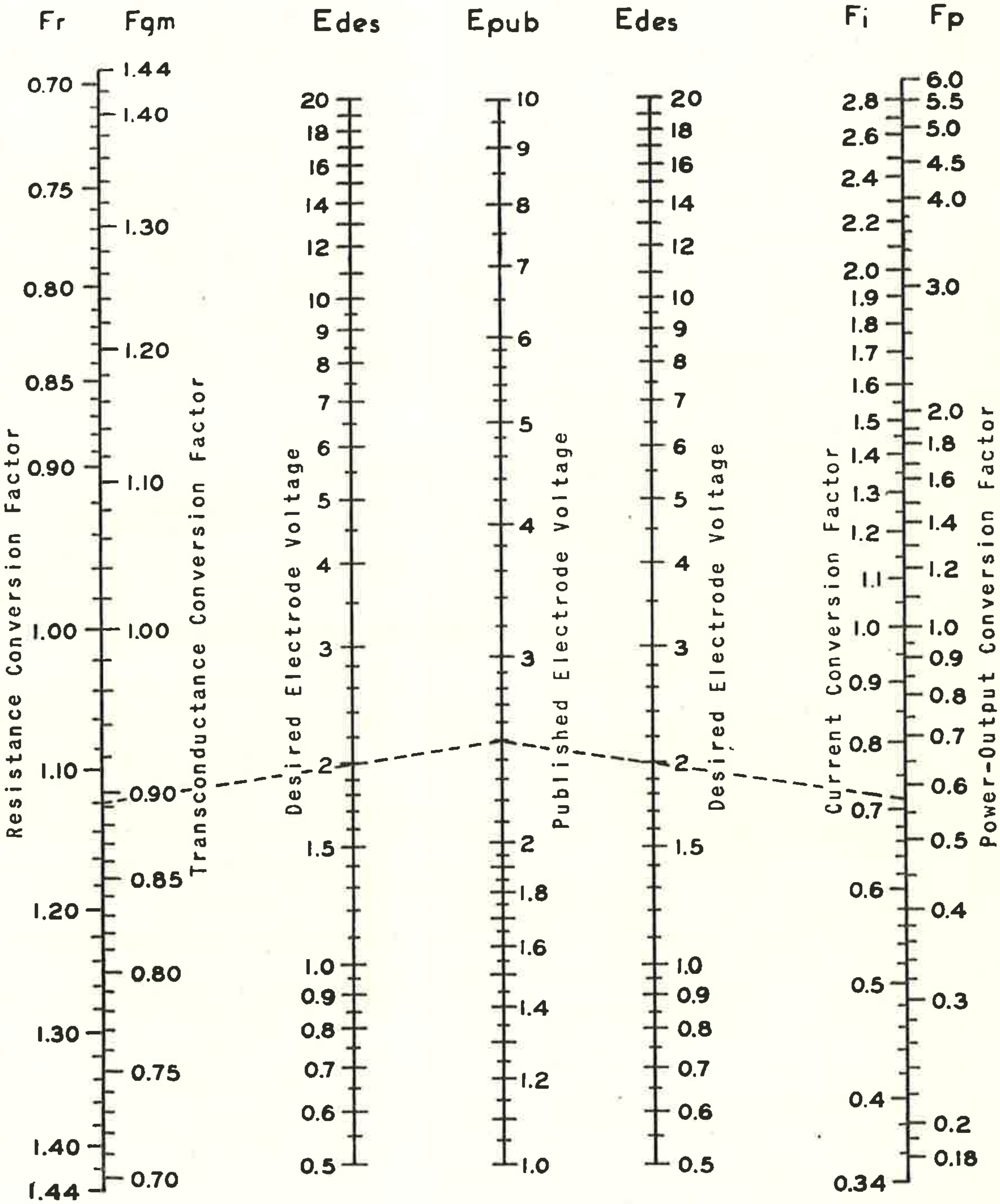


Fig. 1. Nomograph for determining valve-characteristic conversion factors.

TABLE I

Type Radiotron-6BH6 (Class A_1 Amplifier Conditions)

	Measured	Obtained from Nomograph	Measured	Obtained from Nomograph	Measured	Obtained from Nomograph	Measured
Plate Volts (E_b)	250	300	300	200	200	150	150
Grid-No. 2 Volts (E_{c2})	152	182	182	122	122	91	92
Grid-No. 1 Volts (E_{c1})	–1	–1.2	–1.2	–0.8	–0.8	–0.6	–0.6
Plate Resistance (r_p) - ohms	1.29	1.17	1.16	1.44	1.40	1.67	1.44
Transconductance (g_m) - μmhos	4850	5310	5200	4325	4400	3740	4100
Plate Milliamperes (I_b)	7.3	9.6	9.2	5.3	5.6	3.4	4.1
Grid-No. 2 Milliamperes (I_{c2})	2.8	3.7	3.6	2.0	2.1	1.3	1.6

TABLE II

Type Radiotron-6146 (Class C Telegraphy Conditions)

	Measured	Obtained from Nomograph	Measured	Obtained from Nomograph	Measured
Plate Volts (E_b)	600	500	500	400	400
Grid-No. 2 Volts (E_{c2})	150	125	125	100	100
Grid-No. 1 Volts (E_{c1})	–56	–46.6	–46	–37.3	–36
Peak R.F. Grid-No. 1 Volts	66.5	55.4	54	44.3	41
Plate Milliamperes (I_b)	112	85.6	85	61.6	61
Grid-No. 2 Milliamperes (I_{c2})	5.4	4.1	4.6	3.0	3.6
Grid-No. 1 Milliamperes (I_{c1})	2.8	2.1	2.1	1.5	1.5
Power Output (P_o) — watts	52.2	33.4	32.0	18.8	19.6

APPENDIX — Basis of Conversion Factors.

The conversion factors for valve characteristics are derived from the well-known "three-halves-power" relationship for current and voltage. For valves using unipotential cathodes (or filament cathodes provided the plate voltage, E_b, is considerably larger than the filament voltage, E_f), the total plate current, I_b, for positive plate voltages, E_b, under space-charge-limited conditions is given by the following equation:

$$I_b = K E_b^{3/2}$$

where K is a constant determined by the geometry of the valve. When the discussion is limited to a particular valve type, the constant K may be deleted and the expression rewritten to show the direct variation of current with voltage:

$$I_b \propto E_b^{3/2} \qquad (1)$$

This relationship exists for triodes, tetrodes, pentodes, and beam power valves, provided all electrode voltages (plate, grid-No. 1, and grid-No. 2) are varied simultaneously in the same proportion.

