The Measurement of Microphony in Valves

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Up to the present the reduction of the microphony in valves has been very much regarded as a matter of trial and error. However, it is becoming more and more important, so that more definite methods of microphony detection have become necessary as an aid to better valve design.

An early method of investigation of a purely qualitative nature was to connect the valve as the first stage of an audio-amplifier and give it a "standard" blow with a small hammer, the volume, pitch and quality of the audio-frequency output from a loudspeaker giving some idea of the merit of the valve. This method, though extremely crude, had the virtue of simplicity and is still used as a production test for large quantities of valves. This paper is an attempt to describe some of the methods now available for a more searching investigation into the nature and causes of microphony.

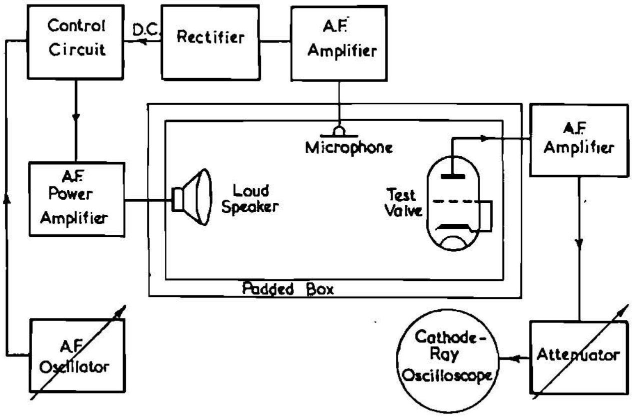


Fig. 1. Apparatus for measuring the microphonic output of a valve

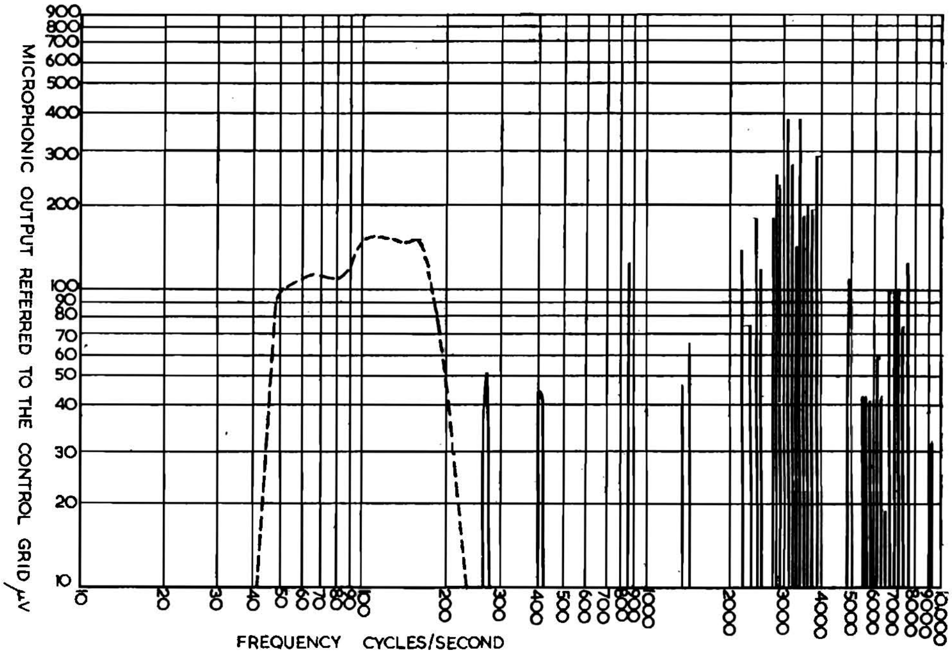
The "Howl Round" Method

A better idea of the level of microphony in a particular valve may be obtained by connecting it as the first stage of a variable gain audio-frequency amplifier while it is situated in the acoustic field from a loudspeaker fed by the output of the same amplifier. At a certain amplifier gain the acoustic feed-back from the loudspeaker to the valve will cause the loop to oscillate at one of the natural resonant frequencies of the valve structure. The amplifier gain for the threshold of oscillation (measured from the grid of the test valve) is then taken as a *figure of merit* for the valve. The disadvantages of this simple and convenient method are that both the frequency and the gain level of oscillation depends on the overall phase shift in the "loop", and particularly on the spatial relationship between the loudspeaker and the test valve.

