RADIOTRONICS

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THE MEASUREMENT OF MICROPHONY

Microphony troubles are amongst the most difficult the receiver design engineer is called upon to solve, particularly when the microphony is occurring in production receivers for which all components are already bought or manufactured.

Two broad classifications of microphony can be made, firstly those cases involving audio frequency components only and, secondly, those in which audio frequency and intermediate or oscillator frequency components are affected.

In the first classification come the problems of microphony due to acoustic feedback from loudspeaker to pick-up in radiograms and record-players or from loudspeaker to an a-f amplifier valve, this latter type being more prevalent with battery valves, especially when operated close to the loudspeaker, as in portable receivers, or with high gain between input circuit and loudspeaker.

In the second classification there is a larger range of possibilities, with gang condenser microphony being probably the most prevalent. Other parts of the local oscillator circuit in a superheterodyne, such as the converter valve, the oscillator coil and even the wiring, may give trouble. At the intermediate frequency, valves are almost the only possible sources of microphony, one interesting case being battery valves which give trouble only when biased to cut-off, a complaint which can be cured by reducing the amount of a.v.c. applied to the stage.

Perhaps the reason why microphony does from time to time occur in production is that microphony *measurements* are rarely made during the course of a design, so that if experimental models are not microphonic it is assumed that production receivers will be satisfactory. This assumption is justified only if the prototype has an adequate margin before sustained microphony occurs to make provision for variation in individual components in production receivers.

A system which has been used to obtain microphony measurements is shown in Fig. 1. A complete receiver is used with all parts correctly mounted and operating, but the connection between the receiver and its speaker is broken and the speaker is connected to a B.F.O. with its output indicated on a suitable voltmeter. The output from the receiver is fed into a dummy load, which is preferably a speaker identical with the one used on the receiver but moved to a distance, or enclosed in such a way that none of its sound output reaches the equipment under test. The voltage output from the receiver is indicated on a second voltmeter. The impedance of this meter must be large enough to have no effect on the indicated voltage.

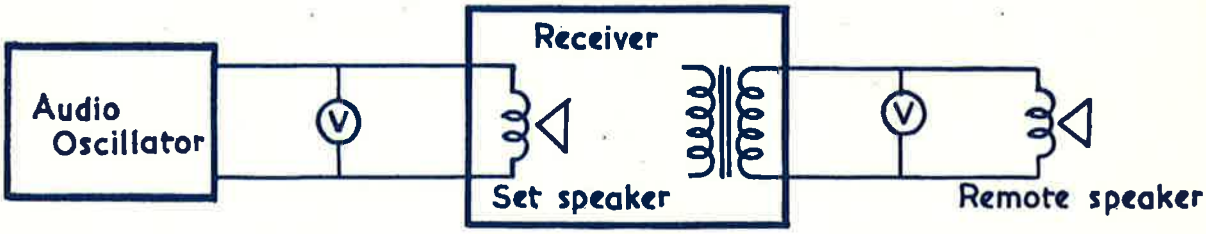

Fig. 1. Set-up for testing for microphony.

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* **Contributed by the Applications Laboratory, Valve Works, Ashfield.**

If now the speaker mounted on the receiver is excited from the B.F.O. as this is tuned through the a-f range it will be found that at some sharply defined frequencies an output is obtained on the output voltmeter. At any frequency at which the output voltage is at least equal to the input voltage sustained microphony will occur when the receiver is operated normally. However, if for example at one particular frequency the output voltage is 30 db below the input voltage there is a 30 db margin at that frequency between the receiver's actual performance and sustained microphony.

Because of the high Q of the mechanical parts of the electrical components causing microphony, the responses obtained are very sharply tuned and it is necessary to move the frequency dial of the B.F.O. very slowly or they may be overlooked completely.

In addition, some types of microphony are very dependent on the level of the source of excitation. Any comparisons or checking of previous readings must be done at the same level as the original readings. In some cases the microphony measurements must be carried out at a level almost equal to the full a-f output of the receiver, as the microphonic responses may not otherwise be observed.

The degree of accuracy obtained in the measurements will vary with the source of microphony, so that several readings should be taken at each response until the order of accuracy for each microphony source is known. For example, microphony due to feedback between a loudspeaker and a pick-up with the needle resting on a record on a turntable mounted in the same cabinet will vary with different positions of the needle on the record, and to a smaller degree with each placing of the pick-up on the record.

