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RCA RADIOTRON
D I V I S I O N

APPLICATION NOTE No.88

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APPLICATION NOTE
ON
HUM IN HEATER-TYPE TUBES

A high-gain audio-frequency amplifier is usually critical as to hum because a small hum voltage on the grid of the first tube is amplified by all the stages in the amplifier. To reduce the hum output of such an amplifier to a very low level, it may be necessary to observe special precautions in the design of the first stage. Hum voltage introduced by the heater to the grid of the second tube is of secondary importance, although hum-reducing precautions may also be observed in the design of this stage.

This Note discusses, first, various causes of hum introduced by a-c operated heaters in heater-type tubes and, second, practical methods for reducing this hum. It will be assumed that tubes and associated wiring are adequately shielded and that the power-supply unit is adequately filtered.

There are several instances when special circuit precautions may not prove adequate to reduce hum. In high-gain amplifiers, for example, the effects of possible variations between tubes of the same type are greatly magnified by the gain of the amplifier. The type 1603 is recommended for use in such cases. This tube type is a sharp cut-off pentode having characteristics similar to those of the 6J7 or 6C6, and is especially designed for applications which are critical as to hum or microphonics. Only one special precaution need be observed in using the 1603: connect a 100- to 500-ohm potentiometer across the heater and ground the adjustable arm. With screen connected to plate (triode arrangement), the 1603 has characteristics similar to those of the 6C5.

Sources of Hum

Hum may be introduced by an a-c operated heater because of: (1) the presence of a magnetic field; (2) capacitive coupling between heater and other electrodes; (3) leakage through heater-cathode insulation; and (4) emission from the heater to other electrodes. It should be noted that the effects of magnetic fields, capacitive coupling, and heater emission are appreciable only when the gain of the amplifier is high. In a medium-gain amplifier, such as used in a radio receiver, only the effects of heater cathode-leakage may be important.

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(1) Hum Due to Magnetic Field

When the heater is fed from a source of alternating voltage, the alternating current that flows through the heater may set up an alternating magnetic field of appreciable magnitude. Because this magnetic field accelerates the electrons in a direction at right angles to that of the electrostatic fields, electrode currents are modulated. Fig.1 shows one manner in which an alternating magnetic field may introduce hum in the plate circuit. Consider the usual direction of electron flow as that shown by A. Then, during one half of the heater-current cycle, the beam is deflected upward (B); if part of the beam leaves the plate, the plate current is reduced. Similarly, during the second half of the cycle, the beam is deflected downward (C), to reduce the plate current again. This change of beam position gives rise to a hum current having a large double-frequency component. This hum current flows through the load, and causes hum voltage on the grid of the succeeding tube.

The ideal remedy for high hum due to a magnetic field is to use d-c on the heater. With a-c heater excitation, it is possible to reduce hum by reducing the value of load resistance, but this expedient is accompanied by a loss in gain. When it is not practicable to use d-c on the heater, the type 1603 is recommended in preference to other tube types.

(2) Hum Due to Capacitive Coupling

Fig.2A is a simplified circuit of an a-f amplifier showing capacitive coupling between control grid and each terminal of the heater. When one side of the heater (B) is grounded, heater voltage (E_h) is applied to C_1 and R_g in series. The fraction of E_h that appears across the grid resistor, R_g , is amplified by the tube and passed on to the succeeding stages. Because the reactance of C_1 is very high compared to the resistance of R_g , the hum voltage that appears across R_g is E_{gh} :

$$E_{gh} = E_h R_g \omega C_1$$

For example, in a triode let $R_g = 2$ megohms, $\omega = 2\pi f$ or 377 radians for $f = 60$ cps, $C_1 = 0.5 \mu\mu f$, and $E_h = 6.3$ volts (rms). Under these conditions, E_{gh} equals 2.38 millivolts. When this small hum voltage is multiplied by the gain of the amplifier, the output hum voltage is appreciable.

Two simple remedies are available when the capacitance of C_2 is very small: (1) reduce the value of R_g , or (2) ground terminal A of the heater instead of terminal B. However, when the capacitance of C_2 is appreciable, changing the ground terminal of the heater may not reduce the hum to an acceptable level. In this case, it is necessary to balance out the hum voltage by connecting a potentiometer across the heater. The bridge circuit for this connection is shown in Fig.2B. In this circuit, $(R_1 + R_2)$ is the potentiometer, C_1 represents the capacitance of the grid to one terminal of the heater, and C_2 represents the capacitance of the grid to the other terminal of the heater. When the bridge is balanced, the hum voltage across R_g is zero.

Most of the grid-heater capacitance is due to the close proximity of the grid lead and the heater leads in the stem press (in glass-type tubes) and in the base; only a small amount of grid-heater capacitance exists between the electrodes themselves. Hence, grid-heater capacitances of top-cap tubes are comparatively low. Of the tube types that have the control-grid lead terminating at a base pin, metal tubes have lower grid-heater capacitance than the corresponding glass types, because there is no stem press in metal tubes.

When it is feasible to ground one terminal of the heater in order to reduce hum, ground that terminal which is nearest the control-grid lead. Moreover, low hum due to capacitive coupling can be expected from a tube type which has its cathode lead between control-grid and heater leads, because the shielding action of the cathode lead reduces grid-heater capacitance.

