RADIOTRONICS

BULLETIN No. 115 **August, 1941**

4.5 WATT AMPLIFIER WITH TONE CONTROL

In Radiotronics 108 a circuit was given for a simple 4.5 watt amplifier using a single type 6V6-G as output valve and providing for voltage negative feedback to the plate circuit of the 6J7-G voltage amplifier. The characteristics of this amplifier were very satisfactory both with respect to overall frequency response and harmonic distortion percentage. When used with a medium-priced loudspeaker of modern design the output was ample for a very large room or for a small hall.

In the case of simple amplifiers incorporating negative voltage feedback, conventional "top-cut" tone controls are, for the most part, unnecessary since the reproduction of the higher frequencies never becomes strident, as happens when an amplifier uses uncompensated pentode output valves. Actually tone-controls were almost unknown before the days of pentode output valves.

However, in cases where the input sourse is lacking at certain frequencies or where the loudspeaker has a non-level frequency response, a means for varying the response of the amplifier itself is often helpful in obtaining a more natural tonal balance. A further advantage is, that it is often possible, with a tone control, to minimise the effects of unwanted noise from one source or another.

Design Considerations:

Ideally, a tone-control system should permit the frequencies above and below certain limits to be independently accentuated or attenuated at will. This naturally requires the use of at least two separate tone-control knobs and the manipulation of these knobs calls for a reasonable amount of discernment on the part of the operator. A further disadvantage is the disproportionate cost of incorporating such a system in a simple amplifier or receiver.

An alternative arrangement, which has the advantage of simplicity, is to use a single control for the purpose of accentuating or attenuating the higher frequencies only. Although the bass response may not be affected, there is a certain amount of illusion in that the bass appears to be accentuated if the treble is attenuated and vice-versa.

A tone-control system preferably should not be included at any point within a feedback network, for the reason that the feedback will tend to resist any change in frequency response. The system would therefore need to be made sufficiently severe to provide the desired acoustic effect in addition to overcoming the effect of the feedback. For this reason a tone-control system preferably should be included at some point external to the feedback network.

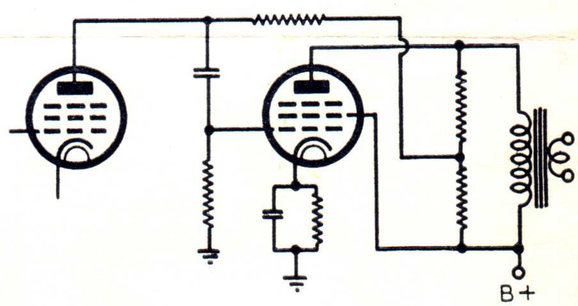

Figure 1.

An alternative is to effect tone-control **by means of the feedback** by introducing frequency discrimination into the feedback network. In so doing it is very necessary to guard against the possibility of excessive phase rotation leading to instability at certain frequencies. Provided that the feedback is only taken back over one stage,

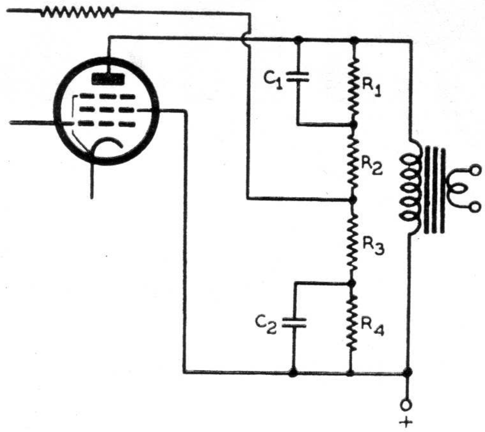

Figure 2.

however, there is no chance of this since the phase rotation will not exceed 90 degrees.

A well known method of obtaining feedback voltage is from a divider network across the primary of the output transformer (see Figure 1). Since the network is purely resistive there is no frequency discrimination and the feedback is equally effective at all frequencies.