By using this method of measurement it is possible to experiment on possible cures for microphony while watching the effect on the output meter. The effectiveness of different remedies is far more easily gauged than when the only indication is that a receiver either is or is not microphonic.

Furthermore, if there are two sources of microphony present, the selection of each by means of the B.F.O. allows measurements of individual improvement to be made even though the receiver would still suffer from sustained microphony due to the second source with the first completely cured.

The system of measurement is most applicable to cases of microphony involving only audio frequencies, as in the example above. When the microphonic system includes radio frequency components as in microphony of a gang condenser in a short wage receiver, measurement is more difficult because another variable, the tuning of the receiver, is involved.

Nevertheless the method is still useful, although it becomes more complicated. For example, to investigate gang condenser microphony a carrier of appropriate amplitude must be applied to the receiver and the tuning may be monitored by means of headphones, which will not affect the source of microphony. At the tuning point giving the greatest tendency to microphony, which may be determined by tapping the chassis, the microphonic output over the a-f range may be determined as before. In this case it will be found that both receiver tuning and B.F.O. tuning must be carried out carefully but results are nevertheless reasonably reproducible.

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in this factor above, say 5, does not result in any appreciable improvement of the damping. For this reason its use has been avoided in compiling the fourth edition.

It is hoped to treat some of the aspects of amplifiers working into loudspeaker loads in greater detail at some future date.

REFERENCES

1. RETMA Standard SE-103 Speakers for sound equipment (April, 1949).
2. Radiotron Designer's Handbook (4th ed.), pages 844-845 and Fig. 20-12.
3. R.D.H. pages 848-849.
4. R.D.H. pages 313-314.

LOOKING AT AMPLIFIERS FROM THE LOUDSPEAKER POINT OF VIEW

By F. Langford-Smith.

A quality loudspeaker is designed to give an approximately constant sound pressure at all frequencies within its frequency range, when supplied with a constant voltage through a specified value of source resistance (Ref. 1). The value of source resistance is specified by RETMA SE-103 (Ref. 1) for speakers for sound equipment as being 40% of the value of the loudspeaker rating impedance; this is equivalent to operating the loudspeaker from a source having a voltage regulation of 3 db. The value of the source resistance used by R.C.A. is zero, so that their loudspeakers are tested with constant voltage applied at all frequencies. Most manufacturers of loudspeakers appear to use zero source impedance.

It is important to realize that a loudspeaker is a device operated with constant, or nearly constant, applied voltage. Many radio engineers seem to look on a loudspeaker as being a device operated with constant audio-frequency power input, but this is quite erroneous and misleading. In a typical case the impedance at the bass resonant frequency and also at 10,000 c/s is eight times the impedance at 400 c/s. If constant voltage is applied at all frequencies, as in the R.C.A. test, then the power input of the loudspeaker will be about 12% of that at 400 c/s. If a source resistance of 40% of the loudspeaker rating impedance is employed, as in the RETMA test (Ref. 1), then the power input of the loudspeaker at either of these two frequencies will be about 22% that at 400 c/s. These values have been calculated on the basis that the loudspeaker impedance is purely resistive at the specified frequencies — this is correct at the bass resonant frequency and approximately correct at 400 c/s but at 10,000 c/s the load is very reactive, so that the power input will be considerably less than the values calculated above for a resistive load. However, the values quoted are sufficient to demonstrate that the power input to the loudspeaker is a maximum at middle frequencies where the impedance is low (200 to 400 c/s) and falls off very markedly at high frequencies and as the frequency approaches the bass resonant frequency.

