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AMALGAMATED WIRELESS VALVE COMPANY PTY. LTD.

EDITORIAL

The operation of the pentagrid converters 1R5 and 6BE6 has been the subject of a full investigation by Mr. H. Wilshire. It was undertaken with a view to determining the conversion transconductance characteristics, and thence to determine how to obtain optimum performance. In the leading article, the measurement and interpretation of the "gc" characteristics have been outlined and these results applied to receiver design.

Mr. Wilshire is the Engineer-in-Charge of A.W.V's Applications Laboratory. He has had many years' experience in the design and production of radio receivers and associated equipment. During the past six years he has been engaged on work relating to the application of valves to a wide range of electronic circuits.

CONTENTS

We are pleased to print in full an alternative ABAC to that printed in March, for solving resistance-in-parallel. We welcome such written comment on our article as Mr. Wilbur-Ham has given.

Two smaller articles are printed which will tie in admirably with earlier issues. Read the notes on the 0C3 and 0D3 in conjunction with "Voltage Regulator Tubes" (Radiotronics, June 1956). Mr. Langford-Smith's article on "Levels Used in Standard Frequency Test Records" may be taken as a supplement to his earlier article on Pick-ups (Radiotronics, February 1956).

This month's issue contains advance data on three new R.C.A. types — 6DQ6A, 1EP1 and 6CU5. Your attention is drawn to the last paragraph in the block below.

Arthur J. Gabb.

Editor .. .. A. J. Gabb, B.Sc.

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The Presentation and Application of the Characteristics of the Pentagrid Converter Valve[†]

By H. R. WILSHIRE, A.S.T.C., A.M.I.E., S.M.I.R.E.
(Applications Laboratory, Valve Works, Ashfield)

Summary.

The conversion transconductance (g_c) of pentagrid converter valves (1R5 and 6BE6) is a function of the signal grid bias, direct screen voltage, screen grid oscillator voltage, oscillator grid current and, in some circuits, the oscillator voltage at the cathode. This paper discusses the measurement and display of the variation of g_c with these five parameters with the object of obtaining optimum performance in the converter stage of radio receivers.

1. Introduction.

This paper is divided into four main parts. The first part will consist of a brief survey of the general theory of the operation of frequency converters, with particular reference to the pentagrid or inner-grid type of converter. In the second and third parts methods will be treated of measuring and usefully displaying the main characteristics of this type of converter, and the fourth part will deal with the use of these characteristics in the design of the converter stage of a receiver.

The main characteristic of a converter valve, as far as the receiver designer is concerned, is the conversion transconductance (g_c). This is defined in approximate terms as the ratio of the intermediate frequency component of plate current to the signal input voltage. The conversion transconductance, together with the dynamic plate resistance, are the two characteristics which determine the gain to be obtained from the converter valve. Since g_c is the major of these two factors (the plate resistance having only a second order effect) it is only g_c which is considered in this paper.

No attempt will be made to demonstrate in detail the manner in which an intermediate frequency results from the combination of an input signal and a voltage obtained from a local oscillator. This can only be done satisfactorily by mathematical methods, which can be studied in any text-book dealing with converters. One of the points it is desired to make at this stage is that the operation of converters can best be understood and that information put to the most practical use by knowing the movements of electrons in a converter and the way in which they are affected by the applied voltages.

Figure 1 is taken from an article by E. W. Herold[1]. It shows the effect of voltage applied to the oscillator electrode on the transconductance from the signal grid to plate. Now, if we apply a sinusoidal voltage to the oscillator grid as shown at A we can see by tracing out its projection on to the curve, that over the cycle it will alter the signal grid transconductance as shown at B with the dip at the top due to plate current saturation and the flattening at the bottom due to plate current cut off.

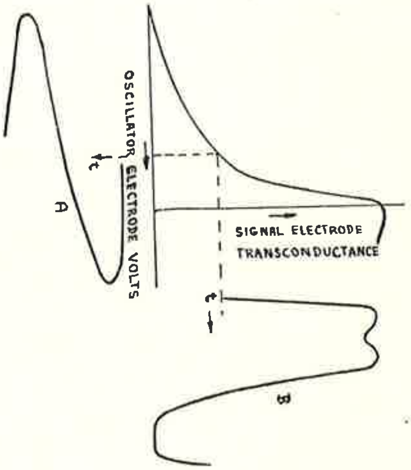


Fig. 1. Signal-electrode transconductance versus oscillator voltage for a typical converter valve. The applied oscillator voltage is shown at A, and B is the resulting time variation of transconductance.

[†] Reprinted from Proc. I.R.E. (Aust.), April 1956, with acknowledgment to the I.R.E. (Aust.).

[1] Herold, E. W., "The operation of frequency converters and mixers for superheterodyne reception", Proc. I.R.E., 30, 1942, 84-103.

The main point to be made about the Curve B is that the application of the sine wave to the oscillator grid has resulted in a very non-sinusoidal modulation of the transconductance measured between the signal electrode and the plate. This curve can be expressed as a Fourier series and the plate current, which is given by the product of this transconductance and the signal voltage, can be shown to consist of a large number of frequency terms. One of these terms is the difference frequency which is the required intermediate frequency. The conversion transconductance is, then, to a first approximation, the ratio of this component of the plate current to signal voltage. This analysis assumes that the signal voltage is small and the oscillator voltage large, so that the transconductance from the signal grid will be unaffected by the signal voltage and can be considered to be a function of the oscillator voltage only.

Although these fundamentals of operation apply to all forms of valve converters, there are major differences in the characteristics of operation between the main types of converters used in commercial AM receiver design. These are commonly referred to as inner grid and outer grid types. The inner grid converters are those which have the oscillator voltage applied to the inner grid and the signal to an outer grid (pentagrids, octodes). Outer grid converters are those which have the oscillator voltage applied to an outer grid and the signal to the inner grid (triode-hexodes, triode-heptodes).

2. Pentagrid Converters.

From this point on it is proposed to restrict discussion to the inner grid or pentagrid type of converter. The two valves of this type which are probably best known and most used are the 1R5 and the 6BE6. Figure 2 shows the layout of the electrode system of the 1R5 and also that of the 6BE6 since these two types have a similar electrode arrangement.

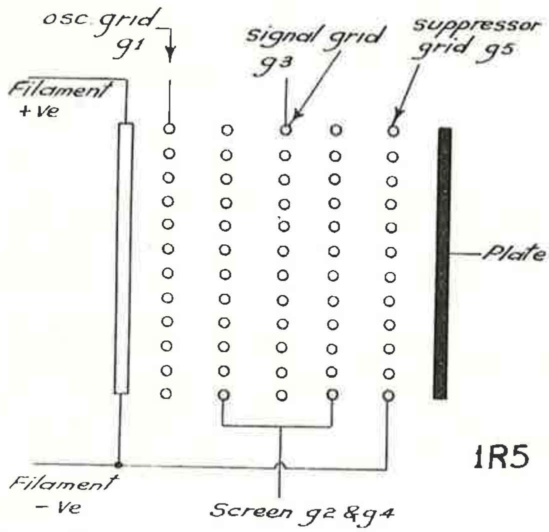


Fig. 2. Electrode system for 1R5 pentagrid converter valve.

The oscillator voltage applied to the first grid modulates the electron stream as indicated in Figure 1 and the action of the signal grid is to change the current distribution between the screen and the plate. Since the signal grid is normally at a zero or slightly negative potential, large numbers of electrons are turned back by this grid. Near their point of reversal the electrons move slowly so that there are a large number just in front of the signal grid at any time. This makes up a space charge and can be considered as a source of the electrons from which the plate current is drawn, in much the same way as the space charge outside the cathode of any valve forms the source of the normal plate current.