It follows, however, that if a condenser having suitable capacitance is connected in parallel with either arm (or portion of either arm) the feedback factor will vary with frequency and the gain of the amplifier will likewise vary with frequency. For example, a condenser connected across all or portion of the lower resistor will have the effect of reducing the feedback factor at the higher frequencies, thereby increasing the gain.

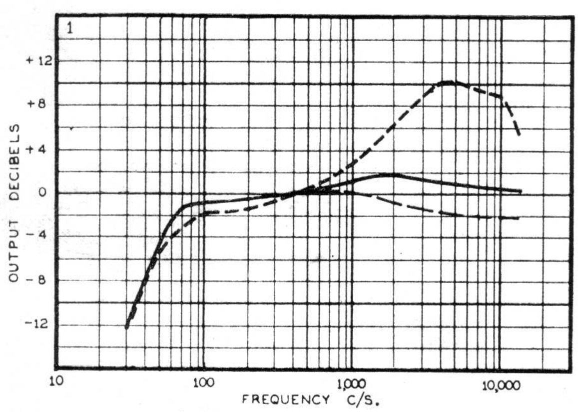

Figure 3.

$R_1 = R_2 = 50{,}000$ ohms.
R_3 and R_4 combined as single 25,000 ohm potentiometer.
$C_1 = .002\mu F.$, $C_2 = .02\mu F.$

It is also apparent that the effect of capacitance in parallel with one arm of the divider may be neutralised completely or in part, by adding another capacitance of suitable value across the other arm.

In Figure 2 is shown a network involving resistance and capacitance which, if desired, can be arranged to have negligible frequency discrimination. Resistors R_3 and R_4 may obviously be replaced by a potentiometer having a resistance equal to the sum of their resistances; provided the moving arm is in the proper position the characteristics of the circuit will be unchanged. However, if the arm is rotated away from the end connected to B+ the feedback factor will be reduced at the higher frequencies and treble accentuation will result. Conversely, as the arm is moved towards the B+ connection, the treble will be attenuated.

If desired, resistors R_1 and R_2 may also be replaced by a potentiometer, the two potentiometers being ganged together and operated as a single control. In one extreme position of the control the lower portion of the divider network would be completely bypassed for high frequencies, there being no bypass across the upper portion. In the other extreme position the reverse would be true; in between these two extremes it would

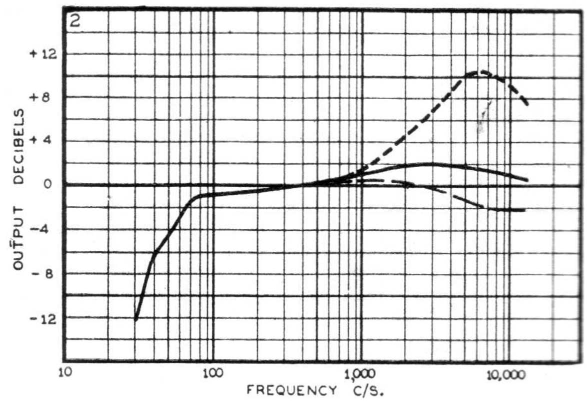

Figure 4.

$R_1 = R_2 = 50{,}000$ ohms.
R_3 and R_4 combined as single 25,000 ohm potentiometer.
$C_1 = .001\mu F.$, $C_2 = .01\mu F.$

be possible to achieve a state of balance. This arrangement, using two ganged potentiometers, would afford a wide range of control but is more complicated than that using a single potentiometer. It should be noted that for smooth control the potentiometers should have a linear resistance characteristic.

Typical Response Curves:

There is an endless number of possible combinations of resistance and capacitance. The amount of treble attenuation possible with a single potentiometer is governed largely by the value of

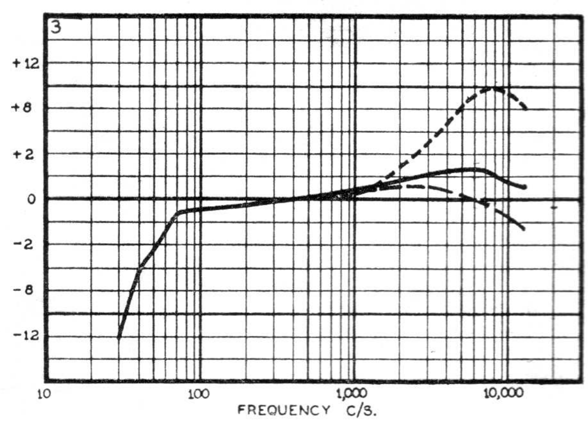

Figure 5.