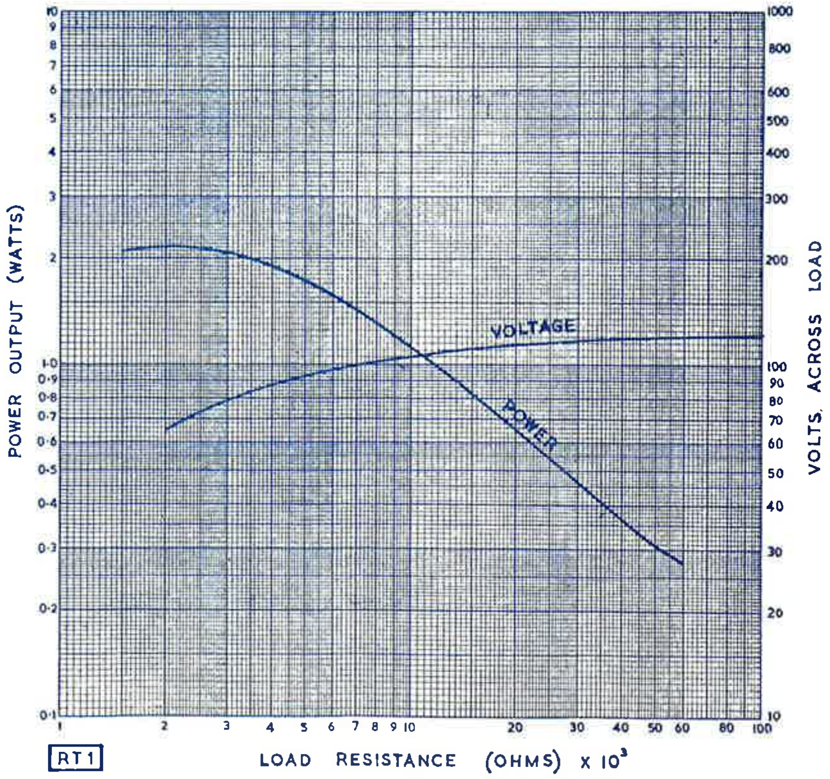

Fig. 1. Power output and voltage across load resistance of type 45 triode, plotted against load resistance.

Most amplifiers are tested for power output and distortion at 400 c/s into a purely resistive load equal to the loudspeaker rating impedance. Although this gives valuable information, it needs to be supplemented by additional tests either on a loudspeaker or on a load simulating the impedance (both in magnitude and in phase angle) of a typical loudspeaker. The voltage across the load should be recorded at all frequencies, and expressed in terms of decibels, the reference level being the voltage at 400 c/s, which may also be expressed as the power in watts at this frequency.

Tests are sometimes carried out by measuring the power output into a resistive load of varying resistance, and recording the results in the form of curves of power output and distortion versus load resistance. While this is a valuable tool for determining the optimum load resistance, it does not indicate what happens on a loudspeaker load. With a loudspeaker load the impedance may vary from the nominal value up to perhaps 10 times this value, and it is the voltage across the load which is significant.

In Fig. 1 there is shown the line curve of power output versus load resistance for type 45 triode for constant grid signal voltage — this is derived from the R.D.H., page 558, Fig. 13-14, and is typical of all triodes. The curve falls off rapidly at high values of load resistance and a natural inference is that the response of a loudspeaker would fall off at high frequencies where the impedance is high. Actually the voltage across the load resistance increases when the load resistance is increased, as shown in the curve indicating voltage across the load. As a result of the finite value of the output resistance of the amplifier, in this case equal to the plate resistance of the valve, the voltage across the load increases when the impedance of the load increases. Consequently the response of a good quality loudspeaker tends to rise at the bass resonant frequency and at high frequencies.

On the other hand, when an amplifier uses a high degree of negative voltage feedback, producing a very low value of output resistance, the voltage across the loudspeaker is practically constant at all frequencies. This condition would give a nearly flat acoustical response from good quality loudspeakers designed and tested for operation at constant voltage, but gives a rather weaker response at low and high frequencies from loudspeakers designed for operation with a finite value of source resistance.

Taking the other extreme, using a pentode output stage with no feedback at all, or else with negative current feedback, the output impedance of the amplifier will be very high and the voltage across the loudspeaker will rise to very much higher values at the bass resonant frequency and at high frequencies than that at 400 c/s. This condition is usually avoided.

EFFECT OF OUTPUT RESISTANCE ON BASS RESPONSE

With a loudspeaker mounted in a completely enclosed cabinet, the bass response of the system is critically dependent on the output resistance of the amplifier. If the output resistance is high, there is likely to be a pronounced peak in the response at the resonance frequency of the system (this will differ from the bass resonance frequency of the loudspeaker in a flat baffle). If the output resistance is low, there will inevitably be a serious drop in the bass response. There will be one, fairly critical, value of output resistance for which the bass response will be neither peaked nor attenuated (Ref. 2).

A similar effect, resulting in bass loss, may also occur in a bass reflex loudspeaker with a small cabinet and small vent (Ref. 3).

There is usually an optimum value of amplifier output resistance for any particular loudspeaker when mounted in its enclosure, and this value is often larger than that of a conventional feedback amplifier. Some design engineers go to considerable trouble to provide the correct output resistance for the optimum loudspeaker bass response, using such methods as bridge feedback (Ref. 4).