The physical position, relative to the signal grid, of this space charge or virtual cathode, will be controlled by all the factors which affect the density and velocity of the electrons in the region between the signal grid and the first of the screen grids. These are:

(a) the bias on the signal grid, since it determines the number of electrons turned back by this grid;
(b) the direct screen voltage, since it varies the total current through the region;
(c) the voltage of oscillator frequency on the screen;
(d) the oscillator grid current;
(e) the value of oscillator grid leak.

These last two fix the peak value of cathode current and the part of the cycle over which it flows. A variation in any of these parameters can be considered as effectively changing the geometry of the tube as far as the signal grid is concerned and hence changing the effectiveness of its control of the plate current or in other words, changing the transconductance between signal grid and plate. For example, referring to Figure 2 it can be seen how an increase in the negative potential applied to the signal grid, g3, will increase the density of the space charge between g3 and the first of the screen grids, g2, and cause it to move further away from the signal grid, thus reducing the control of this grid on the current flowing to the plate. By applying similar reasoning the effects of changes in the voltages on the other electrodes can be deduced.

One point that may not be generally realised is that the cathode current in converters of this type is cut off over a large part of the oscillator cycle by the voltage on the first grid and hence all operating conditions break down once every oscillator cycle. This is illustrated by Figure 3 which shows plate, screen and cathode current plotted against a cycle of oscillator voltage applied to g1 for a particular set of operating conditions. The pulse of cathode current made up of the sum of plate and screen currents and existing for a little more than 120 degrees of the oscillator voltage cycle can be seen. This figure also shows the small effect on cathode current of a change from 0 to +3 volts in bias (E_{c3}) applied to the signal grid.

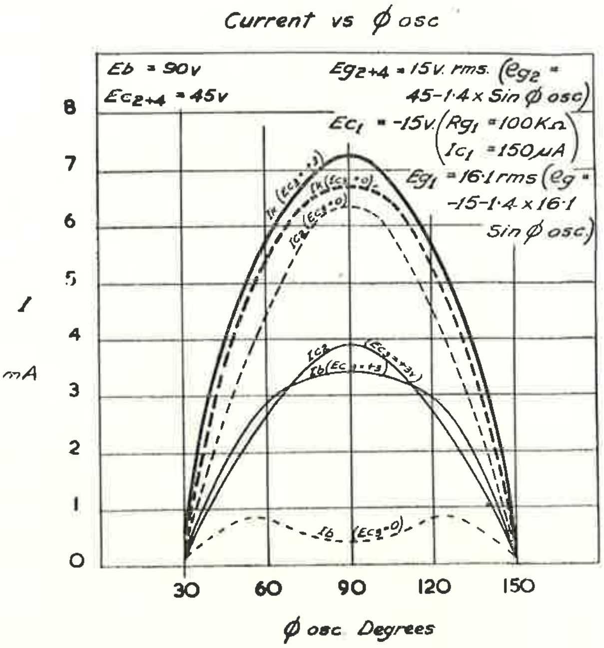


Fig. 3. Plate, screen and cathode currents (I_b, I_c and I_k respectively) plotted against a cycle of the oscillator voltage applied to g1, of a 1R5 for a typical set of operating conditions. Instantaneous values of the screen and oscillator grid voltages are shown by e_{g2} and e_{g1} respectively.

The cathode current reaches a relatively high peak value at the crest of the positive cycle of oscillator voltage. This peak may be between three and five times the average value so that in the case of a 1R5, for example operating with a steady cathode current of say 3.0 mA, the peak value each cycle may approach 15 mA. A 6BE6 with a steady cathode current of say 10 mA may have a peak between 30 and 50 mA. When the cathode current reaches high peaks such as these the corresponding transconductance (g_m) of the valve can reach a value which is very high and which perhaps is normally never associated with valves of this type. For example, in the case of a 6BE6 with a peak cathode current of 50 mA, the g_m may reach 13 mA/V. Incidentally, this very high peak g_m presents a major difficulty in the measurement of the conversion transconductance when it is necessary to apply an alternating voltage to the cathode. This will be discussed later when the measurement of converter valve characteristics is treated.

Figure 4 shows simplified circuits of the type in which these valves are operated and indicates the symbols used throughout this paper for the voltage applied to the valve.

3. Presentation of Characteristics.

Various methods exist, of which more will be said later, whereby the variation of conversion transconductance with variation of electrode voltages can be measured and the information so gained presented in the form of curves. One difficulty which immediately becomes apparent when this is attempted, is that of showing the effects of five variables in a readily understandable way. The effect on conversion transconductance of these parameters and the way in which they are interlinked is shown in Figures 5, 6, 7 and 8.

Figure 5 shows a set of curves drawn for a 1R5 valve operating under typical conditions. This set of curves shows the effect on g_c of only two parameters — bias (E_{c3}) on the signal grid and oscillator grid current (I_{c1}) — with the other three — direct screen voltage (E_{c2}), voltage of oscillator frequency on the screen (E_{g2}) and oscillator grid resistor (R_{g1}) — fixed at particular values.

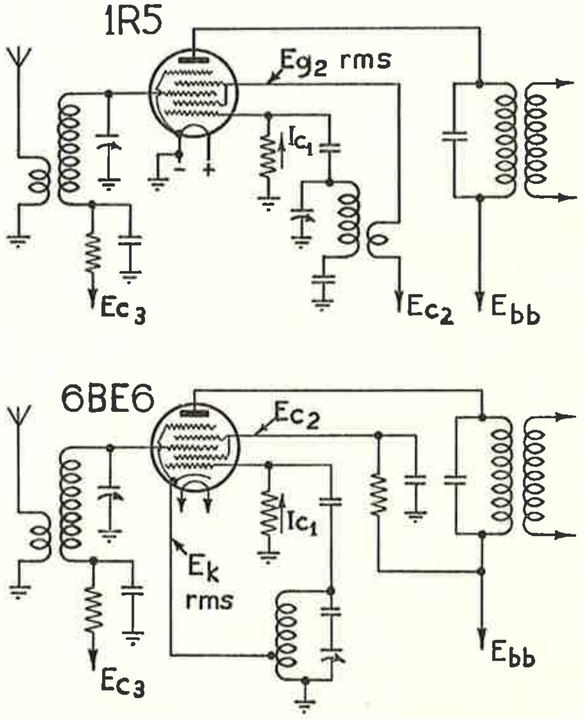


Fig. 4.—Simplified circuits of the type used with the 1R5 and 6BE6 pentagrid converters.

It will be noticed that one of the variables is the oscillator grid current. An alternative way of representing the oscillator amplitude is to use the oscillator voltage developed at the first grid. As far as the valve is concerned what is important is the effective grid voltage which at any instant is the algebraic sum of the direct negative bias developed across the grid leaks and the instantaneous value of the alternating grid voltage. In this respect the operation is similar to that of any class C RF amplifier. Since in a self-biassed oscillator the alternating and direct components of grid voltage are very interdependent, the current in the grid leak can be used as indicator of the amplitude of oscillation. This fact together with the ease of measuring grid current and the absence of any disturbing effect on the oscillator circuit in so doing has led to its almost general use as an indicator of oscillation amplitude.

Figure 5 shows the large effect that the oscillator drive or g1 current has on the peak conversion transconductance available and also the shift in a positive direction of the signal grid bias, E_{c3}, required for maximum g_c. From the curves it will be seen that for these particular conditions the peak g_c changes from approximately 170μA/V at—1 volt bias to approximately 400 μA/V for +2 volts bias on g3 for a change in oscillator grid current from 50μA to 250μA. It should be noted here that g_c values reached on the positive side of the zero bias line cannot of course be realised in normal receiver design.