The Variation of Microphonic Output with Frequency

An attempt has been made by previous workers to determine the absolute microphonic performance of a valve by relating its electrical output to the frequency and intensity of a sound field in which it is situated. A schematic diagram of a similar apparatus used by the author is shown in Fig. 1. The test valve, functioning as an amplifier, is placed in the acoustic field from a loudspeaker in a chamber which is padded in an attempt to reduce acoustic standing waves. The microphonic output from the test valve is amplified a known amount and then displayed on a C.R.T. screen. The acoustic pressure within the padded chamber is kept approximately constant by an audio-automatic volume control (A.V.C.) system. The loudspeaker output is controlled by the A.V.C. voltage applied as bias to a variable conductance valve in the loudspeaker driving amplifier. This A.V.C. voltage is the rectified output from a second amplifier fed from a crystal microphone in the sound field from the loudspeaker. Thus an increase in sound output above a fixed level increases the negative

Fig. 2. Microphonic output from high slope miniature pentode



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bias on the variable conductance valve and so tends to reduce the loudspeaker output again, partially counteracting the original rise.

To test a valve, the frequency of the sound wave excitation is varied slowly through the audio-range and the valve output is noted at those frequencies at which an internal resonance is excited. The microphonic performance is most conveniently quoted as the voltage input to the test valve grid to produce an anode current modulation equal to that produced by the microphony. A typical pentode valve response diagram is shown in Fig. 2. It is usually found that some of the low frequency responses are very flat and may hardly be termed resonances, while those above, say 1kc/s, have a very high Q, being excited over a frequency band of only a few cycles. The method, though giving a good indication of the behaviour of the valve is not an absolute measure of microphony; for unfortunately, owing to standing waves, the sound pattern within the padded chamber is by no means uniform. The audio A.V.C. system keeps the sound pressure at the face of the crystal microphone approximately constant, but the pressure at the test valve may vary over a wide range. The method might be made absolute if the loudspeaker, test valve, and controlling microphone were situated in an "acoustically dead" room.

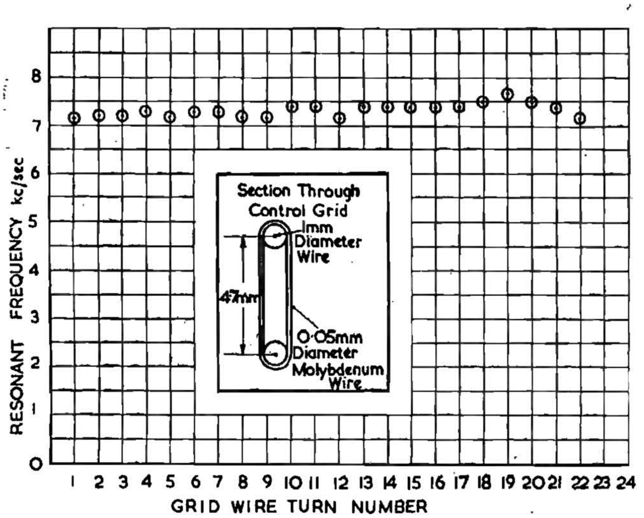

Fig. 3. Resonant frequency of individual control-grid wires of a miniature pentode

Location of the Vibrating Element

Before structural changes in a valve can be made to reduce microphony it is essential to know which portion of the valve assembly is responsible for the microphonic output at a particular frequency.

OPTICAL METHODS

The valve structure may be observed stroboscopically while subjected to vibration and the offending portion detected visually. With the high gain miniature valves now in production, movements of less than a thousandth of an inch in grid or cathode structure will modulate the electron stream appreciably and it will be necessary to use a microscope to detect them.

Observation through the glass envelope of the valve is often difficult because the anode, shield, or the getter patch may obscure the inner electrodes. Valve electrodes, particularly the cathode, often become loose in their micas and then may refix themselves, so that a particularly troublesome vibration may cure itself while the effect is being investigated. Breaking open the envelope on the other hand, destroys the valve, and may also in the process remove resonances or alter the microphonic performance in other ways.