1. Current Conversion Factor.

The factor by which all electrode voltages are varied, F_e, is equal to the ratio between the desired voltages, E_{des}, and the published or measured voltages, E_{pub}:

$$F_e = E_{des}/E_{pub}$$

The new plate current, I_b', therefore, is given by

$$I_b' \propto (F_e \times E_b)^{3/2}$$

This plate current can also be expressed in terms of the published plate current, I_b, as follows:

$$I_b' = F_i \times I_b$$

where F_i is the factor by which the plate current is changed. This value for I_b' can then be substituted in the expression given above:

$$F_i \times I_b \propto (F_e \times E_b)^{3/2} \qquad (2)$$

Equations (1) and (2) can then be combined to show F_i as a function of F_e:

$$F_i = F_e^{3/2}$$

2. Power-Output Conversion Factor.

The power output, P_o, is proportional to the product of plate voltage and plate current:

$$P_o \propto E_b \times I_b$$

The new power output, P_o, therefore is given by

$$P_o' \propto (F_e \times E_b)(F_i \times I_b)$$

or

$$P_o' \propto (F_e \times F_i)(E_b \times I_b)$$

The new valve can then be expressed in terms of the published value, P_o, as follows:

$$P_o' \propto (F_e \times F_i)(P_o)$$

The power-output conversion factor, F_p, therefore, is given by

$$F_p = F_e \times F_i = F_e \times F_e^{3/2} = F_e^{5/2}$$

3. Transconductance Conversion Factor.

The transconductance, g_m, is equal to the quotient of the change in plate current divided by the change in grid-No. 1 voltage. The transconductance conversion factor, F_{gm}, therefore, is given by

$$F_{gm} = F_i/F_e = F_e^{3/2}/F_e = F_e^{1/2}$$

4. Resistance Conversion Factor.

The plate resistance, r_p, is equal to the quotient of the change of plate voltage divided by the change of plate current. The resistance conversion factor, F_r, therefore, is given by

$$F_r = F_e/F_i = F_e/F_e^{3/2} = F_e^{-1/2}$$

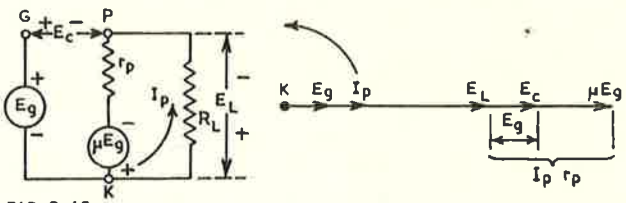
This conversion factor may be applied to resistance values of output loads and cathode resistors, as well as to plate resistance.

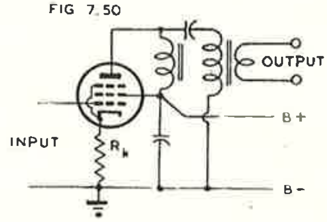
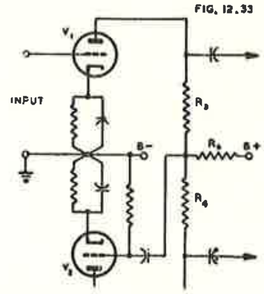
RADIOTRON DESIGNERS HANDBOOK

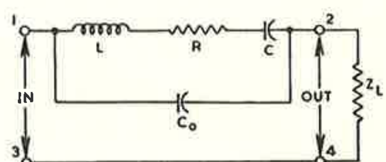
Below are listed corrections to the Fourth Australian Impression (1955) of Radiotron Designers' Handbook. In a technical volume covering such a diffuse range of subjects as in R.D.H. it is impossible to detect all the errors which may occur during printing. Again, each year more information becomes available from manufacturers and research laboratories. We appreciate the number of engineers who have written to us pointing out errors and omissions.

An Enlarged Supplement was prepared for the Third Impression (and later incorporated in the Fourth Impression). There are still copies of this Supplement available which we shall be pleased to forward to Radiotronics readers on request to the Technical Service Dept., Amalgamated Wireless Valve Co. Pty. Ltd., 47 York Street, Sydney.

CORRECTIONS TO R.D.H.

PAGE:—		TO READ:—
19	Bottom paragraph. Lines 1 and 2: is normally positive (up to say +0.5 volt) but	may be either positive or negative and
47	Bottom paragraph: Lines 3 to end	the grid-to-cathode voltage E_g, the vector μE_g is drawn in the same direction but is μ times as large. The output voltage E_L is also in the same direction as μE_g, but smaller by the value $I_p.r_p$. All of these voltages are with respect to the cathode and the centre-point of the vector diagram has accordingly been marked K. The a.c. component of the plate current (I_p) is in phase with E_L, since E_L is the voltage drop which it produces in R_L. The grid-to-plate voltage E_c is the sum of E_L and E_g owing to the phase reversal between grid and plate.
48	Fig. 2.42. Replace by new Fig. 2.42 (Vector diagram redrawn)	 FIG. 2.42
48	Bottom paragraph	delete
182	Eqn. (32)	$f_o = 1/(4\pi\sqrt{LC})$
206	Line 10	delete: and of power transformers
212	Table 1. Line 1: 3.63	2.76