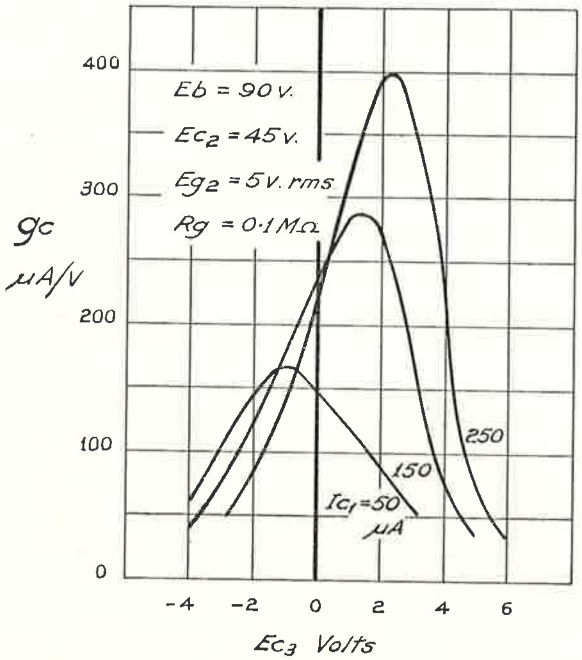


Figure 5.—Conversion transconductance of g_c versus signal grid bias E_{c3} for three values of oscillator grid current I_{c1} for a 1R5 operating under typical conditions.

Figure 6 shows for the same typical operating conditions the effect of the direct voltage on the screen. The three points to be noted here are (1) the sharpness of the curve for low screen voltages, (2) the fact that for zero signal grid bias almost the same g_c is obtained for screen voltages of 45, 55 and 67.5 volts and (3) the slope of the curves to the left of the zero bias point. The significance of these characteristics will be treated more fully later when their use in the design of the converter stage of the receiver is discussed.

The effect of oscillator voltage on the screen, with other parameters fixed as before, is shown in Figure 7. The main points here are (1) the increasing sharpness of the curves with increasing oscillator voltage on the screen and, (2) the reduction suffered in g_c at zero bias if E_{g2} is allowed to increase beyond say the 5 volts figure.

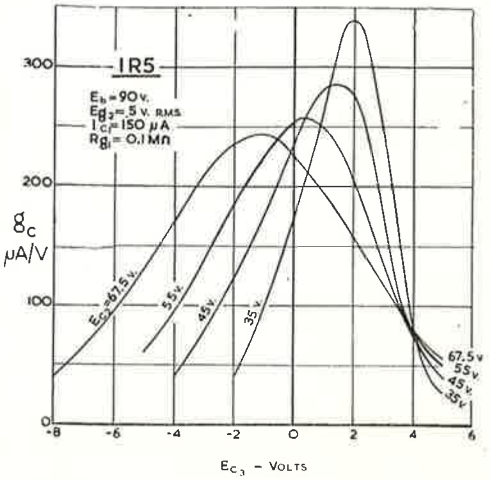


Figure 6.—Conversion transconductance versus signal grid bias and direct screen voltage E_{c2} for a 1R5 operating under typical conditions.

The final important variable is the oscillator voltage, which in some circuits will appear on the cathode or filament of a pentagrid converter. This is more important in the case of the 6BE6 valve, since it is frequently used in a cathode tapped circuit, whereas with the 1R5, due to difficulties in having the filament "hot", this type of circuit is seldom used. Figure 8 shows, for a 6BE6, curves of g_c versus signal grid bias for alternating cathode voltages of 0, 1, 2 and 3 volts rms. It can be seen how the peak in the g_c curve moves towards the positive bias side by an amount equal to the peak value of the oscillator voltage on the cathode.

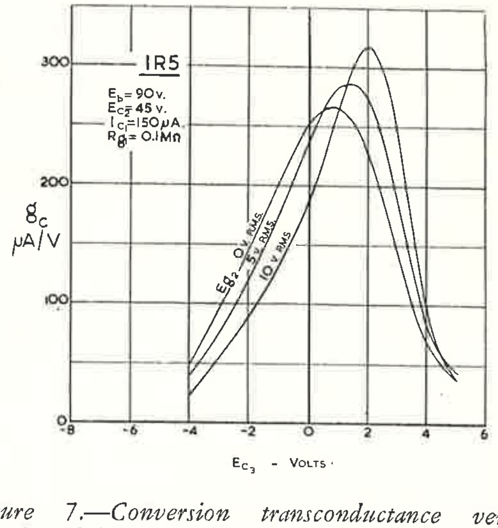


Figure 7.—Conversion transconductance versus signal grid bias and oscillator voltage on the screen grid for a 1R5 operating under typical conditions.

Thus the presence of this voltage on the cathode is equivalent to the application of a negative bias to the signal grid and effectively reduces the maximum g_c available.

In order to show more clearly the inter-linked effects of the various electrode voltages a series of twelve sets of curves has been drawn.

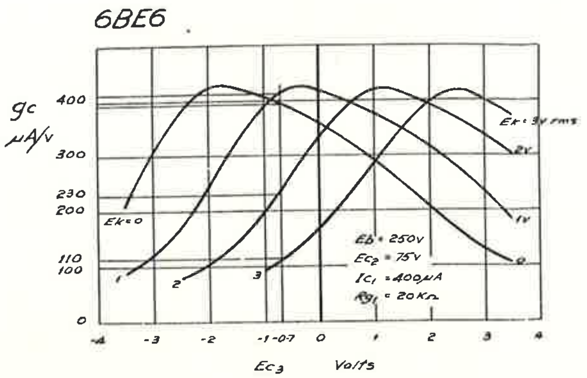


Fig. 8.—Conversion transconductance versus signal grid bias and oscillators voltage E_k on the cathode for a 6BE6 operating under typical conditions.

Figure 9 shows the g_c versus signal grid bias characteristics measured on a 1R5 valve for different values of direct screen voltage, alternating screen voltage and oscillator grid current. From these curves the general trends of g_c versus bias for each of the parameters can be seen.

The sets of curves have been grouped to show the effects of increasing direct screen voltage E_{c2} from left to right and increasing voltage of oscillator frequency on the screen from top to bottom. The changes in the shape of the three rows of curves from left to right show the general *broadening* which takes place as the direct screen voltage is increased. Also shown is the progression of the peak g_c towards the *negative* bias side with increasing E_{c2}. Looking from top to bottom it will be seen that for each value of direct screen voltage, increasing the value of the oscillator voltage on the screen increases the *sharpness* of the curves and also moves the peak g_c point towards the *positive* side. In other words an increase in the direct and alternating screen voltages produces an opposite change in the g_c characteristic.