$R_1 = R_2 = 50{,}000$ ohms.
R_3 and R_4 combined as single 25,000 ohm potentio meter.
$C_1 = .0005\mu F.$, $C_2 = .005\mu F.$

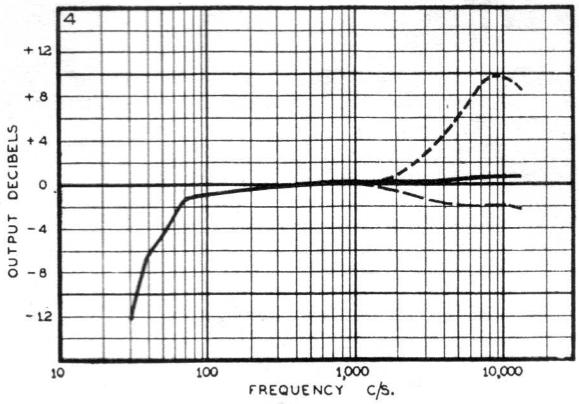

Figure 6.

R_1 = R_2 = 50,000 ohms.
R_3 and R_4 combined as single 25,000 ohm potentiometer.
C_1 = .002μF., C_2 = .005μF.

C_1 and by the ratio of R_1 to R_2. The treble accentuation depends on the initial feedback factor and on the natural tendency for the output valve to accentuate the higher frequencies (being a tetrode with loudspeaker load and little or no feedback).

Figures 3 to 6 show a number of curves taken with various capacitances and for extreme and intermediate settings of a tone-control potentiometer in place of R_3 and R_4. In each case maximum treble accentuation is of the order of +10 decibels and the attenuation —2 decibels. The latter could be increased by suitable modification to the circuit. However, for ordinary radio reception at least, it is seldom necessary further to attenuate the treble when the overall response of the **audio amplifier** is initially level.

The most desirable curve depends on the particular conditions. The conditions for figure 3 give the most obvious effect to the listener, but accentuate the frequencies in the vicinity of 3000 cycles, which may or may not be deemed desirable. On the other hand, the conditions for figure 6 affect the middle frequencies little, but give full boost at 10 Kc/s. With a speaker having a reasonable high-frequency response, the effect on music is quite apparent, but with speakers having a deliberate "top-cut" the effect of a boost at 10 Kc/s. may largely be lost. It is not suggested that the amount of control afforded is sufficient to offset marked deficiencies elsewhere in the equipment but it does provide a simple means for varying the treble response within certain limits.

Complete Amplifier Circuit.

Figure 7 shows the circuit of a complete amplifier incorporating the constants used for figure 6. The circuit is generally similar to the previous circuit A502 and does not call for special comment. The sensitivity is sufficient to allow full output when used with a radio tuner or with an ordinary gramophone pickup. When used with a microphone it would normally be necessary to add an additional voltage amplifier stage. (See Radiotronics 110, page 20).

As a precaution against capacitive feedback at high frequencies it is wise to arrange the layout in such a way that the plate circuit wiring of the output valve does not pass close to the input terminals. The .002 μF condenser between the plate of the output valve and B+ is a further precaution.