PAGE:—		TO READ:—
313	Eqn. 25a: $r_p + \mu R_3$	$r_p + (\mu + 1)\ R_3$
	25b: $1 + \mu R_3/r_p$	$1 + (\mu + 1)\ R_3/r_p$
	25c: $r_p + A_1\mu_2 R_3$	$r_p + A_1\ (\mu_2 + 1)\ R_3$
	below 25c: $\frac{r_p + \mu R_3 + R_L}{(r_p + \mu R_3)\ R_L}$	$\frac{(r_p + (\mu + 1)R_3)R_L}{r_p + (\mu+1)R_3 + R_L}$
	above 26: $\frac{r_p + A_1\mu_2 R_3 + R_L}{(r_p + A_1\mu_2 R_3)R_L}$	$\frac{(r_p + A_1\ (\mu_2 + 1)R_3)R_L}{r_p + A_1\ (\mu_2 + 1)R_3 + R_L}$
316	Table, Col. 4: effective plate resistance of final stage.	$r_p + (\mu + 1)R_3 = r_p\ (\mu + 1)R_L$
330	Eqn. (30): $r_p + \mu R_k$	$r_p + (\mu + 1)R_k$
331	Line above eqn. (35): voice coil	plate of V_2
334	add to lower footnote:	This method assumes that $(r_{p1} + R)$ is large compared with R_k and that R_f is large compared with R_{L2}.
351	Fig. 7.50 Redrawn	(connect lower end of primary to earth). FIG 7.50 
356	Line 5 from bottom	delete: approximately.
358	Fig. 7.54 Title line 2: Fig. 7.41.	Fig. 7.53.
525	Line 21: only slightly less	slightly greater.
525	Fig. 12.33: amend (make grid connections to V_2).	FIG. 12.33 
531	(1V) Line 3: $(E_{bb}/I_b)-R_6$	E_c/I_b.

PAGE:—		TO READ:—
534	Eqn. (4)	$= \dfrac{1}{\dfrac{\mu + 2}{g_m(\mu + 1)R_L} + \dfrac{1}{\mu(\mu + 1)}}$ (4)
534	Eqn. (5)	$\mu' = \mu(\mu + 1)$ (5)
534	Eqn. (6)	$g_m' = g_m\,(\mu + 1)/(\mu + 2)$ (6)
534	Eqn. (7) right-hand side	$(\mu + 2)r_p$
554	Fig. 13.9B: G_p curve: 475	175
572	Line 10: would not be cancelled and the other	would be cancelled but some
661	Fig. 15.39	Add earth connection on left-hand side.
698	Fig. 16.27	amend: lead goes to Grid. No. 1.
739	Pre-amplifier for use with G.E. pick-up: Lines 6-8	Delete sentence commencing:—"The filter . . ."
779	Last line: dynes/cm	dynes/cm[2]
791	Lines 17-29	0.5 db variation. This circuit may be criticised on the choice of valve type for the first stage of a low level pre-amplifier. Type 5879, 1620 or 6BK8/Z729 could be used to advantage in the first stage.
943	(ii) line 14: exceeds	is less than
1051	Fig. 26.9	Redrawn (add load Z_L)  ELECTRIC CIRCUIT REPRESENTATION OF QUARTZ CRYSTAL FIG. 26.9
1402	Last line: 2π	4π
1421	Above table 73, line 2	$\varepsilon = 2.718 = 1/0.3679$.
1498	At foot add:	NEUTRALIZING CIRCUITS (reference to page 1065). These circuits in Figs. 26.19 and 26.21 are strictly not neutralizing circuits but the effect achieved by using C_N is similar to that achieved by true neutralization as it allows the effect of feedback due to grid-to-plate capacitance to be reduced to negligible proportions, although it does not completely eliminate it.

NEW RCA RELEASES

RADIOTRON: 21AXP22-A COLOUR KINESCOPE

Electrostatic Focus
Magnetic Deflection
Magnetic Convergence
Three-Gun Shadow-Mask Type Aluminized Tricolour Phosphor-Dot Screen

Radiotron 21AXP22-A is a directly viewed picture tube of the metal-shell type for use in colour television receivers. It is capable of producing either a full-colour or a black-and-white picture measuring $19\frac{1}{16}''$ x $15\frac{1}{4}''$ with rounded sides and having a projected area of 255 square inches.

The 21AXP22-A features an internal neck coating having high resistance which eliminates the need for an external resistor between the ultor power and supply and the tube to protect the tube against damage caused by a monetary internal arc. The resistance of the neck coating permits use of a tube insulating boot having an external conductive coating which, with the metal envelope of the tube, forms a supplementary filter capacitor.

The 21AXP22-A utilizes three electrostatic-focus guns spaced 120° apart, with axes tilted toward the tube axis to facilitate convergence of the three beams at the shadow mask; individual convergence control of each beam radially by internal magnetic poles and supplemental control of the beams horizontally by internal magnetic poles; and an assembly consisting of a spherical metal shadow mask with uniform holes and an aluminized, tricolour, phosphor-dot screen on the inner surface of the spherical Filterglass faceplate.

The tricolour, phosphor-dot screen is composed of an orderly array of small, closely spaced, phosphor-dots arranged in triangular groups (trios). Each trio consists of a green-emitting dot, a red-emitting dot, and a blue-mitting dot, and is aligned with a corresponding hole in the shadow mask.

RADIOTRON-6CG8 TRIODE-PENTODE CONVERTER

For TV Receivers Using I-F of 40 Mc/s.

The multiunit, miniature type 6CG8 is designed especially for use as a combined oscillator and mixer tube in television receivers utilizing an intermediate frequency in the order of 40 Mc/s.

This type contains a medium-mu triode unit and a sharp-cutoff pentode unit in one envelope. These units have a common cathode with two leads connected to separate base-pin terminals. This arrangement reduces effective cathode-lead inductance and thereby minimizes input-loading effects of the pentode-mixer unit; makes possible the elimination of a common return for input and output circuits of the pentode-mixer unit and thus minimizes interaction between the two circuits; and provides greater flexibility in circuit design.

The low grid-No. 1-to-plate capacitance of the pentode-mixer unit minimizes feedback problems encountered in mixer circuits operating at an intermediate frequency of 40 Mc/s. The low output capacitance of the mixer unit enables the valve to work into a high-impedance plate circuit with resultant increase in mixer gain.

The 6CG8 also offers versatility of application to designers of AM/FM receivers. The pentode unit in each type may be used in the AM section as a pentode mixer to provide high gain, and in the FM section either as a pentode mixer or as a triode-connected mixer depending on signal-to-noise considerations. The triode unit of this type makes a satisfactory oscillator for either AM or the FM section.

RADIOTRON-5894 TWIN BEAM POWER VALVE

The 5894 is a small, sturdy, twin beam power valve. It is intended primarily for use as a push-pull r-f power amplifier or as a frequency tripler in fixed and mobile equipment operating in the uhf range between 450 and 470 Mc/s.