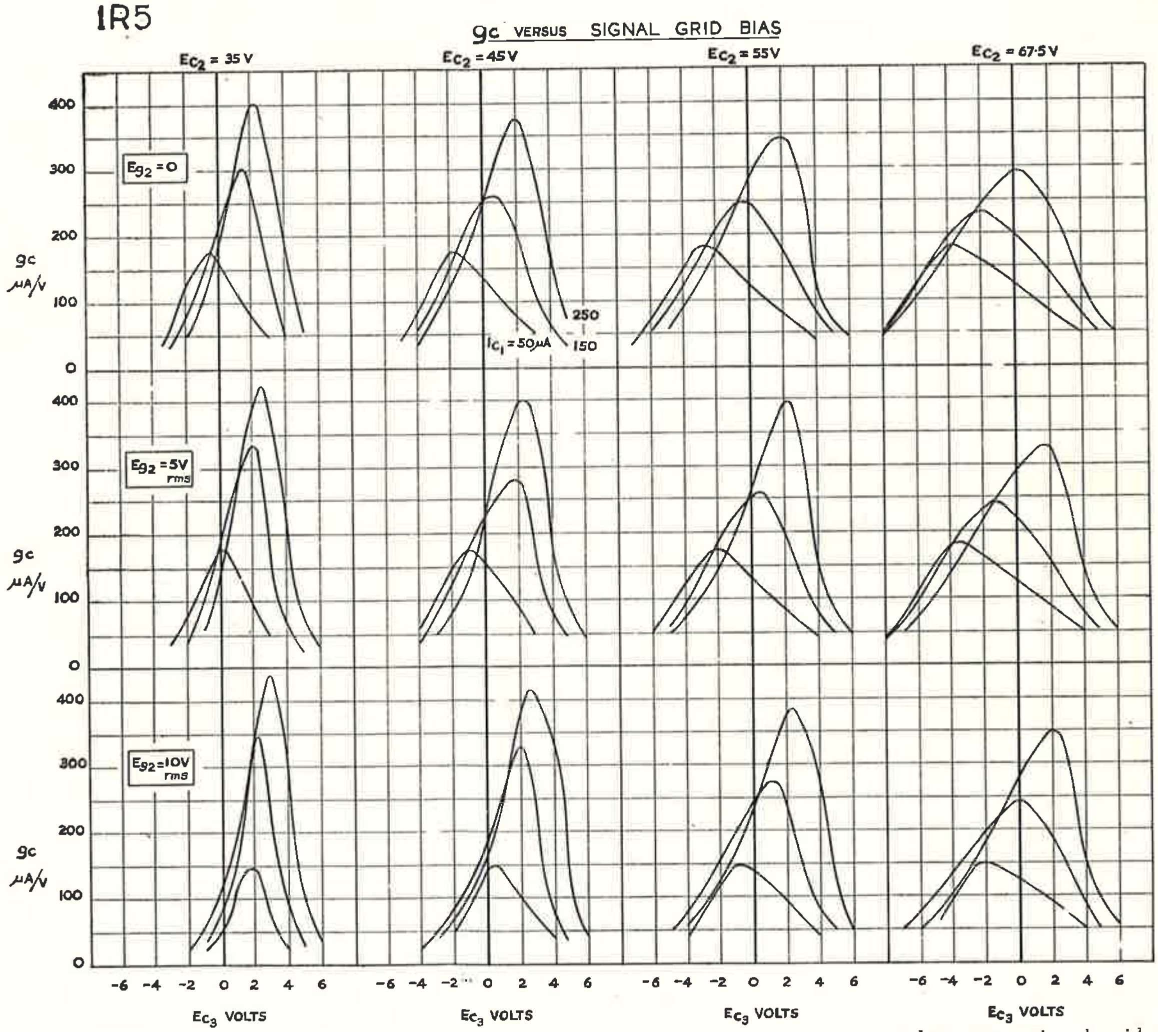


Fig. 9.—Group of curves for a 1R5 showing variations in the conversion transconductance—signal grid bias characteristics for changes in oscillator grid current I_{c1}, direct screen voltage E_{c2} and oscillator voltage E_{g2} on the screen.

This effect is due to the fact that when the alternating component of screen voltage is positive, the oscillator grid voltage is negative and the cathode current, which flows for approximately 120 degrees of the positive half cycle of the oscillator grid voltage, is cut off. Only the negative component of oscillator voltage on the screen is therefore effective and its presence is equivalent to reducing the direct screen voltage.

Generally then it may be said that the presence of oscillator voltage on the screen can be compensated for by increasing the direct screen voltage. As far as g_c is concerned this is so, as can be seen from the curves by moving downwards for say an increment of 5 volts rms on the screen and then to the right for an increase of 10 volts in E_{c2}. The set of curves applying to these new conditions will be found to be almost identical to those applying to the original conditions. This applies if one moves diagonally down the set of characteristics from any point. A rough rule is to increase the direct screen voltage by an amount equal to the peak value of the oscillator voltage on the screen. A disadvantage associated with compensating in this way is the fact that although the same g_c can be obtained, the cathode current is appreciably increased.

A similar set of curves has been prepared for a 6BE6 tube operating in a cathode coupled circuit and these are shown in Figure 10. The main points about these curves, in common with those of the 1R5, are (a) the increasing sharpness of the curves as the direct screen voltage is reduced and (b) the rapid shift of the peak g_c towards the positive signal grid bias side as the oscillator voltage on the cathode is increased. This latter point means, of course, a reduction in the useful g_c since, as mentioned previously, it is normally not possible to use a

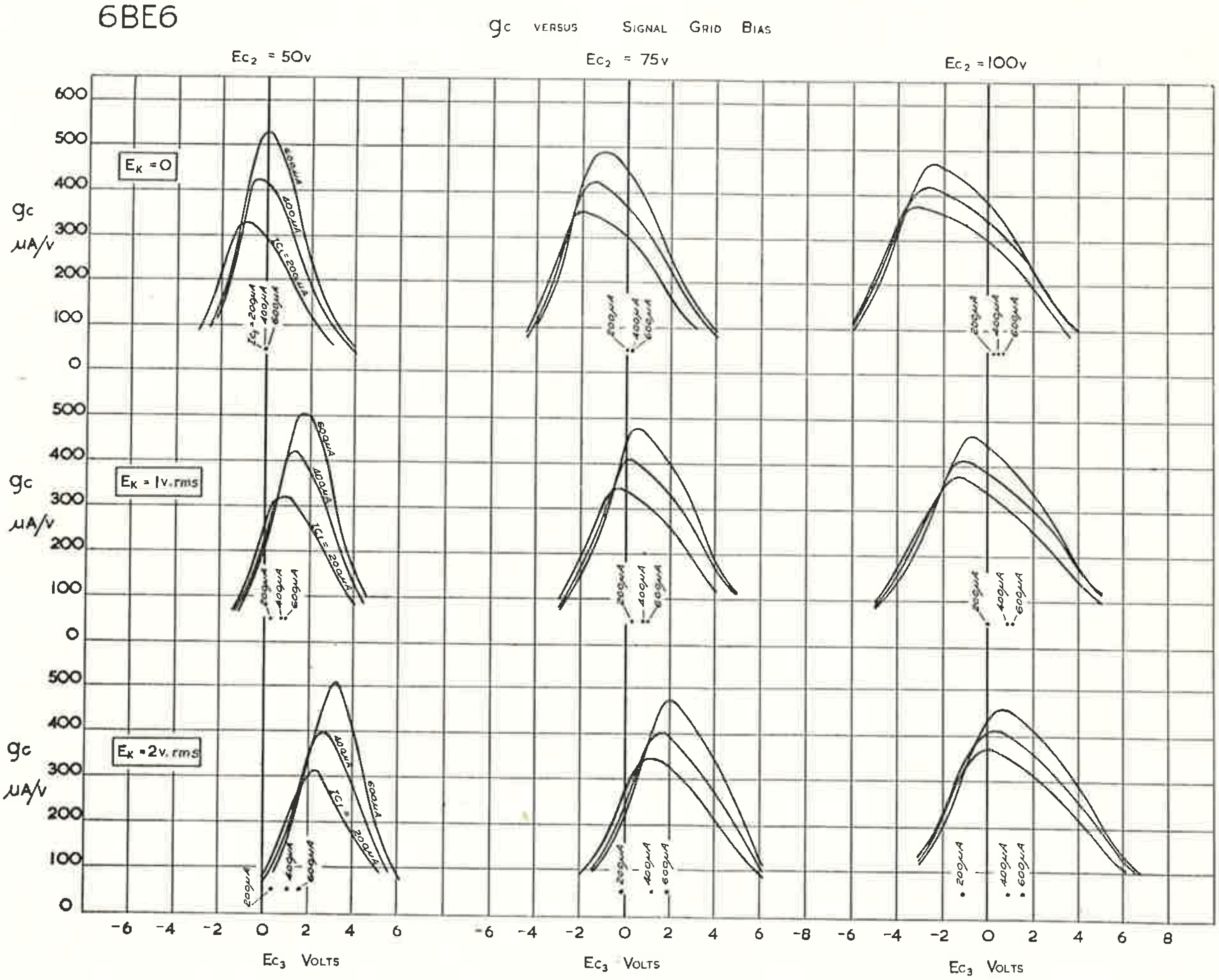


Fig. 10.—Group of curves for a 6BE6 operating in a cathode coupled circuit showing variations in the g_c—E_{c3} characteristics for changes in oscillator grid current I_{c1}, direct screen voltage E_{c2} and oscillator voltage E_k on the cathode.

positive or even zero bias on the signal grid in normal receiver design.