LOUDSPEAKER DAMPING

All loudspeakers have a certain amount of internal damping, caused partly by friction in the suspension, and partly by acoustical loading, the latter being particularly prominent in the case of horn loudspeakers. In addition to the internal damping there is also electro-magnetic damping, which is a function of the output resistance of the amplifier. In the vicinity of the bass resonant circuit, the loudspeaker acts as a resonant system having an electrical equivalent circuit as in Fig. 2, comprising an inductance (L_1) and a capacitance (C_1) forming a parallel resonant circuit shunted by the total internal equivalent resistance (R_1). Most typical loudspeakers have values of Q between 8 and 18 when the amplifier output resistance is high and R_1 is the only damping resistance. However, when a finite value of output resistance (R_o) is used, there is an additional shunt resistance producing damping, equal to $R_o + R_d$ where R_d is the d.c. resistance of the voice coil. Even if the amplifier output resistance (R_o) is zero, the value of this damping resistance cannot be less than R_d. No appreciable increase in damping occurs by reducing the output resistance below one fifth of the d.c. resistance of the voice coil; in this case the total damping resistance would be $1.2R_d$ as compared to $1.0R_d$ in the limiting case when $R_o = 0$. The most convenient way of expressing the damping relationship appears to be as a fraction of the d.c. resistance of the voice coil.

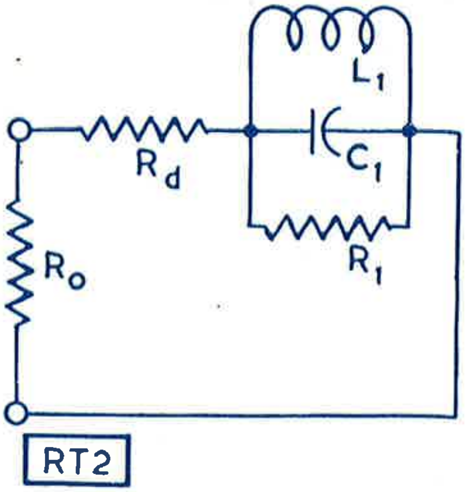

Fig. 2. Equivalent electrical circuit of dynamic direct-radiator loudspeaker valid for damping considerations at low-frequencies. The value of output resistance of the amplifier (R_o) is here referred to the secondary circuit.

In the third edition of the Handbook, on page 15, the writer "coined" the expression Damping Factor as being the ratio of the load resistance to the output resistance of the amplifier. This form of expression has been widely adopted both in this country and overseas, but it is inclined to be misleading since the true damping is not proportional to the so-called Damping Factor, and any increase

(*Continued on page 26*)

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LOW VOLTAGE OSCILLATOR OPERATION

The end-of-life point for the A-battery in a battery-operated radio receiver is usually the highest voltage at which the local oscillator will not operate, and because of the shape of the discharge curve of dry cells[1] it may sometimes be possible to obtain a significant improvement in A-battery life by means of improved low-voltage oscillator operation.

Moreover, as the oscillator valve ages, progressively higher minimum filament voltages are required before oscillation will start. An oscillator circuit which has been designed to provide optimum conditions for oscillator valve operation at low filament voltages may thus also result in longer valve life before replacement.