The 5894 has a maximum plate dissipation rating of 40 watts in modulator service and in cw service. In the latter service, it can be operated with full voltage and full input up to 250 Mc/s and with reduced voltage and input to 500 Mc/s. In class C telegraphy and frequency-modulated service at 470 Mc/s, the 5894 can deliver a useful power of approximately 55 watts measured at load of output circuit; and as a tripler to 462 Mc/s it can deliver about 16 watts.

The excellent efficiency obtainable with the 5894 in push-pull service with circuits of the conventional line type is made possible by several design features. Included among these is the balanced, compact structure of the beam power units which have low interelectrode capacitances, internal neutralization, close electrode spacing, and a cathode common to the two units. R-F losses are minimized by the use of short, heavy, internal leads. Use of a single cathode common to the two units, instead of a cathode for each unit, reduces cathode inductance to a negligible value. Furthermore, input degeneration in push-pull service is prevented by the balanced arrangement of the units.

The heater of the 5894 is designed with a mid-tap so that it can be operated with sections in series from a 12.6-volt supply or with sections in parallel from a 6.3-volt supply.

NEW RCA RELEASES

RADIOTRON-6BN4 MEDIUM-MU TRIODE

The miniature type 6BN4 is a medium-mu triode designed for use as an r-f amplifier in grounded-cathode circuits of vhf television tuners.

This type has a high transconductance of 6800 micromhos to permit high gain and reduced equivalent noise resistance, relative freedom from microphonics, and double base-pin connections reduce cathode and grid. The double connections for both effective lead inductance and lead resistance with consequent reduction in input conductance. Furthermore, the basing arrangement simplifies isolation of the input and the output circuits, facilitates neutralization, and permits short, direct connections to the base-pin terminals.

RADIOTRON-6850 TWIN BEAM POWER VALVE

For Mobile Equipment in 450-470 Mc/s Range.

The 6850 is a small, sturdy, twin beam power valve designed for service as a push-pull r-f power amplifier or as a frequency tripler in the uhf range 450 and 470 Mc/s. Having a 12.6-volt heater, but otherwise like the 6524, the 6850 is intended especially for use in mobile equipment operating from a 12-volt storage battery.

The 6850 has a maximum plate-dissipation rating of 25 watts under ICAS conditions. Under these conditions in class C telegraphy service and frequency-modulated amplifier service at 462 Mc/s, the 6850 can deliver the output-circuit load a useful power of approximately 20 watts.

The excellent efficiency obtainable with the 6850 in push-pull service with circuits of the conventional line type is made possible by several design features. Among these are: balanced, compact structure of the beam power units; low inter-electrode capacitances; close electrode spacing; short, heavy internal leads and high-conductivity seals; and single cathode common to the two units. The balanced arrangement of the units prevents input degeneration in push-pull service; the short, heavy leads and high-conductivity seals minimize r-f losses; and the single cathode reduces cathode inductance to a negligible value.

RADIOTRON-6694-A PHOTOCONDUCTIVE CELL

Cadmium-Sulfide Type.

The 6694-A is a very tiny, cadmium-sulfide photoconductive cell of the head-on type. It features high luminous sensitivity, very low dark current, extremely low background noise, and signal output which is approximately proportional to the incident light intensity.

Because of its tiny size and high sensitivity, the 6694-A is especially useful in those light applications where a single tiny photosentitive device is desired, in light-controlled relay applications, and in light meters for measuring the brightness of small luminous spots.

The 6694-A has a radiant sensitivity of 5000 angstroms of 415 microamperes per microwatt, a luminous sensitivity of 1 ampere per lumen, and a luminous intensity sensitivity of 4 microamperes per foot-candle. The sensitivity is directly proportional to the applied voltage between terminals within their rating of the cell.

The spectral response of the 6694-A covers the visible range from about 3500 to 5500 angstroms. Maximum response occurs at about 5000 angstroms.

The 6694-A has a maximum seated length of 0.300″; a maximum depth of 0.220″; and a maximum sensitive area of 0.020″ x 0.018″.

RADIOTRON-5AZP4 PROJECTION KINESCOPE

For 8′ x 6′ TV Pictures.

The 5AZP4 is a 5-inch projection-type kinescope designed to provide a clear, bright, projected television picture approximately 8 feet by 6 feet in size when operated with a suitable reflective optical system. Contributing to the brightness of the "auditorium" size picture is a high-efficiency, aluminized, white fluorescent screen having very good colour stability under varying conditions of screen current, and an unusually high ultor voltage for a tube of this type.

The 5AZP4 employs electrostatic focus and magnetic deflection. Electrostatic focus facilitates use of the tube with a reflective optical system; magnetic deflecion provides essentially uniform focus over the entire picture area.

High-voltage design features of the 5AZP4 include (1) a moulded-on ultor-connection cable, (2) a bulb with insulating coating to minimize leakage over its external surface under conditions of high humidity, (3) a gun structure utilizing anti-corona thimbles to prevent internal arc-over and stray emission, (4) only one high-voltage envelope connection—other connections are made through a plastic-filled, duodecal 7-pin base, and (5) an optical quality spherical faceplate on non-browning glass.

The 5AZP4 can be used with an average ultor input up to 9 watts without forced-air cooling of the face-plate, but at higher values of average ultor input up to the maximum of 12 watts, forced-air cooling is required.

RADIOTRON IB3GT

HALF WAVE, HIGH VOLTAGE RECTIFIER

The Radiotron 1B3GT is a vacuum type of rectifier designed for use in high-voltage, low-current applications. It is particularly suitable for use in a television receiver as the e.h.t. rectifier producing the final anode or ultor voltage for the picture tube from the high-voltage pulses present in the output stage of the horizontal scanning system.

When used as an r-f rectifier, one 1B3GT in a half-wave circuit is capable of delivering a maximum direct output voltage of about 15,000 volts. In a voltage-doubler circuit, two valves will give about 30,000 volts.

In television service where the e.h.t. rectifier is supplied with a pulsed, positive plate voltage, with a relatively small negative component, the 1B3GT can develop a maximum e.h.t. of 24,000 volts (approximately).