The resonant frequencies of the elements within the valve can, in theory, be calculated, but in practice the mathematics soon become very involved. For instance, calculation of the resonant frequency of grid wires is difficult, since they often have complex shapes, unknown tensions, and indeterminate mechanical properties. However, these frequencies may be found experimentally as follows. The grid structure, consisting of the two support wires and the grid wire helix, is cemented to a small moving coil such as those found in moving coil earphones. The coil is replaced in the field of its permanent magnet and driven by a powerful audio-oscillator of variable frequency. The wires are observed through a low-power microscope and as the resonant frequency of each individual wire is reached, the wire springs into vibration and becomes blurred. The spread of resonant frequencies in the wires of the control grid of a miniature R.F. pentode whose performance is shown in Fig. 2 may be seen in Fig. 3.

THE BRIDGE METHOD

It has been suggested by Dr. E. G. James, of the G.E.C. Laboratories, that the capacitance change produced between a vibrating electrode and its neighbours might be used as a method of locating individual vibrations.

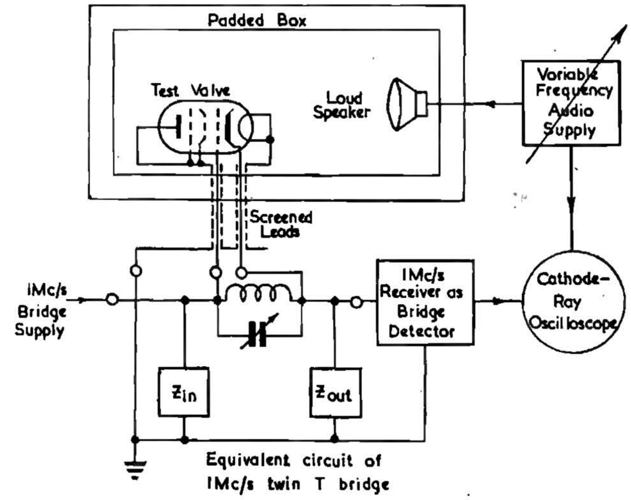

Fig. 4. Apparatus for microphony detection by means of a capacitance bridge

A highly sensitive capacitance bridge of the Twin-*T* type[1] was found to be suitable for this purpose and the 1Mc/s bridge used could detect a capacitance change of 0.00003pF. This type of bridge measures the capacitance and conductance between two, live terminals to earth.

The same acoustical excitation system is used as in Fig. 1, while the valve and bridge connexions are as shown in Fig. 4.

A pair of adjacent valve electrodes such as the control and screen grids are connected to the live terminals of the bridge through two lengths of coaxial cable, the remaining electrodes being earthed to the cable screening. The coaxial cable connexions are used primarily to reduce the stray capacitance between the live wire terminals so that variation in these strays will not affect the balance of the bridge.

Clearly the bridge will become unbalanced cyclically when a natural frequency of vibration of one of the two live electrodes is excited. The frequencies and approximate magnitudes of the bridge unbalance are recorded for each pair of adjacent electrodes in the valve, the results being presented as in Fig. 5.

If a capacitance change occurs at the same frequency in two adjacent pairs of electrodes it may be concluded that it is the common member which is vibrating. It may be argued that every vibration should produce an unbalance in two different pairs of electrodes at the same frequency, whereas in practice, sometimes only one is detected. This is probably due to the capacitance unbalance being too small to be detected in the second pair. It is found in practice that harmonics in the loudspeaker output also excite vibrations in the valve, and it is therefore, advisable to check this by comparing the output of the bridge detector aurally with the output from the loudspeaker exciting the test valve. Thus vibrations due to loudspeaker harmonics may be separated from those due to the fundamental, and a true picture of the resonant frequencies obtained. The output from the bridge when a resonance is excited is an amplitude modulated 1Mc/s signal. If the resonance inside the valve is of the order of 10kc/s then the bandwidth of the radio receiver used as the bridge detector must be at least this, for even single sideband reception.

Conversely, there are vibrations within the valve which change the capacitance between the electrodes, but may not necessarily modulate the electrons stream sufficiently to be detected. Anode vibrations in a pentode are an obvious example of this.

The frequencies at which microphony is most troublesome are those below 1,000c/s, for vibrations above this frequency may be prevented from reaching the valve by mounting it in a special resilient holder.