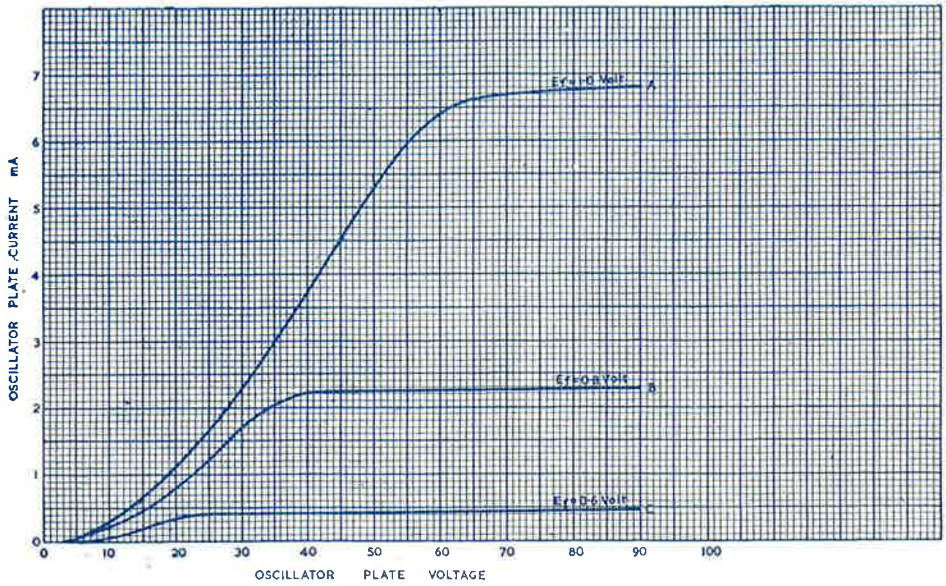

Fig. 1. Effect of filament voltage on 1R5 oscillator plate (pentagrid plate plus pentagrid screen) characteristic.

In a typical receiver design the oscillator plate voltage is lower than the B supply voltage and at normal filament voltages increased oscillator grid current can be obtained by increasing the oscillator plate voltage. However, an attempt to obtain more grid current in the same manner at much reduced filament voltages (e.g., below 1.1 volts) may result in oscillation stopping altogether. A characteristic of the oscillator under such conditions is that the grid current suddenly falls to zero from a comparatively high value as filament voltage is reduced instead of decreasing gradually to currents of the order of a few microamps.

Fig. 1 provides the explanation for this effect. The curves were taken on a particular 1R5 valve and show oscillator plate current, i.e., plate plus screen current, vs. oscillator plate voltage with grids 1 and 3 (oscillator and signal grids) returned to the negative filament, for three different filament voltages covering ranges in emission in which difficulty may be experienced in obtaining oscillation.

Although the curves of Fig. 1 have been plotted for filament voltages as low as 0.6 volt, they are not necessarily typical and are intended only to illustrate the effect on oscillator performance of saturated emission, which occurs at filament voltages of this order. Since the filament voltage required to obtain a given emission will increase during life, the curves shown in Fig. 1 may well represent the emission

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* **Contributed by the Applications Laboratory, Valve Works, Ashfield.**

[1] Radiotron Designer's Handbook, 4th edition, Chap. 35, Section 7 (iii).

characteristics of a valve at some later stage in its life at A-battery voltages at which operation can reasonably be expected.

Considering curve A it will be seen that it consists of three parts, the first with the plate voltage below 50 volts, in which plate current increases approximately with the three-halves power of the plate voltage. The second part, covering oscillator plate voltages of approximately 50 to 70 volts, is a transition phase and the third, with oscillator plate voltages of 70 volts and upwards is a region in which plate current is unaffected by plate voltage. Curves B and C have the same general shape as curve A, but the knees of the curves occur at progressively lower plate voltages and currents and the flat sections extend correspondingly as the filament voltage is lowered. The flat portion of the curves is due to the saturation of emission which occurs at these filament voltages and the plate voltage of the knee, though not sharply defined, is the minimum voltage at which all the electrons emitted by the filament flow to the plate.

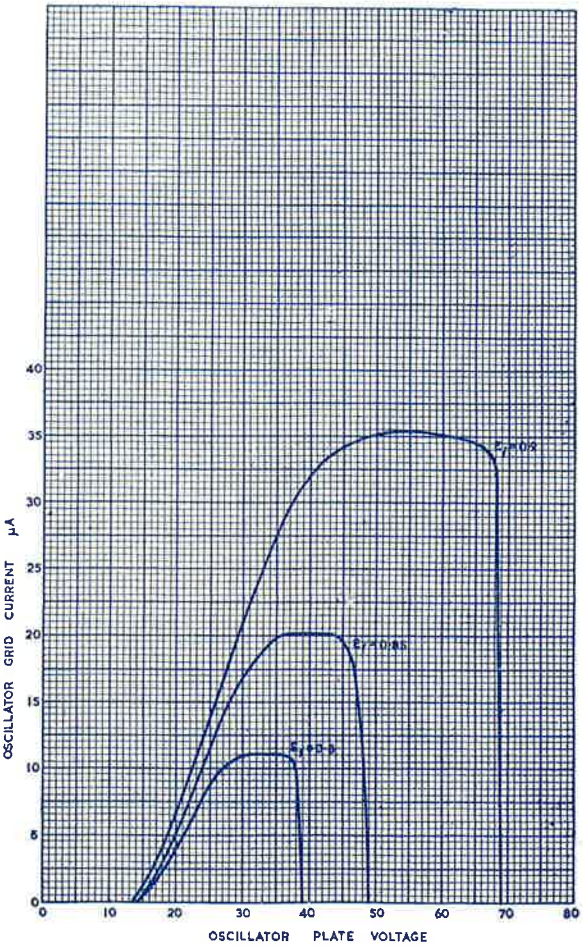


Fig. 2. Effect of oscillator plate voltage on 1R5 oscillator grid current in 100,000 ohm resistor for different values of filament voltage.