Shown in this figure near each zero line are three points marked 200, 400 and 600 μA. These indicate the bias E_{c3}, applied to the signal grid at which current in this circuit just commences. It will be seen that for all the conditions shown with the exception of $E_{c2} = 100V$, $E_k = 2V$ rms and $I_{c1} = 200$ μA grid current does not commence until the signal grid bias is positive.

Further consideration will be given to these effects in section 5 of the paper when the application of the curves to the design of a converter stage of a receiver is discussed.

The difficulty has been dealt with of presenting in an understandable way the variation of the g_c characteristic under the influence of up to five variables. Another way in which this can be done is to use a three dimensional model and represent the peaks of each g_c curve as a point on a surface. These surfaces will then take up a curvature and a position in space, relative to the three axes, depending on the other variables. Figure 11 shows such a representation. It is difficult to obtain from a sketch using only the plane of the paper much in the way of a picture of the variations of these surfaces. For this reason the method using the combined sets of curves is more valuable.

4. Measurement of Conversion Transconductance.

The measurement of the conversion transconductance of a converter valve presents some problems not met with in the ordinary measurements made on other types of valves. Most of the difficulty lies in the fact that g_c is given by the ratio of the intermediate frequency component of plate current to the signal frequency voltage on grid 3. This is in contrast to the measurement of g_m in an amplifier valve where it is obtained using a bridge circuit with a low frequency signal, generally 1000 c/s, and adjusting the bridge to obtain a balance between output and input voltages. A simple measurement such as this is not possible due to the different frequency components in the input and output circuits. An additional requirement which is peculiar to converters and which increases the complexity of the measurement, is the need to apply to either the cathode or the screen a voltage of oscillator frequency correctly phased with respect to the oscillator voltage on g1.

In general there are two methods of making these meaurements — the direct and indirect. The first uses a signal input voltage of the desired operating frequency, a voltage of oscillator frequency applied to both g1 and cathode or screen with an indicator in the plate circuit to measure the intermediate frequency component of plate current. The second or indirect method can be carried out in various ways. One method relies on the fact that if alternating voltages are applied to the appropriate grids of the tube, and the phase of the signal grid voltage is reversed, a small change in the steady plate current is produced. Sturley and others have shown that a very simple relationship exists between this plate current change, the signal voltage, and the g_c of the valve. A second variation applies low frequency alternating voltages to the appropriate grids and to the cathode or screen and measures the magnitude of the plate current component which has a frequency equal to the difference between the frequencies applied to the signal and oscillator grids. A suitable selection of frequencies allows a wave analyser to be used to measure this difference component.

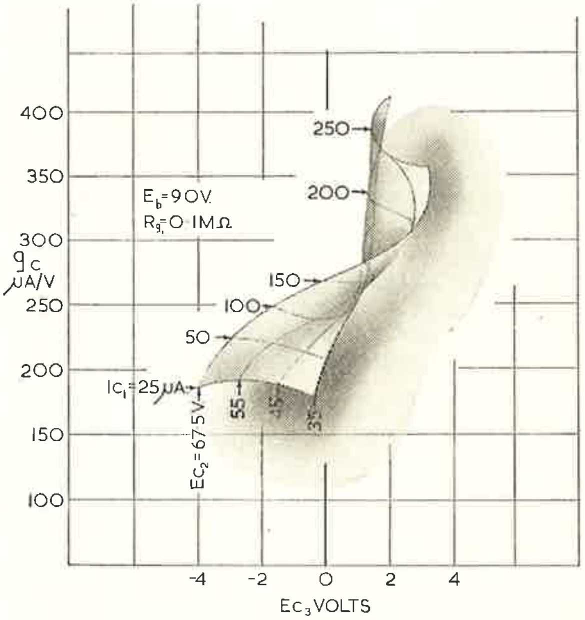


Fig. 11.—Three dimensional representation of the variation in the peaks of g_c—E_{c3} characteristics under the influence of two variables — the oscillator grid current I_{c1} and the direct screen voltage E_{c2}.

The main advantage of these two indirect methods is that by using low frequencies, say 50 c/s, really low impedance sources can be used for the signals applied to the valve. This is particularly important in the case of the alternating voltage applied to the cathode circuit. As mentioned earlier the cathode current of a 6BE6 may reach a peak of 50 mA every oscillator cycle with a corresponding g_m of near 13 mA/V. Under these conditions the cathode presents a low impedance and requires a very low source impedance for any signal connected in this circuit. For the error introduced in this way to be small, the source of cathode voltage must have an impedance less than one ohm.

Because of the difficulties involved in achieving such a low impedance using RF voltages, most of our work has been carried out using a 50 c/s voltage applied to the cathode and oscillator grid circuits, a low audio frequency voltage to the signal grid and a wave analyser to measure the difference component. Measurements made in this way are accurate as far as the valve is concerned and give a reliable indication of its performance in equipment for all frequencies except those in which capacitive coupling between signal and oscillator circuits becomes effective. The high frequency end of the broadcast band is about the upper limit. An additional source of error at high frequencies is the space charge coupling which, for frequencies greater than say 12 Mc/s, becomes more important in its effects on the performance of the converter than the pure capacitive coupling.

5. Use of Characteristics in Receiver Design.

This section of the paper will deal with what is perhaps the most important subject of any discussion concerning converters. The receiver design engineer is often torn many ways in the compromises he finds necessary in his work. He is always pressed to the limit, and sometimes beyond it, by the commercial people who always insist on better performance from more economical receivers. The first question he will ask at this stage — How can I use this material to improve the performance of my receivers'

Optimum performance for a pentagrid converter valve is obtained by making, as usual, a compromise between the requirements of the valve and those of the other features of the receiver. For example it may be that the direct screen voltage is fixed within narrow limits by the need to tie it to say an IF amplifier screen or that limitations of coil design or band switching prevent the use of a cathode tapped oscillator circuit. In a similar way the choice of bias applied to the signal grid may be limited. The proper use of these curves, by indicating the adjustments which should be made in some of the parameters when the others are fixed, allows optimum performance to be obtained.

It is desirable to stress here the following two points:

(1) the real value of these curves lies in the fact that they show the trends in the g_c versus signal grid characteristic under the influence of a number of variables;

(2) all curves shown are the results of measurements made on a particular valve. Other samples of the same type of valve may produce somewhat different values of g_c although both the shape of the characteristics and the changes in their shape will be similar.

The importance of the direct and alternating voltage on the screen of a 1R5 and the value of the