As the circuit stands, provision is made to supply a tuner drawing a high tension current of 35 mA. If at any time the tuner is disconnected or switched off, the equivalent current should be passed in a special bleed resistance of 7,000 ohms (10 W.). If, on the other hand, a tuner is never

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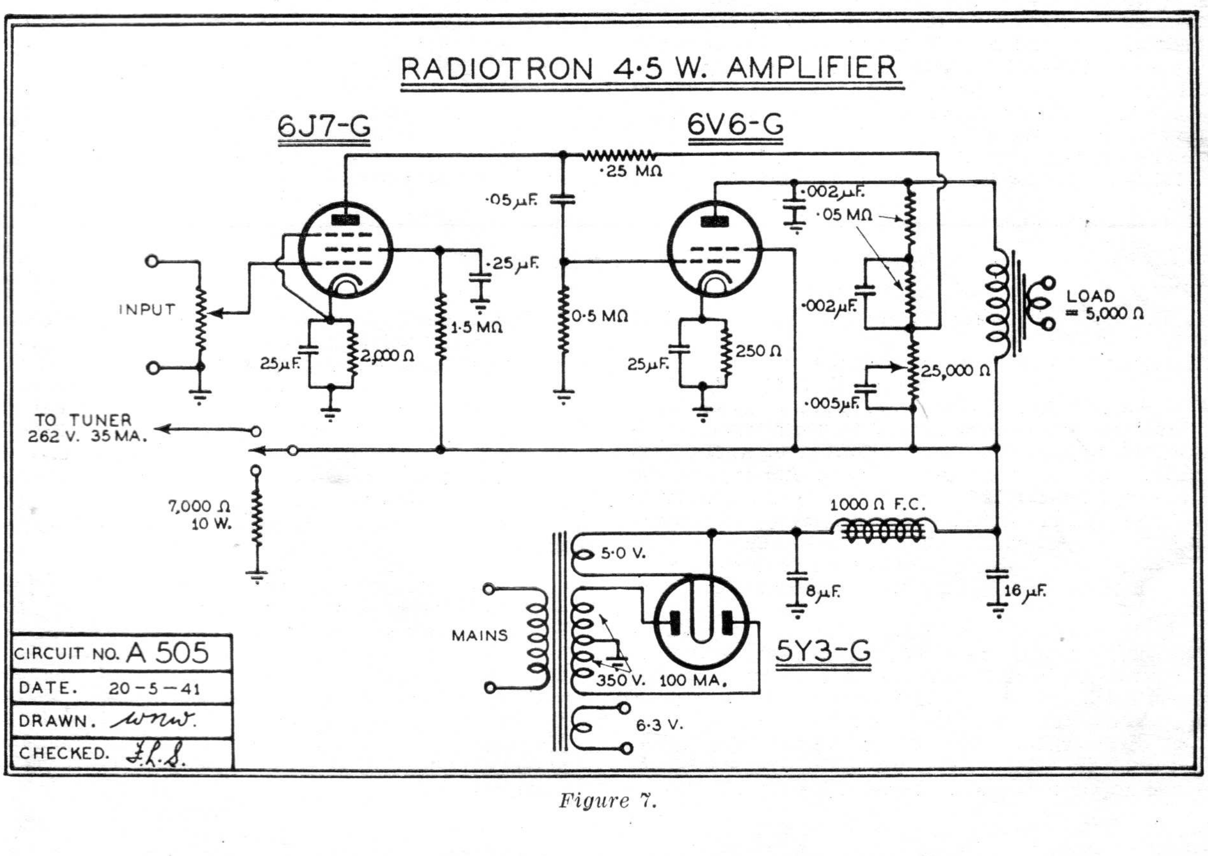

Figure 7.

I.F. NEUTRALISATION

With low-gain and careful shielding an intermediate frequency amplifier is normally stable even though there is some degree of feedback through the grid-plate capacitance of the valve. As the gain is increased, either through the use of a valve having greater mutual conductance or I.F. transformers having higher Q, the "selectivity" curve tends to become unsymmetrical or lopsided, and in the extreme case oscillation may occur.

In receiver production it is found that it is necessary to guard against incipient instability which, in some cases at least, may develop into actual instability at some time during the life of the set. In addition, there is the danger of the I.F. transformer in the plate circuit becoming detuned and so causing oscillation. Finally, there is the difficulty in quantity production of making allowances for working tolerances between receivers, some of which will necessarily be less stable than others.