If the voltage on grid 1 is increased or decreased slightly when saturation plate current is flowing the plate current is not affected, so that the transconductance of the valve is zero. Thus, the flat section of each curve in Fig. 1 represents an operating region in which the valve has zero transconductance.

The result of these saturation effects is that as filament voltage is reduced, the oscillator plate voltage must be kept *below* some particular value if oscillation is to be maintained.

Fig. 2 shows the effect, with three different values of filament voltage, of plate current saturation on oscillator grid current in a receiver. The way in which oscillation stops when oscillator plate voltage is excessive for a particular filament voltage is clear. From the point of view of the receiver designer it is noticeable that for any value of filament voltage the plate voltage can be reduced by a considerable margin from the critical region without loss of oscillator grid current.

Fig. 3 presents similar information on another 1R5 valve in a manner which is closer to normal receiver operation. By plotting oscillator grid current against filament voltage for different values of plate voltage, it is shown that provided the filament voltage is sufficient, oscillator grid current increases rapidly with increasing oscillator plate voltage.

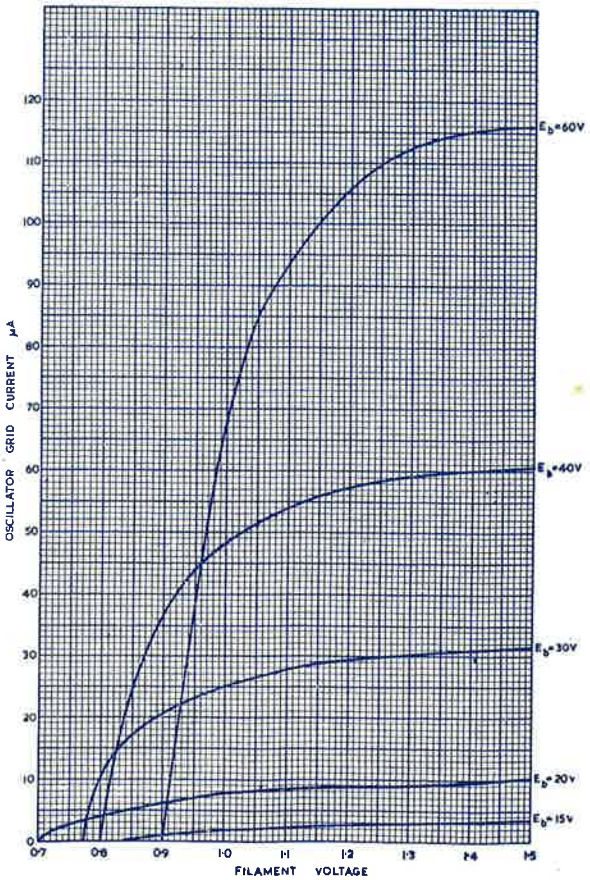


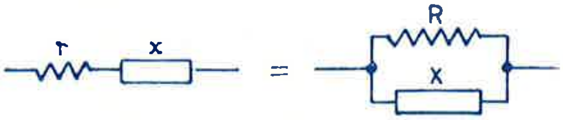
Fig. 3. Effect of filament voltage on 1R5 oscillator grid current in 100,000 ohm resistor for different values of oscillator plate voltage.

However, if the oscillator is to continue operating to a low filament voltage the plate voltage must be progressively decreased. The limit occurs when the plate voltage is insufficient to draw the plate current necessary to give an oscillator transconductance sufficient to maintain oscillation. Thus, with a plate voltage of 15 volts the plate current will not maintain oscillation below a filament voltage of 0.85 volt even although saturation does not occur, whereas with a plate voltage of 20 volts oscillation continues below 0.75 volt.

In a particular design a compromise must be made between the requirements of sensitivity at full battery voltage, current drain and the maintaining of oscillation to low battery voltages. This compromise may be complicated by the independent replacement of A and B batteries.