Below 1,000c/s one of the most common causes of microphony is a loose cathode. The cathode cannot be rigidly held at each end since it needs to expand and contract with the rise and fall of temperature. If prevented from expanding the hot cathode will "bow" or bend as it becomes mechanically weak at 800° C. On the other hand if one end passes through a tight fitting mica which still allows the cathode to slide it may wear itself loose after a number of heating cycles. One possible method of overcoming this difficulty is to fix it to the two micas, securely at one end and by thin flexible strips at the other.

The variation in microphonic performance between valves of the same type, produced concurrently on one assembly line may be as large as that between different types. Thus, to get a fair picture of the performance of any valve type a large number of specimens must be tested. It should then be possible to select the troublesome frequency ranges and attempt to isolate the offending portion of the structure by the optical or the capacitance method. The particular mode of vibration may perhaps be detected by the optical method, but if this is not possible, it must be located by trial and error. The field of possibility has, however, been considerably reduced and successive modification to the structure will eventually provide a solution. Thus the design of a valve with low microphony is a long and tedious process, but research continues in an attempt to produce a truly non-microphonic valve.

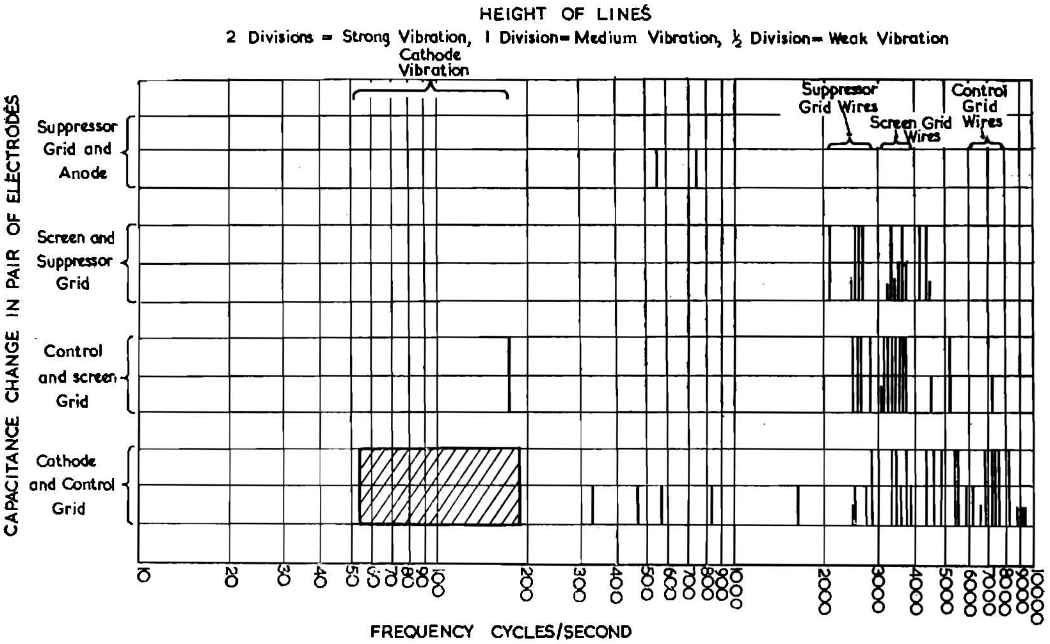

Fig. 5. Variation with frequency of capacitance between adjacent electrodes in a miniature pentode

Discussion of Results

Fig. 2 shows the frequency response of a typical miniature B7G based pentode when used as an amplifier, and Fig. 5 the corresponding mechanical resonances as detected by the bridge method.

It is obvious that the large microphone output centred on 100c/s is due to a vibration of the cathode as shown by the capacitance change method.

Similarly the outputs at about 7,000c/s are due to control grid resonances (probably the grid wires themselves). This is borne out by actual measurement of the control grid wire resonant frequencies which are shown in Fig. 3.

There are, on occasion, microphonic outputs which have no detectable capacitance change associated with them, e.g., a grid wire vibration in the plane of the grid will have a definite effect on the space current, but a very small effect on the capacitance between grid and cathode or screen.

Acknowledgment

In conclusion, the author wishes to tender his acknowledgments to the M.-O. Valve Co., Ltd., on whose behalf the work described was carried out.

REFERENCE.

[1] JAMES, E. G. and PROCTOR, R. F. A Radio-Frequency Capacitance and Inductance Bridge. *J.I.E.E., 92.* Part III. 287. (1945).