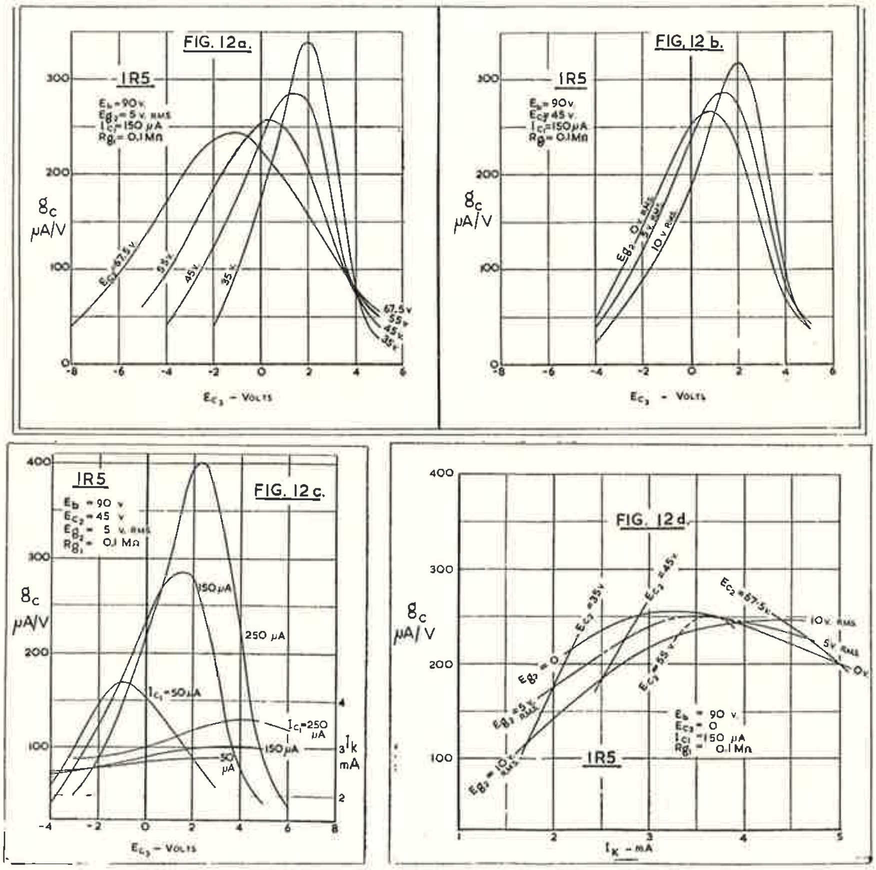


Fig. 12.—a, b, and c show g_c — E_{c3} characteristics of a 1R5 for different values of direct screen voltage E_{c2}, oscillator voltage E_{g2} on the screen and oscillator grid current I_{c2} respectively. d shows the effects of these parameters on the cathode current I_k.

oscillator grid current can be seen from Figure 12 which is a combination of Figures 5, 6, and 7. Figure 12 (a) shows again the effects of changing the direct voltage E_{c2}, Figure 12 (b), the effects of varying the oscillator voltage E_{g2}, and Figure 12 (c), the effects of varying oscillator grid current with all other parameters fixed at typical values.

Dealing first with the alternating voltage on the screen and the value of oscillator grid current — Figure 12 (b) shows the increased sharpness of the curves and the reduction in available g_c for high values of oscillator voltage on the screen, and Figure 12 (c) shows the effects of changing the oscillator grid current which has a rather broad optimum of near 150μA in a 100 kΩ grid leak. An increase above 150 μA actually causes at zero bias a small decrease in g_c, while a decrease to 50 μA causes a considerable reduction in g_c. The cathode current is almost constant between 50 and 150 μA and increases as the drive increases to 250 μA.

High oscillator drive currents present some problems in oscillator coil design, particularly when only moderate values of E_{g2} and E_{c2} are desirable. To obtain low values of oscillator voltage on the screen the oscillator coil should have a small primary which is coupled as tightly as possible to the secondary or tuned winding. The same considerations apply to the design of an oscillator coil for a 6BE6. For a cathode coupled circuit the best arrangement is to use a tap on the tuned winding since this provides as tight a coupling as possible.

In the case of the direct screen voltage Figure 12 (a) shows that as this is reduced the g_c curves move toward the positive bias side and become more "peaked" in form and, although the peak reached becomes higher, the usable g_c becomes lower, since normally only zero or negative bias voltages are available. Due to the increased sharpness of the low voltage curves, operation at voltages approaching 35 volts becomes more critical and performance more variable from valve to valve. The differences in the slope of the curves to the left of the zero bias point can be seen. The rate of decrease of g_c, or gain, with increase in bias becomes less as E_{c2} is increased until at 67.5 volts the slope has changed sign and an initial increase in negative bias from 0 volts then causes an increase in g_c with the maximum g_c occurring at —1 volt.

Similarly placed curves apply to the 6BE6 and therefore for both these converters the control obtained from the valve when AVC is applied can be materially affected by the direct screen voltage. As an example of the improvement in AVC that can be obtained in this way, some performance figures measured on a typical four valve receiver (using a 6BE6) will be quoted. The bias on the 6BE6 was increased from —1.3 to —2.3 volts to place the initial operating point near to, or perhaps slightly to the left of, the peak g_c point. The converter grid sensitivity improved from 195μV to 180μV and the overall distortion measured with 0.3 V input to the aerial at 1000 kc/s improved from 14 to 7 per cent. and with 1 V input from 45 to 10 per cent.

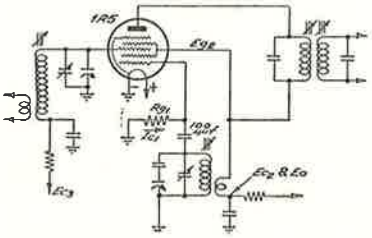
While dealing with the AVC characteristics of these valves it should be noted that the pentagrid types have an opposite screen current versus bias voltage characteristic to that of normal amplifier valves. In other words, as the bias voltage applied to the signal grid of a pentagrid converter is made more negative the screen current increases. By connecting the screens of the converter and say an IF amplifier valve together, the sliding characteristic of the IF amplifier screen voltage can be reduced, cancelled or even reversed. In this way a considerable improvement in the receiver's AVC can be obtained.

Earlier it was mentioned that the presence of oscillator voltage on the screen could be compensated for by increasing the direct voltage E_{c2} by an appropriate amount, with a corresponding sacrifice in cathode current for the same conversion transconductance. Figure 12 (d) shows this effect. For a change of E_{c2} from 45V to 67.5V (compensating for a change from 0 to 10V rms on the screen) the cathode current increases from 2.8 mA to 4.4 mA with almost no change in g_c. This of course can be seen in Figure 12 (a) where the close grouping of the curves where they cross the zero bias line is evident.

The determination of the screen voltage is affected by another factor which is not apparent from these curves. In battery operated valves as the filament voltage is reduced the voltage of the oscillator plate (the screen in normal 1R5 converter operation) requires to be reduced also to maintain oscillation. Under slump battery operation, with say 1.0 V on the filament, an increase in screen voltage instead of steadily increasing the amplitude of oscillation will cause the oscillator grid current to drop suddenly to zero. This is due to saturation effects, with loss of effective g_m in the valve, as the filament emission is reduced. A proper choice of screen voltage under normal battery conditions can therefore keep the oscillator operating for a longer time and effectively prolong the life of the batteries.

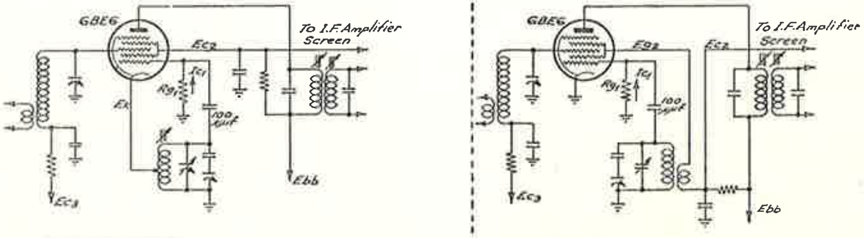
In common with all valves the characteristics of a pentagrid converter will vary to some extent with life. Our work has shown that if the operating point is chosen properly and lies on a non-critical point on the curve the variations in performance as the valve ages will be materially reduced. A further reason why this non-critical operating point should be obtained is that variations in performance from valve to valve will then be considerably reduced. As an indication of what can be done in this respect the case of a receiver manufacturer can be quoted who in a particular receiver experienced a 2 to 1 variation in sensitivity by changing 1R5 valves. This was reduced to a 1.3 to 1 variation by feeding the plate together with the screen through the primary of the oscillator coil, and