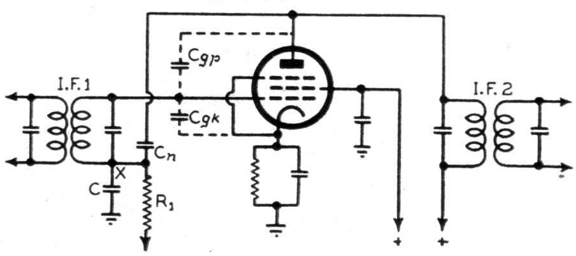

Figure 1.

Summing up, there are very good reasons for the maintenance of complete I.F. stability by means of neutralisation, provided that a simple and cheap arrangement is available. One such method is shown in Fig. 1, in which the secondary of the first I.F. transformer is returned to earth for radio frequencies by means of the condenser C, and a neutralising condenser C_n is connected between the plate and the cathode end (x) of the secondary or I.F.1. A.V.C. may be applied through the resistor R_1, which should have a resistance very much greater than the reactance of C.

The operation of this circuit depends upon the total capacitances from grid to plate and from grid to cathode, and these are shown in broken lines in Fig. 1. The capacitance bridge by which neutralisation is obtained is shown more clearly in Fig. 2 from which all non-essential components have been omitted. Balance is obtained when

$$\frac{C_n}{C} = \frac{C_{gp}}{C_{gk}}$$

so that

$$C_n = C.\frac{C_{gp}}{C_{gk}}.$$

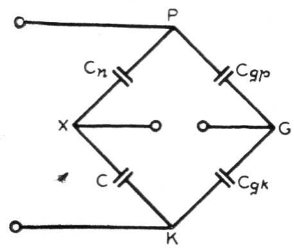

Figure 2.

In a typical case, C_{gp} may be 0.007 $\mu\mu$F., C_{gk} may be 15 $\mu\mu$F., and C may be selected to be 0.01 μF. Balance will be obtained when

$$C_n = .01 \times 10^{-6} \times \frac{.007}{15} = 4.67\ \mu\mu F.$$

In practical cases C_{gk} may vary considerably, since it is mainly composed of stray capacitances from the grid circuit to earth, and C_n will therefore require to be adjusted to correspond. In the more highly priced receivers it might be possible to make an individual adjustment of C_n for each receiver, but in the case of quantity production it will normally be satisfactory to select a value of fixed capacitance which is reasonably close in all cases.

With this circuit, and a fixed capacitor C_n, the additional cost is only the cost of one capacitor and its wiring, since C and R_1 normally form part of the A.V.C. network.

(Continued from page 53)

to be used, the power supply may be modified as follows:—

Transformer, Secondary Voltage 350 V. RMS., 60 mA.

Field Coil Resistance .... 2500 ohms.

In cases where it is desired to use a larger loudspeaker requiring a field excitation of about 11.0 watts, the value of the field resistance may be increased from 1,000 ohms to 1,500 ohms and the voltage rating of the transformer to 375 volts R.M.S. Once again when the tuner is disconnected or switched off the equivalent current should be passed through a special bleed resistance of 7,000 ohms.

If the amplifier is built up on a very small chassis, difficulty may be experienced owing to hum arising from eddy currents induced in the chassis by the power transformer. The simplest way to combat this is to return the cathode bypass and bias resistor (for the first valve), the screen bypass, the grid resistor or volume control, the lower input terminal and the input circuit shielding to a single point insulated from the chassis. This central point is then earthed to some point on the chassis which gives the least hum. This scheme, of course, necessitates using an initially insulated earth terminal and covering any copper braiding where it passes close to the chassis. Another point to watch is, that the first valve is not mounted any closer than necessary to the power transformer.

Hum is not normally picked up by the output stage.

The 6J7-G, 6V6-G combination used in this amplifier makes a very satisfactory amplifier for operation from a vibrator or motor-generator power supply. For this purpose the a-c power supply unit is disregarded and a permanent magnet speaker is used. The external power supply would be required to deliver an output of 250 volts at 50 milliamps. Should a tuner be required the current rating of the supply would need to be increased.