This valve was selected for the Radiotron TV preferred valve range because its low filament-power requirement presents a small load to the horizontal output transformer, and because its octal base construction provides excellent insulation at the high voltages encountered in television service.

GENERAL DATA

Electrical:

Filament Voltage (a.c.)	1.25*	volts
Filament Current	0.2	amp.
Direct Interelectrode Capacitance (Approx.):°		
Plate to filament	1.5	μμF

Mechanical:

Mounting Position	any
Overall Length	$3\frac{7}{8}'' \pm \frac{3}{16}''$
Seated Length	$3\frac{5}{16}'' \pm \frac{3}{16}''$
Maximum Diameter	$1\frac{5}{16}''$
Bulb	T-9
Cap	Small
Base	Short Intermediate Shell Octal 6-Pin

* The filament voltage must never exceed 1.45

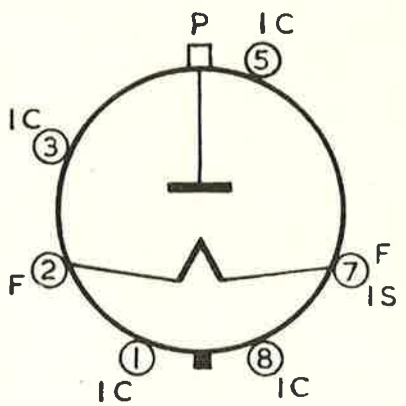
HALF-WAVE RECTIFIER

Maximum Ratings (Design-Centre Values):

Peak Inverse Plate Current ...	30,000 max.	volts
Peak Plate Current	17 max.	mA
Average Plate Current	2 max.	mA
Frequency of Supply Voltage ..	300 max.	Kc/s

+ The filament voltage must never exceed 1.45 volts, even momentarily. See also installation and application data.

° With no external shield.



Bottom view.

Pin 1: †	Pin 5: †
Pin 2: Filament	Pin 7: Filament
Pin 3: †	Pin 8: †
	Cap: Plate

† Internal Connection: Do not use.

INSTALLATION AND APPLICATION

Although the peak plate current of the 1B3GT is rated at 17 mA or 8.5 times the average value of 2 mA, it is desirable to check this peak current under actual operating conditions. If facilities are not available for measuring peak current, the curve in Fig. 1 may be used for determining the peak current under pure sine-wave conditions. From the operating conditions, the rectification efficiency of the system (ratio of direct output voltage to the peak value of the alternating plate-supply voltage) may be calculated and used to determine the corresponding ratio of peak-to-average current from the curve. From this current ratio the approximate peak plate current may be calculated and it should not exceed 17 mA under design-centre conditions.

The base of the 1B3GT fits the standard octal socket which may be mounted to hold the tube in any position. The plate connection is made to the cap at the top of the bulb.

The filament is of the coated type and is designed for operation at 1.25 volts. The filament voltage supply should give the rated voltage under average line-voltage conditions. The design of the filament will permit the use in continuous operation of filament voltage within ± 10% of the rated value without seriously affecting the life of the valve. If greater variations are encountered, it is recommended that some method be provided for automatically regulating the filament voltage in order to ensure satisfactory valve life.

When the valve is used in a TV receiver, the filament voltage has a pulsed waveform. It is essential that the effective filament voltage be correct; the recommended method of checking the filament is discussed in the paper "The Measurement of the Filament Voltage of the Radiotron 1B3GT E.H.T. Rectifier", by H. R. Wilshire.

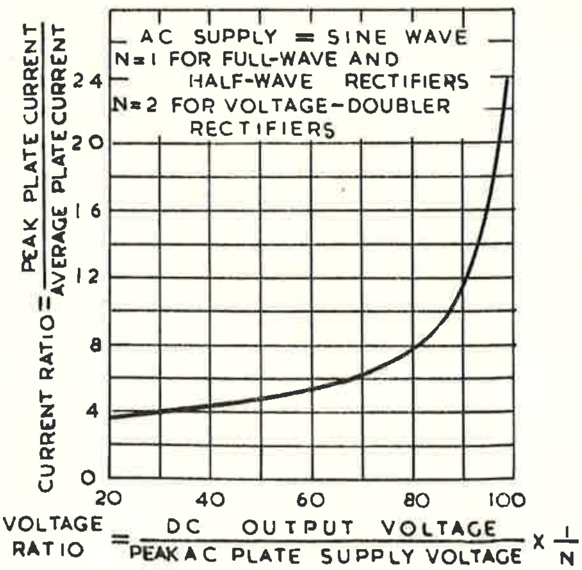


Fig. 1. Curve of voltage ratio v. current ratio for use in determining the peak current under pure sine-wave conditions.

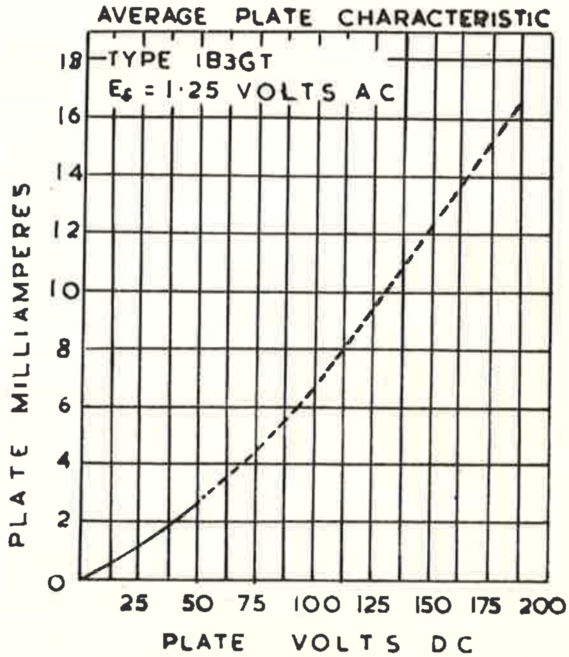


Fig. 2. Average plate characteristic of the Radiotron 1B3GT.

The filament transformer, whether it is of the iron-core or the air-core type, must have sufficient insulation to withstand the maximum peak inverse plate voltage encountered in the installation.