1R5 - RECOMMENDED OPERATING CONDITIONS



DIRECT PLATE VOLTAGE E_a	45-90
DIRECT SCREEN VOLTAGE E_{c2}	45-55
ALTERNATING SCREEN VOLTAGE E_{g2} (OSCILLATOR VOLTAGE)	< 5 r.m.s. (as small as possible)
DIRECT SIGNAL GRID VOLTAGE E_{c3}	0 to -0·3
OSCILLATOR GRID CURRENT µA I_{c1}	100-150
OSCILLATOR GRID RESISTOR Ω R_{g1}	100,000

6BE6 - RECOMMENDED OPERATING CONDITIONS



CATHODE - COUPLED OSCILLATOR

SCREEN - COUPLED OSCILLATOR

	CATHODE - COUPLED OSCILLATOR	SCREEN - COUPLED OSCILLATOR
DIRECT PLATE VOLTAGE E_{bb}	250	250
DIRECT SCREEN VOLTAGE E_{c2}	75-100	60-100
ALTERNATING SCREEN VOLTAGE E_{g2} (OSCILLATOR VOLTAGE)	—	< 5 r.m.s (as small as possible)
ALTERNATING CATHODE VOLTAGE E_K (OSCILLATOR VOLTAGE)	< 2 r.m.s (as small as possible)	—
SIGNAL GRID BIAS VOLTAGE E_{c3}	0 to -1·5	-1·0 to -3·0
OSCILLATOR GRID CURRENT µA	300-400	300-400
OSCILLATOR GRID RESISTOR Ω	22,000	22,000

Fig. 13.—Recommended operating conditions for a 1R5 and for a 6BE6 used in either a cathode or screen coupled oscillator circuit.

thereby increasing the oscillator grid drive and, also increasing the bias applied to the signal grid.

Finally, to summarise, Figure 13 shows the recommended operating conditions of circuits suitable for the 1R5 and 6BE6 valves. Figure 13(a) shows a recommended arrangement for the 1R5. In this circuit the total cathode current is used for oscillator feedback and as a result the oscillator voltages on the screen will be lower for the same oscillator grid current. Also, the value of the oscillator grid current will not be significantly affected by the application of AVC voltage to the signal grid, since the g_m of the valve, looking from the oscillator grid to the screen and plate, is almost independent of the voltage applied to g3.

Figure 13 (b) shows two arrangements for the 6BE6. In general they will give similar conversion gains but the screen-coupled circuit has the disadvantage of greater coupling between signal and oscillator circuits. On the broadcast band this coupling is small but on the short-wave band it may cause excessive "pulling" of the oscillator frequency when AVC is applied to the signal grid.

6. Acknowledgment.

In conclusion it is desired to acknowledge the very great assistance received from E. Watkinson of the Amalgamated Wireless Valve Company, to whom a great deal of the original work is due and also the management of A.W.V. and the members of the Application Laboratory Staff who have greatly facilitated the preparation of this material.

See also P. 71

NOTES ON RADIOTRON OC3 AND OD3 REGULATOR TUBES

The following notes apply to both OC3 and OD3 tubes, although for simplicity only type OC3 is referred to in the text.

Sufficient resistance must always be used in series with the OC3 to limit the current through the tube. The value of the series resistor is dependent on the maximum anode-supply voltage and the ratio of the current through the load to the operating current of the OC3, and should be chosen to limit the operating current through the tube to 40 milliamperes at all times after the starting period.

The maximum load current that can be regulated by the OC3 is determined by the minimum and maximum values of the supply voltage for fixed load resistance. After the value of series resistor for the maximum supply voltage has been calculated as indicated above, it is then in order to determine whether this will permit adequate starting voltage when the supply voltage falls to its minimum value. If adequate starting voltage is not obtained, a new load current of lower value must be used and the calculations repeated. It will be apparent from such calculations that the higher the minimum supply voltage and the smaller the difference between its minimum and maximum values, the higher will be the load current that can be regulated.

When equipment utilizing the Radiotron OC3 is "turned on", a starting current in excess of the average operating current is permissible as indicated under Maximum Ratings. When the tube is subjected to high starting currents, the regulated voltage may require up to 20 minutes to drop to its normal operating value. This performance is characteristic of voltage-regulator tubes of the glow-discharge type. Similarly, the regulation is affected by changes in current within the operating current range. For example, the regulation of a tube operated for a protracted period at 5 milliamperes and then changed to 25 milliamperes, may be somewhat different from the value that will be obtained after a long period of operation at 25 milliamperes. Likewise, the regulation may change somewhat after a long idle period.

In order to handle more load current, two or more OC3's may be operated in parallel, but such parallel operation requires that a resistance of approximately 100 ohms be used in series with each OC3 in order to equalize division of the current between the paralleled tubes. The disadvantage of this method is that the use of resistors impairs the regulation which can be obtained.

If the associated circuit has a capacitor in shunt with the OC3, the capacitor should be limited in value to 0.1 μF. A larger value may cause the OC3 to oscillate and thus give unstable regulation performance. However, if a larger value of capacitor is used it may be necessary to use a small resistor, say 50 to 100 ohms, in series to prevent oscillation.

New RCA *Releases*

RCA-6DQ6-A
BEAM POWER TUBE
For use as Horizontal Deflection Amplifier

The new glass-octal type 6DQ6-A is a high-perveance beam power tube for use as a horizontal deflection amplifier tube in high-efficiency deflection circuits of TV receivers.

Designed with a large reserve of power capability this new tube has ratings which are substantially higher than those of the 6DQ6 as follows: maximum dc plate voltage (including boost) of 700 volts; maximum dc grid-No. 2 voltage of 200 volts; maximum average cathode current of 140 milliamperes; and maximum grid-No. 2 input of 3 watts. These higher ratings, together with a high operating ratio of plate current to grid-No. 2 current, make possible the design of an efficient horizontal-deflection circuit in which the tube can deflect fully picture tubes having deflection angles in excess of 90 degrees.

Structural features include a T-12 envelope and a mount which permits cool operation of both grids, with the result that emission from them is minimized. The structure also provides for maximum distribution of heat in order to prevent hot spots on the plate. These features all contribute to the superior performance of this new type in horizontal-deflection service.

RCA-6CU5
BEAM POWER TUBE
For AF Output of TV Receivers

The 6CU5 is a beam power tube of the 7-pin miniature type intended particularly for use in the audio output stage of television receivers.

Because of its high power sensitivity and high efficiency at low plate and screen voltages, this new type is capable of providing relatively high power output. For example, in class A amplifier service, this type operated with a plate voltage of 120 volts and a grid-No. 2 voltage of 110 volts, can deliver a maximum-signal power output of 2.3 watts.

RCA-1EP1
OSCILLOGRAPH TUBE

Just released by the RCA Tube Division is a very small oscillograph tube — only $1\frac{1}{4}$" in envelope diameter — intended for use in lightweight portable equipment, in aircraft, or in continuous monitoring service for large electronic equipment.

Designated as the 1EP1, this new tube utilizes electrostatic focus and electrostatic deflection. It has a flat face, a minimum useful screen diameter of $1\frac{1}{16}$ inches, a maximum overall length of only $4\frac{1}{16}$ inches, and weighs but 2 ounces.

Other design features of the 1EP1 include separate base-pin terminals for each deflecting electrode to permit use of balanced deflection, and a new small-button unidekar base.