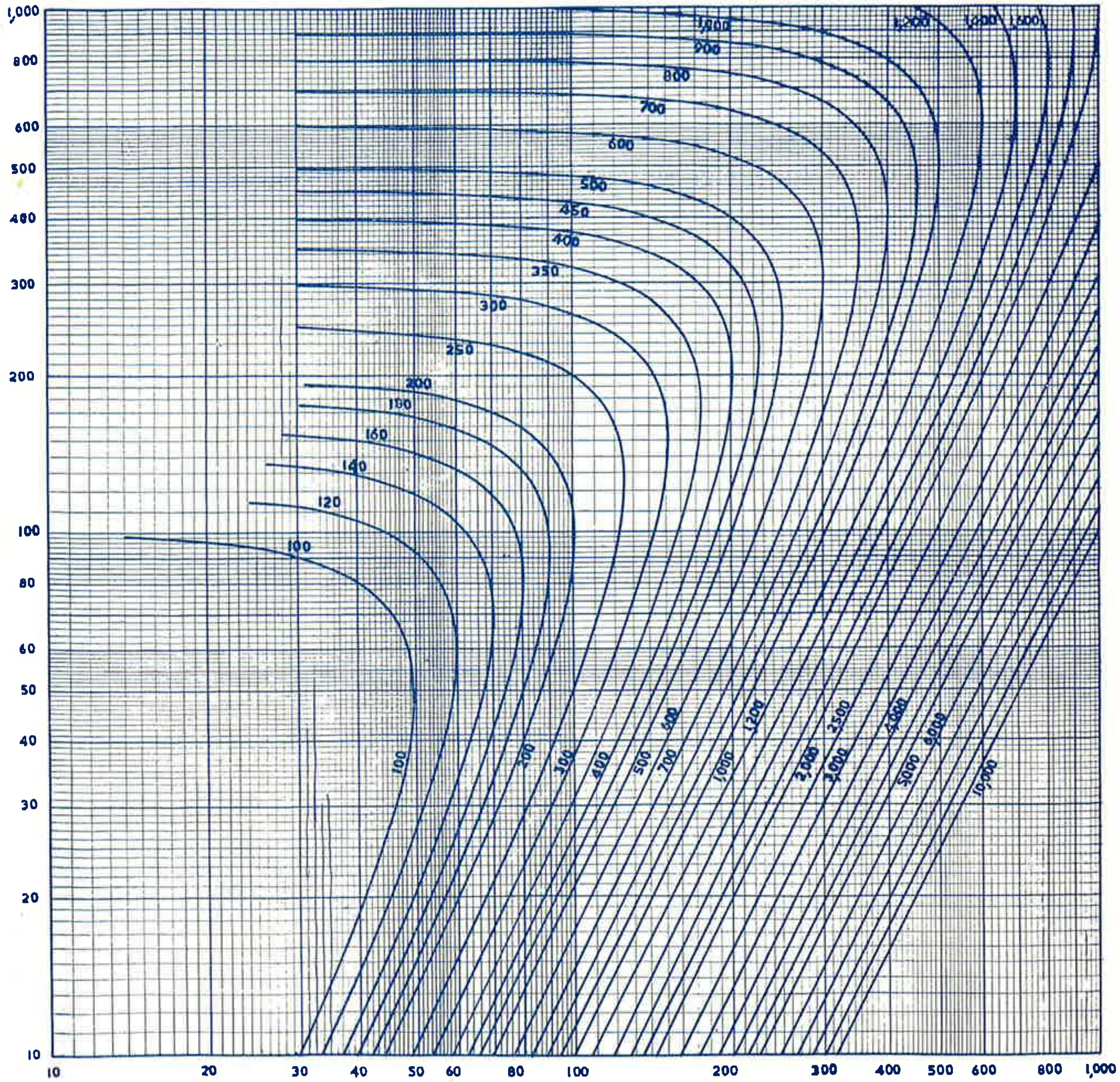
IMPEDANCE CONVERSION CHARTS

Charts supplied by D. Macdonald, A.W.A., Ashfield.



1. Series to Parallel.

Use
x to obtain R
and
r to obtain X.



Use r to obtain R and x to obtain X.