The high voltages at which the 1B3GT is operated are very dangerous. Great care should be taken in the design of apparatus to prevent the operator from coming in contact with these high voltages. In those circuits where the filament circuit is not grounded, the filament circuit operates at direct potentials which can cause fatal shock. Extreme precautions must be taken when the filament voltage is measured. These precautions must include safeguards which definitely eliminate all hazards to personnel. Under any circumstances, all circuit parts which may be at high potentials should be enclosed and "interlock" switches should be used to break the primary circuits of the high-voltage power supply when access to the equipment is required.

In the design of equipment using the 1B3GT, special precautions must be taken to avoid "corona". In the both filament and plate circuits there must be no bare wire: sharp edges such as with solder joints must be rounded.

The voltages employed in some television receivers and other high-voltage equipment are sufficiently high that high-voltage rectifier tubes may produce soft x-rays which can constitute a health hazard, unless such tubes are adequately shielded. Relatively simple shielding should prove adequate, but the need for this precaution should be considered in equipment design.

THE MEASUREMENT OF THE FILAMENT VOLTAGE OF THE RADIOTRON 1B3GT E.H.T. RECTIFIER

By H. R. WILSHIRE, A.S.T.C., A.M.I.E. (Aust.), S.M.I.R.E. (Aust.)
(Applications Laboratory, A.W. Valve Co. Pty. Ltd.)

SUMMARY: A method is outlined for measuring the filament voltage of the 1B3GT rectifier, which is supplied from the horizontal output transformer of the TV receiver. This method is simple and more accurate than those previously used. A mathematical treatment covering an error, which may be introduced, is also discussed.

The accurate measurement of the filament voltage of the e.h.t. rectifier in a television receiver presents some problems due to the pulsed nature of the

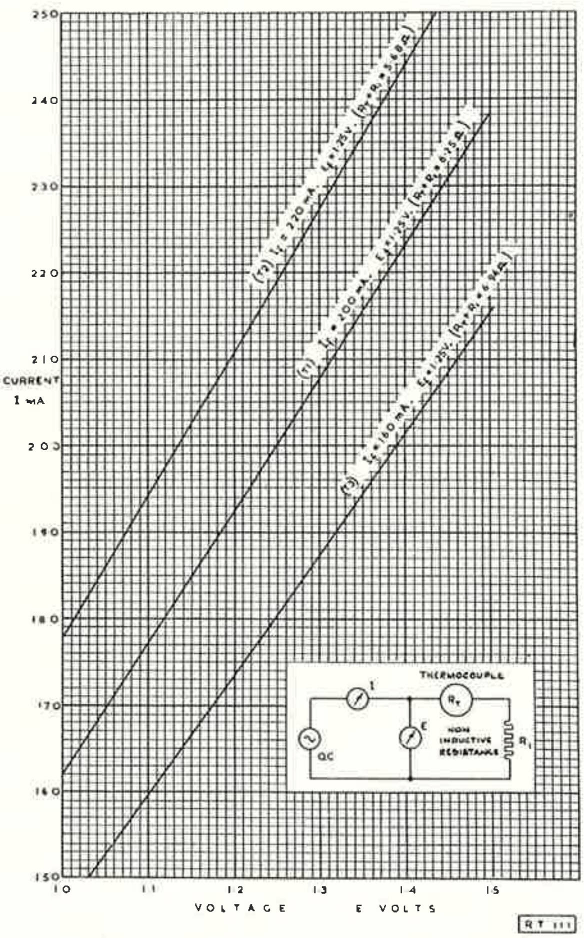


Fig. 1. Current v. voltage relationship in a particular thermocouple circuit for three values of the resistor R_1 corresponding to valves having filament currents near top, bottom and bogie limits.

voltage. A knowledge of this voltage by the receiver designer is desirable since in the interests of valve reliability it is important to maintain operating voltages within the specified ratings for the valve.

The method described here, for the determination of the heating value of the pulsed filament voltage of the e.h.t. rectifier, is an improvement on those previously used in both accuracy and speed of measurement.

Briefly, the measurement is carried out by connecting a 250 mA thermocouple in series with a non-inductive resistor directly across the filament winding of the horizontal output transformer in place of the filament of the 1B3GT rectifier. The value of the non-inductive resistor is chosen so that, when added in series with the heater of the thermocouple meter, the combination equals the hot resistance of the filament of a "bogie" 1B3GT valve, i.e. when placed across 1.25 volts will allow a current of 200 mA to flow. When connected across this secondary of the horizontal output transformer this combination will then present a load identical to that represented by the hot filament of a bogie 1B3GT. This is strictly true only for the case where the voltage of the filament winding on load is exactly 1.25 volts. Errors introduced for other cases will be discussed later. The thermocouple meter now measures directly the r.m.s. or heating value of the current flowing in the filament circuit under normal operating conditions. A knowledge of the relation between current and voltage in the thermocouple circuit then allows the voltage to be determined (see Figure 1). T_2 is the curve obtained with R_1 adjusted to make the combination equivalent to a 1B3GT having a filament current very close to the top limit with 1.25 volts applied. Similarly T_3 corresponds to a 1B3GT having a filament current very close to bottom limit. To ensure normal operating condition in the horizontal output circuit the transformer high voltage lead which previously was connected to the 1B3GT plate should be connected to the plate of another 1B3GT. The filament of