Graphical Method for Calculating the Resultant of Two Resistances in Parallel

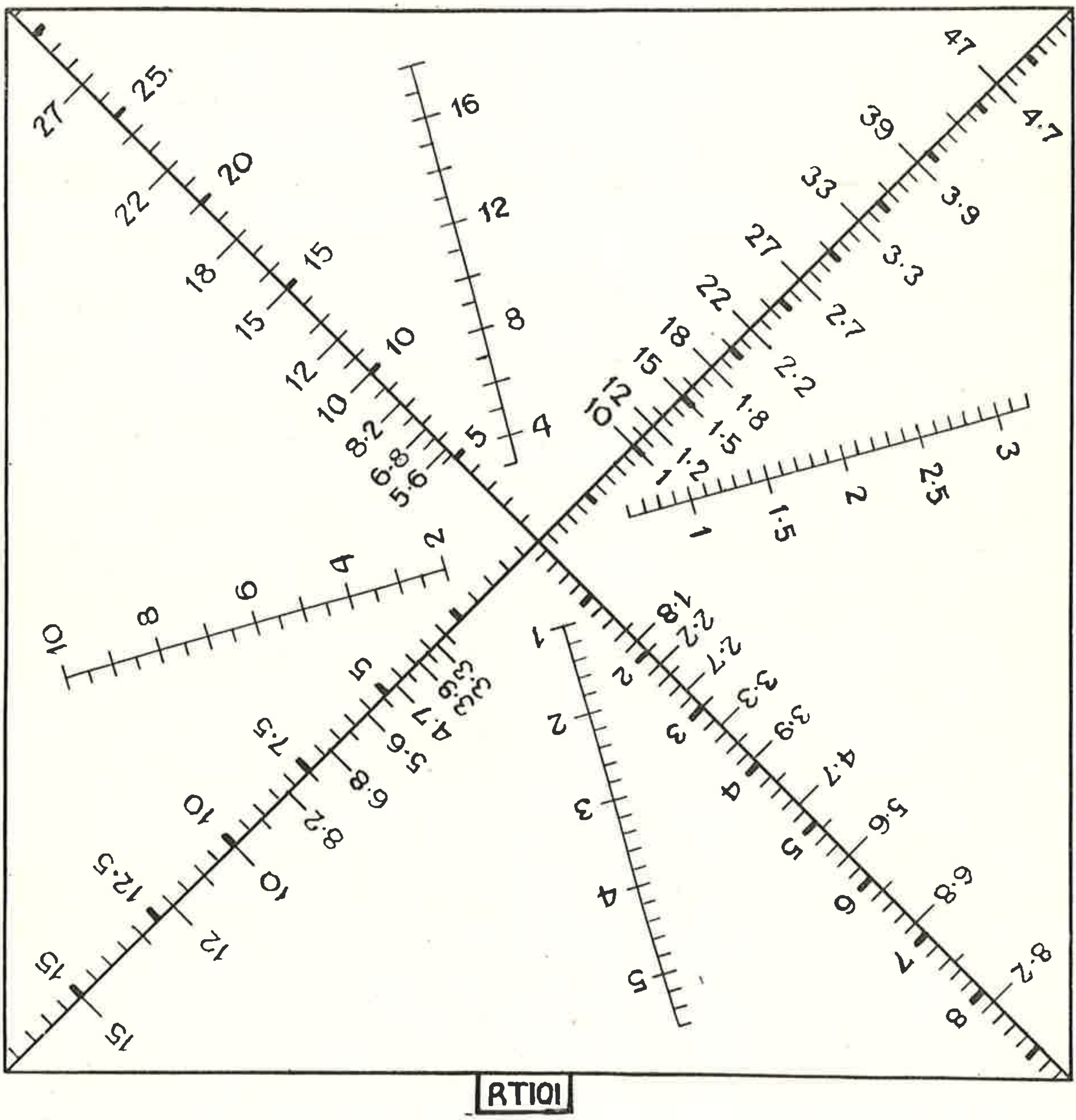
Since the publication, in the March issue (Ref. 1), of the method due to Mr. A. A. Campbell, we have received an alternative ABAC to solve similar problems, but which has greater accuracy under some conditions. Difficulty arises with the earlier form when it is used for deriving the resultant of, say, 150 and 68 ohms in parallel. This particular case could be handled by this method if the vertical scale in the graph had been extended to, say, 16 or 20 instead of 10 units. This was done in the original one submitted by Mr. Campbell, although not shown in the printed form.

We print below the letter received from Mr. J. Wilbur-Ham, together with the ABAC as drawn by him.

"Dear Sir:

ABAC FOR TWO RESISTANCES IN PARALLEL

Mr. A. A. Campbell's graph (Ref. 1) is a useful application of the abac for the equation $(1/a) + (1/b) = 1/c$ (Ref. 2). This type of abac cannot be accurately read near the point where the scales intersect (Note 1), so the usual practice is to multiply or divide the scales mentally by 2.



RT101

This is simple enough, but it cannot be applied to the preferred values or resistors, because they do not increase by multiples of 2.

If the graph were provided with several scales, preferred values could be shown on each. The user could select the range on which the resistance values were well separated, if he could distinguish one scale from another.

The alternative is to draw separate abacs for each of the required ranges. Four such abacs are combined in the accompanying chart (RT101). Each occupies one sector of the square, and together they cover every range (Note 2). No multiplication is necessary except by powers of 10 (Note 3).

Each of the diagonal scales represents one of the two resistors that are connected in parallel. When a straight edge is laid between a pair of diagonal scales, the intercept on the intermediate, shorter scale gives the value of the parallel resistance.

This chart may also be used to find the capacitance of two capacitors in series (Note 4).

Yours, etc.,
(Signed) JOHN WILBUR-HAM.

REFERENCES.

1. **F. Langford-Smith, "Graphical method for calculating the resultant of two resistances in parallel", Radiotronics, Vol. 21, No. 3, page 34, March, 1956.**
2. **M. Kraitchik, "Alignment Charts", page 32, New York, D. Van Nostrand and Company Inc., 1944.**

NOTES.

1. Find the resultant of 150 and 68 ohms in parallel!
2. Any value can be read to an accuracy of 1 per cent. or better, if the scales are accurately drawn.
3. The pseudo-exponential scales of preferred values are easily distinguished from the linear scales, and the scales for parallel resistance are separately calibrated.
4. If the two resistances are very unequal, remember that a resistance is reduced by an $(N + 1)$th when a resistance N times greater is in parallel. The approximation $N + 1 \cong N$ is satisfactory (within 1 per cent.) if N is greater than 10.

LEVELS USED IN STANDARD FREQUENCY TEST RECORDS

By F. Langford-Smith

Data on a wide range of Standard Frequency Test Records have been published (Ref. 1). In some cases the recorded level at 1000 c/s was not published because it was not known. The writer has been collecting information on this subject for some time past, and the following table is given as a guide, although in several cases the figures were obtained from sources other than the manufacturer, and cannot be guaranteed.

This table also includes some test records not included in Ref. 1.

If any of our readers can let us have additional information, particularly on records available in Australia, we would be pleased to publish it.

Audiotone	78-1*	1000 c/s		5.0 cm/sec
B.S.R.A.	PR301*	Fine groove test disk 33⅓ r.p.m. British Sound Recording Association: 1000 c/s 1 cm/sec 50 c/s — 17db; 100 c/s — 11.2; 200 c/s — 6; 500 c/s — 1.6; 1 Kc/s 0; 2 Kc/s + 1.4; 3 Kc/s + 2.8; 4 Kc/s + 4.2; 5 Kc/s + 5.5; 6 Kc/s + 6.7; 7 Kc/s + 7.8; 8 Kc/s + 8.7; 9 Kc/s + 9.6; 10 Kc/s + 10.5. Data from Sound Recording and Reproduction Aug. 1955 p. 277.		
Columbia	LOX650	1000 c/s		7.4 cm/sec
Decca	K1804	1000 c/s	78 r.p.m.	4 cm/sec
Decca	LXT2695	1000 c/s LP		1.2 cm/sec
E.M.I.	JG449	1000 c/s	78 r.p.m.	3.16 cm/sec
H.M.V.	DB4037	1000 c/s		3 cm/sec
R.C.A.	12-5-49*	Inner band		5.5 cm/sec
R.C.A.	12-5-31V*	1000 c/s		4.4 cm/sec
R.C.A.	12-5-51	Inner band		5.5 cm/sec

* New release, not published in Ref. 1.

1. Radiotron Designer's Handbook, 4th ed., pp. 753-757, and Enlarged Supplement, 1954, pp. 1485-1486.


AWV