SERIES TUNED CIRCUIT ADMITTANCE CIRCLE DIAGRAM

A series tuned circuit is shown in Fig. 1 and it is well known* that resonance occurs where

$$LC\omega^2 = 1$$

Where $\omega = 2\pi f$

and that the impedance at resonance is equal to the resistance r.

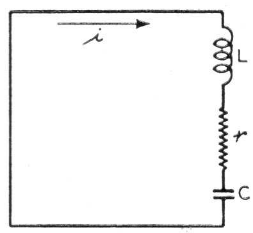

Figure 1.

The admittance is the reciprocal of the impedance, so that the admittance at resonance is equal to 1/r. In many cases it is convenient to work in terms of admittance rather than impedance, for example, when two or more electrical networks are in parallel. When working in terms of admittance it is sometimes helpful to use the admittance circle diagram (Fig. 2).

The admittance at any frequency is represented by the vector OY, where Y is any point on the circle. The diameter of the circle is equal to 1/r and the admittance at resonance is represented by OA.

As the frequency of the voltage applied to the series tuned circuit (Fig. 1) is increased from zero to infinity, so the point Y moves from O (at zero frequency) through C to A (at resonance) and thence through E to O again (at an infinite frequency). The angle ϕ is the angle by which the current i leads the applied voltage e; when ϕ is negative the current lags behind the voltage. Thus when OY lies in the upper portion of the circle the circuit is capacitive, and when it lies in the lower portion of the circle the circuit is inductive.

* See the Radiotron Designer's Handbook, page 116.

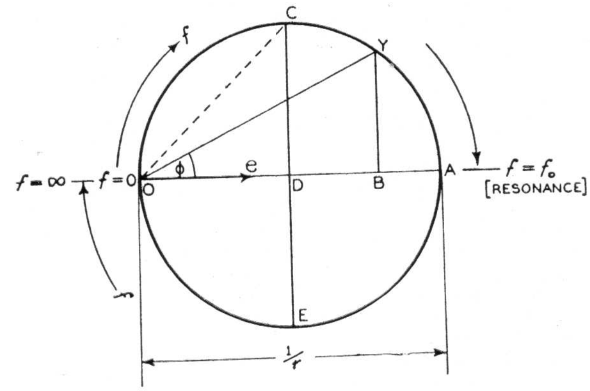

Figure 2.

When Y is at the point C, the admittance will be represented by OC and ϕ will be 45°; the reactive and resistive components of the impedance will therefore be equal. At Zero frequency ϕ will be +90° and the admittance will be zero; at infinite frequency ϕ will be —90° and the admittance will also be zero.

RADIOTRON DESIGNER'S HANDBOOK

Overseas Success

The Radiotron Designer's Handbook is not only widely known throughout Australasia, but has taken on well in the United Kingdom, and should shortly be equally well known in U.S.A.

The English edition (which is known there as "The Radio Designer's Handbook") is printed in Australia and bound and distributed in England by Messrs. Iliffe and Sons Limited, the publishers of "The Wireless World" and "The Wireless Engineer." The price of this English edition is 7/6 sterling, but in spite of this it is a popular seller. A further large order running into several thousands has been received from Messrs. Iliffe and Sons Limited and re-printing will commence immediately. This is in addition to the 7,000 previously supplied, as announced in Radiotronics 110 (March, 1941), and makes a total of 25,000 copies for the United Kingdom and Australia.

Limited quantities have been supplied on order from Messrs. R.C.A. Manufacturing Company Inc. of U.S.A., and American radio engineers are so pleased with it that R.C.A., by arrangement with A.W. Valve Co. Pty. Limited, are having it printed in America to avoid any possibility of disappointment in the deliveries from Australia. It is expected that very widespread distribution will follow, and that its popularity will be even more evident in U.S.A. than has been the case in U.K.