IMPEDANCE CONVERSION CHARTS

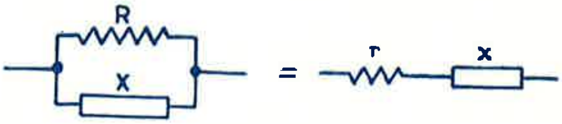
Example: Assume a parallel circuit with R = 1000 X = 500.
r is found by locating intersection of R = 1000 (on vertical scale) with X = 500 (on the horizontal scale) and reading r = 200 from curves. The value of x is found by interchanging the axes, giving x = 400. The same principles apply when using the Series to Parallel Chart.

Use

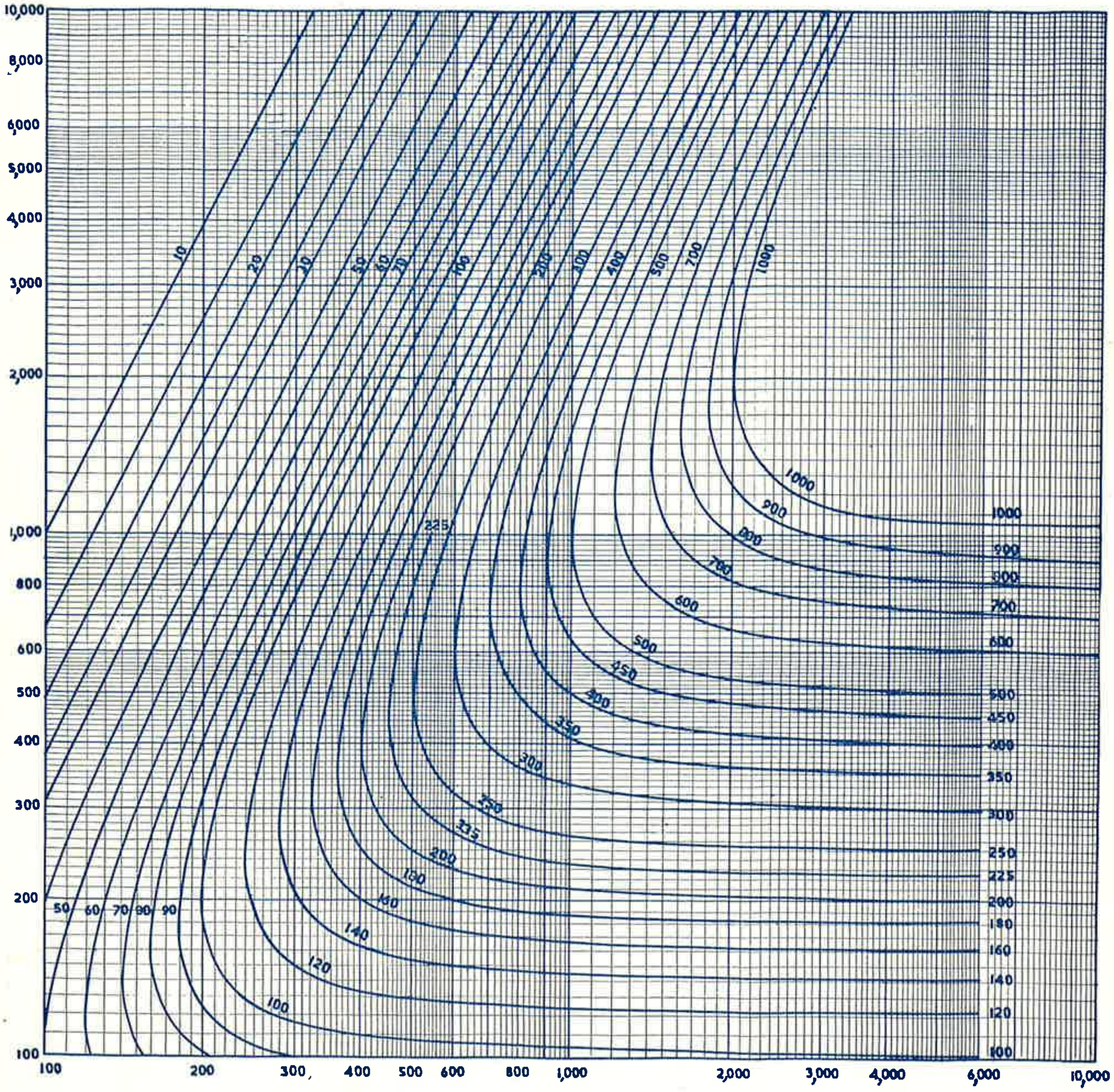
R to obtain r

and

X to obtain x



2. Parallel to Series.



Use X to obtain r and R to obtain x.