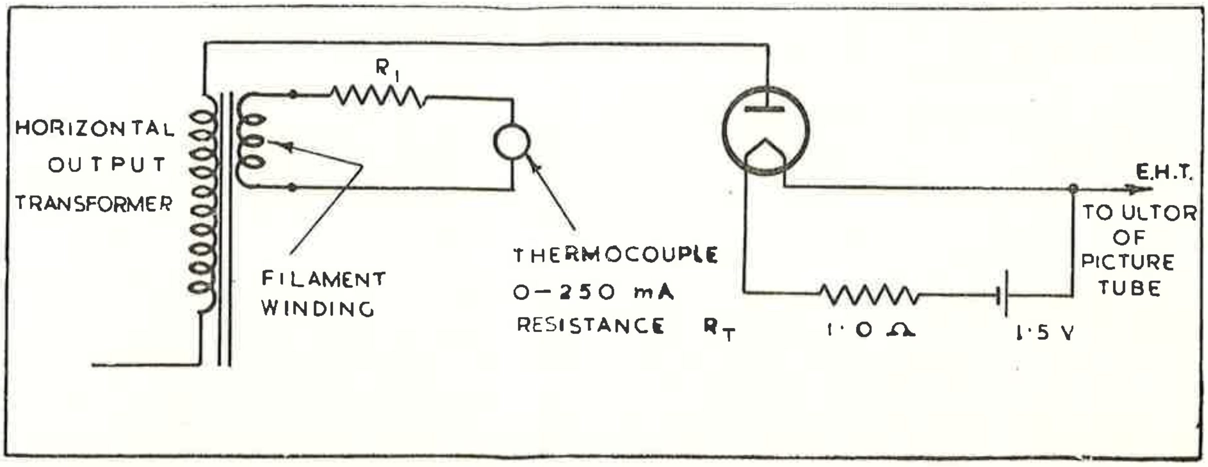


Fig. 2. Circuit diagram for measurement of filament temperature.

this second valve which now supplies the e.h.t. for the picture tube may have its filament current supplied from an insulated dry cell of 1.5 volts: a 1.0Ω resistor should be connected in series with the battery and the filament of the 1B3GT. The circuit diagram is illustrated in Fig. 2.

Use of the three values of R_1 corresponding to 1B3GT valves having filament characteristics near those of a low limit, bogie and high limit valve, and reference to the appropriate curve of Fig 1 enables the voltage applied to the filament of the 1B3GT under operating conditions to be determined.

Since the voltage-current curve of the thermocouple heater and the resistor has a different slope from that of the 1B3GT filament, measurements made as described above are strictly accurate only when the voltage being measured is equal to the nominal filament voltage of 1.25. If the filament voltage in the normal receiver circuit differs from the nominal value, then the load in the transformer in Fig. 2 will differ slightly from the load in the normal receiver.

Fig. 3 shows curves of current versus voltage for a 1B3GT having a bogie filament characteristic and the thermocouple circuit with R_1 adjusted to make the total resistance equal to that of a hot filament of a bogie 1B3GT. It can be seen from these curves that for, say, a +10% change in voltage from the nominal of 1.25, the load resistance differs by +5%, and similarly, for a –10% change in voltage, the load resistance differs by –5% (approx.).

The maximum error, due to this change in resistance, in measuring voltages which differ from the design centre value for say, ±10% can be calculated and will depend on the regulation of the filament winding of the horizontal output transformer. The error varies from a maximum of ±5% (approx.) for the case where the effective source resistance R_g of the filament supply is large compared with the load resistance R_L, to much less than ±1% for the case where R_g is small compared to R_L. (See Appendix for the derivation of this result).

For a typical case using a Radiotron horizontal output transformer type TH01 the effective source resistance of the filament winding has been measured and found to be 3.1Ω approx. The error for a ±10% variation in applied voltage can then be shown to ±1.7% (see appendix).

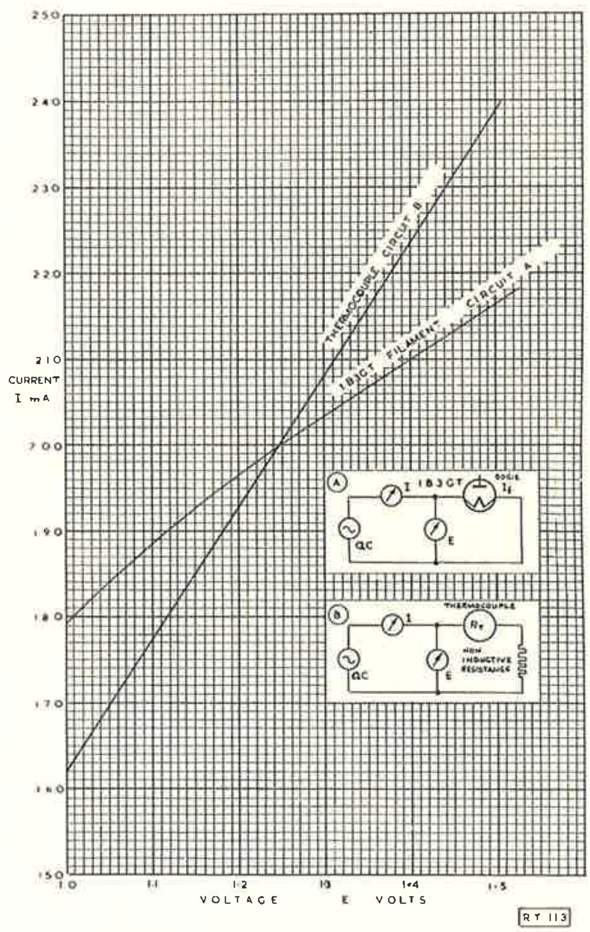


Fig. 3. Current v. voltage curves for a 1B3GT as in circuit (A) and a thermocouple as in circuit (B).

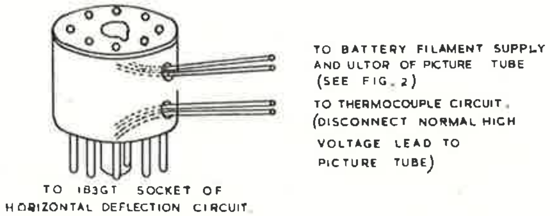


Fig. 4. Adaptor used to simplify measurements.

The measurements as outlined above can be simplified if a small adaptor (see Fig 4) is made to plug into the normal 1B3GT socket of the deflection circuit. The 1B3GT then plugs into the adaptor, the appropriate connections made to the leads and the measurement carried out.

The socket and plug of the adaptor should be well insulated from each other to avoid the e.h.t. developed by the second 1B3GT being applied to the thermocouple circuit. Apart from possible damage to the thermocouple, severe leakage and consequent loading of the e.h.t. may occur. This will change the operating conditions in the output transformer and reduce the accuracy of the measurement.

In addition the 1.5V battery and the circuit used during the measurement to heat the filament of the 1B3GT, which supplies the e.h.t. to the ultor of the picture tube, is at a high potential with respect to ground and therefore should be well insulated.