When the third edition of the Radiotron Designer's Handbook was under consideration, the Editor made an extensive search of all available radio publications in order to determine what information was readily available. This search revealed the incomplete and scrappy nature of the information available and the large gaps with no readily accessible information. The editorial policy which was adopted was to decide what information was most likely to be required by those beyond the stage of beginners and to incorporate this information in a handy summarised form. It was found, however, that there was a tremendous amount of more-or-less original work in filling in the gaps so that the "editorial" work often resolved itself into extensive mathematical or graphical investigation. In general, no formula has been incorporated in the Handbook without having been checked from first principles, and then cross-checked.

The result of this work is now apparent in the popularity of the Radiotron Designer's Handbook in three continents, with total sales of 25,000, without including the American reprint.

RADIOTRON NEWS

Radiotron 6K7-GT: Production of this type has been suspended for an indefinite period. Type 6U7-G may be used as a direct substitute in all cases since the electrical characteristics of the two types, apart from minor differences in capacitances, are identical.

Radiotron 6K8-G: Supply of this type for initial equipment or replacement purposes in broadcast receivers has been suspended for an indefinite period. See article elsewhere in this issue for details concerning a substitute type.

Radiotron 6V6-G: The maximum screen voltage rating for this type has been increased from 250 volts to 285 volts. This allows a power output of 14 watts to be obtained from push-pull 6V6-G valves under class AB_1 conditions with equal plate and screen voltages of 285 volts. Four new data sheets for type 6V6-G are released concurrently with this issue.

REPLACING TYPE 6K8-G

In cases where a replacement is required for type 6K8-G in a broadcast receiver, it will generally be possible to use Radiotron type 6J8-G. No change will be necessary in the socket or socket connections, and in some cases it may be possible to make the change of valve type without any internal changes in the receiver. However, it is advisable in all cases to make the following circuit alteration.

In the 6K8-G, the oscillator plate is usually supplied through a dropping resistor from B+ which is common with the screen. With the 6J8-G the screen should be operated at a voltage of 100 volts, which could be obtained either from a voltage divider or a dropping resistor. In the latter case the value should be 50,000 ohms if supplying the 6J8-G screen alone.

The oscillator plate of the 6J8-G should be supplied from B+ through a dropping resistor of 20,000 ohms with a suitable bypass condenser.

When these changes have been made it would then be advisable to check the oscillator grid current under working conditions, by means of an 0 — 1 milliammeter. The normal operating region of the 6J8-G is from 0.15 to 0.50 mA., but it is permissible for the grid current to drop down to 0.1 mA. with some drop in performance. On the shortwave band it is advisable to maintain an oscillator grid current of at least 0.15 mA. on the more important wavebands (e.g., 19, 25 and 31 metres), but some falling away at the extreme ends of the scale is to be expected.

If the oscillator grid current is too low for satisfactory results it may be necessary either to increase the number of turns on the primary of the oscillator coil, or to remove the oscillator coil and replace by one designed for use with the 6J8-G. In borderline cases the use of "padder" feedback may be helpful.

VALVE DATA SHEETS

Four valve data sheets are released concurrently with this issue of Radiotronics. These are:

6V6-G sheet 1 .... data
6V6-G sheets 2, 3, 4 .... curves

The data has been expanded to include additional operating conditions both as a class A_1 and class AB_1 beam power amplifier; operating conditions as a class A_1 and class AB_1 triode power amplifier have also been added. The curves include plate families with screen voltages of 100, 225, 250 and 285 volts. Sheet 4 shows average plate characteristics as a triode and triode mutual characteristics.

RADIOTRONICS

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AUGUST, 1941

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RADIOTRON EQUIVALENT TYPE CHART

Third Edition

In Radiotronics 113 it was announced that the Radiotron Equivalent Type Chart was to be revised and brought up to date. This has duly been done and copies of the third edition dated August, 1941 are now available.

Owing to paper rationing, it will not be possible to distribute this particular chart in the normal manner to all subscribers. However, subscribers to Radiotron Technical Publications may obtain a copy free of charge (and post free) by applying personally or by letter to the Head Office of the Company.