Capacitive coupling from heater to plate causes plate-circuit hum. When grid-heater capacitance is low, the recommendations for reducing plate-circuit hum are the same as those discussed for grid-heater capacitance. However, it is not desirable to reduce the value of load resistance in order to reduce plate-circuit hum, because the gain of the amplifier decreases with load.

(3) Hum Due to Heater-Cathode Leakage

The resistance of the insulation between heater and cathode is finite and non-linear. Therefore, leakage current of peculiar waveform flows from heater through heater-cathode insulation and cathode-circuit impedance Z_c to ground. When Z_c is appreciable, the hum voltage across Z_c is applied to other electrodes in the tube and appears in the output. (See Fig.3)

Three remedies are suggested for this type of hum: (1) reduce Z_c to a low value by adequate by-passing, (2) obtain bias from a source that is not common to heater and cathode, and (3) bias the heater either positive or negative with respect to cathode by about 10 volts. The value of suggestions (1) and (2) is generally appreciated, but that of (3) may require further explanation. The success of (3) depends on a resistance characteristic peculiar to heater cathode insulation. Curves showing the relation between hum voltage and d-c heater bias indicate that maximum hum occurs at biases between ± 1 volt on the heater; that hum voltage falls rapidly with increasing bias; and that hum voltage remains at a constant low value for heater cathode biases greater than approximately ± 10 volts. The general shape of a hum curve is shown in Fig.4.

(4) Hum Due to Emission from the Heater

In the process of tube manufacture, it is possible for a portion of the heater to be coated with a small amount of electron-emitting material. When the potential of any electrode in the tube is positive with respect to the heater, emission from the heater to that electrode may take place.

There are two practical remedies for reducing hum due to heater emission: (1) reduce the value of impedance in the electrode circuit that is most critical as to hum (usually the control-grid circuit) and (2) bias the heater more positive with respect to cathode than any other electrode in the tube. In most cases, however, the control grid is the most critical electrode; it is only necessary, therefore, to bias the heater more positive than the control grid in order to reduce hum caused by heater emission to a low value. Instances do arise, however, when it is necessary to bias the heater as much as +50 volts with respect to cathode in order to reduce hum to an acceptable level. In such cases, it is suggested that the bias be held to the lowest acceptable value.

In some instances emission from cathode to heater causes hum. The remedy in this case is to apply a negative bias to the heater. Whether hum is caused by cathode emission to heater or by heater emission can be determined from the polarity of the heater bias that is necessary to reduce the hum. This bias should not be too high, because the effects of heater emission increase with negative heater bias.

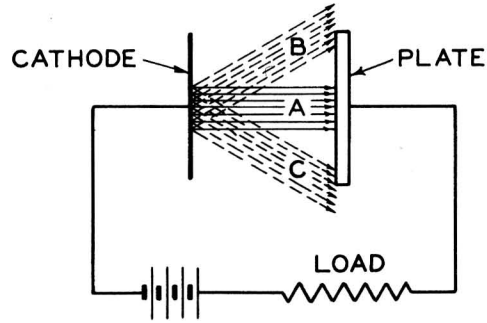


FIG. 1

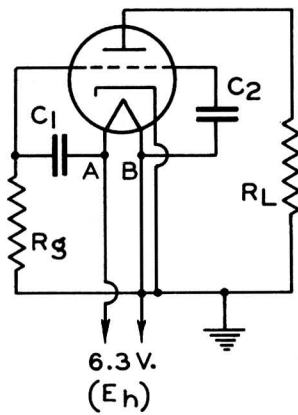


FIG. 2A

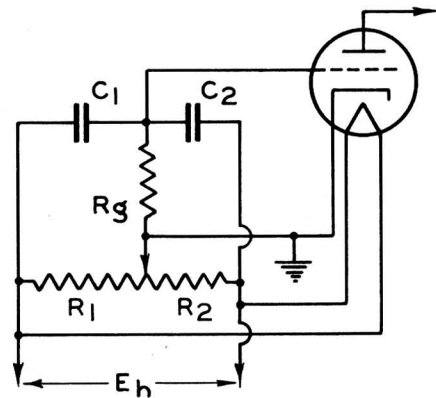


FIG. 2B

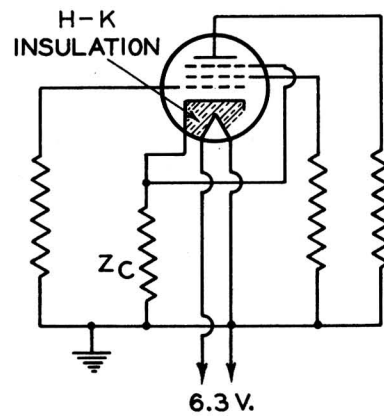


FIG. 3

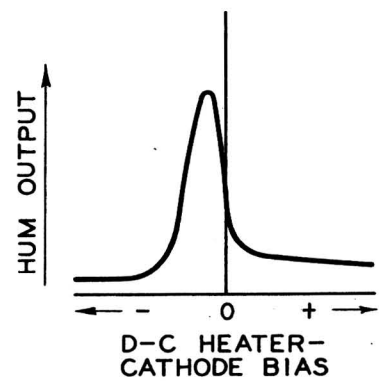


FIG. 4

The license extended to the purchaser of tubes appears in the License Notice accompanying them. Information contained herein is furnished without assuming any obligations.