Due to the interdependence of the horizontal width, linearity, drive and frequency controls in a TV receiver and the large effect they have on the operating conditions in the horizontal output circuit, it is strongly recommended that the measurement of the effective filament voltage of the e.h.t. rectifier as detailed above be carried out for various settings of these controls. An investigation of the effect of changes in the mains supply voltage of a magnitude likely to be met with during the use of the receiver, in combination with changes in the settings of the controls, should also be carried out.

APPENDIX

It is required to determine the error, introduced in the measurement of the filament voltage of a 1B3GT circuit by replacing the filament of the valve by a resistance, which places a different load on the filament voltage source when the voltage differs from the design centre value.

The curves of Fig. 3 show that for, say, a + 10% change in the applied voltage, the difference in the value of the resistance presented to the source by the resistive thermocouple circuit compared with the 1B3GT filament is + 5% approx.

In the equivalent circuit shown below (see Fig. 5), is the open circuit voltage of the filament source, R_g is the resistance of the source and R_L is the resistance of the filament load.

a. For the 1B3GT (Change of + 10% in E_g, + 5% in R_L [from Fig. 3]).

Then $E'_g = 1.1\ E_g$, and $R'_L = 1.05\ R_L$

$$\therefore\ I_L = \frac{E_g}{R_g + R_L} \text{ becomes}$$

$$I'_L = \frac{R_g + 1.05\,R_L}{1.1\,E_g} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

E_{LV} = Voltage across the valve filament.

Let E'_{LV} = Voltage across the valve filament when E_g is changed + 10%, and R_L changes + 5%,

then $E'_{LV} = I'_L\ R'_L$

$$= \frac{1.05\,R_L}{R_g + 1.05\,R_L}\,(1.1\,E_g) \quad \ldots\ldots (2)$$

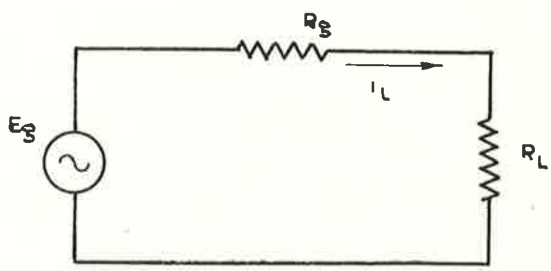


Fig. 5. Circuit equivalent to filament source and load of the 1B3GT filament.

b. For Resistive Load (Change of + 10% in E_g, with constant R_L).

E_{RL} = Voltage across the resistive load.

$$= \frac{R_L}{R_g + R_L}\,E_g$$

$$\therefore\ E'_{LR} = \frac{R_L}{R_g + R_L}\,(1.1\,E_g) \quad \ldots\ldots\ldots (3)$$

E'_{LR} changes + 10% for a corresponding change in E_g.

Let A be the ratio of the voltage across the valve filament to the voltage across the resistive load, when the source E_g changes by $+10\%$ and the corresponding change in resistance of the load is $+5\%$.

Divide eqn. (2) by eqn. (3).
Then A

$$= \frac{E'_{LR}}{E'_{LV}} = + \frac{1.05\,R_L}{R_g + 1.05\,R_L} \quad \frac{1.1\,E_g(R_L + R_g)}{1.1\,E_g.R_L}$$

$$= \frac{1.05\ (R_L + R_g)}{1.05\ R_L + R_g}$$

$$= \frac{R_L + R_g}{R_L + R_g/1.05} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Now the error in E_L caused by using a resistive load instead of the valve filament (expressed as a percentage of the voltage across the resistive load) is given by:—

$$\text{Error } \% = \frac{E'_{LV} - E'_{LR}}{E'_{LR}} \quad 100\%$$

$$= \frac{E'_{LV}}{E'_{LR}} - 1\ .\ 100\%$$

$$= (A - 1).\ 100\% \quad \ldots\ldots\ldots\ldots \quad (5)$$

To calculate the error for some particular valves of R_g and R_L

1. $R_L = R_g$

from eqn (4) $A = \dfrac{2R_g}{R_g + R_g/1.05}$

$$= \frac{2}{1 + 1/1.05}$$

$$= 1.023$$

Then from eqn (5), for $+10\%$ change in E_g and the corresponding $+5\%$ change in R_L, a reading taken using a resistive load in place of the valve filament gives:—

Error in voltage $= (A\text{–}1).100\%$
$= (1.023\text{–}1).100\%$
$= 2.3\%$

2. $R_L = 5R_g$

Then error rapidly becomes small as R_L becomes greater than R_g

From eqn (4) $A = \dfrac{6R_g}{5R_g + R_g/1.05}$

$$= \frac{6}{5.953}$$

$$= 1.0075$$

$\therefore$ Error in voltage $= (1.0075 - 1).100\%$
$= 0.75\%$

3. $R_L = 0.2R_g$

From eqn (4) $A = \dfrac{0.2R_g + R_g/1.05}{0.2R_g + R_g}$

$$= \frac{1.2}{0.2 + 0.953}$$

$$= 1.042$$

$\therefore$ Error in voltage $= (1.042 -).100\%$
$= 4.2\%$

4. Example

Consider $R_L = 6.25\Omega$ (equivalent to a bogie valve)
$R_g = 3.1\ \Omega$ (Horiz. output transformer e.g. Radiotron TH01)

For $+10\%$ change in applied voltage:—

From eqn (4) $A = \dfrac{6.25 + 3.1}{6.25 + 3.1/1.05}$

$$= \frac{9.35}{9.2}$$

$$= 1.017$$

$\therefore$ Error in voltage $= (1.017 - 1).100\%$
$= 1.7\%$

Similarly it can be shown that for a -10% change in E_g, i.e., for a -5% change in R_L, the ratio A is given by:—

$$A' = \frac{R_L + R_g}{R_L + R_g/0.95}$$

so that for the above example

$$A' = \frac{6.25 + 3.1}{6.25 + 3.1/0.95}$$

$$= \frac{9.35}{9.52} = 0.983$$

$\therefore$ Error in voltage $= (0.983 - 1).100\%$
$= -1.7\%$

i.e., for the case of a typical horizontal output transformer the error in measurement of the filament voltage introduced by using a load having a different volt-amp characteristic to that of the 1B3GT filament is $\pm$ 1.7% for voltages differing by $\pm$ 10% from the design centre value.

120.