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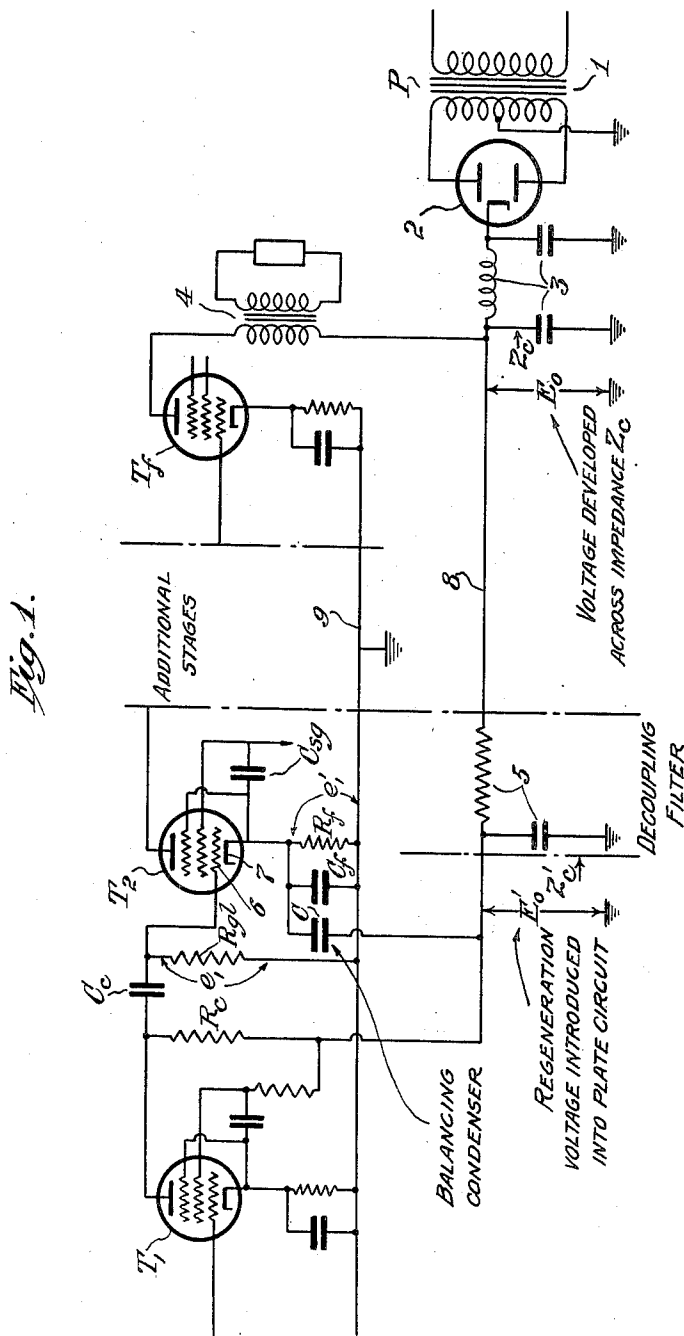
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2,364,403

REDUCTION OF LOW FREQUENCY REGENERATION AND
HUM IN MULTISTAGE AUDIO AMPLIFIERS
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Fig. 2.

EQUIVALENT CIRCUIT OF NORMAL REGENERATION

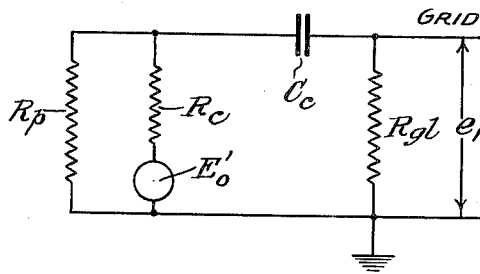
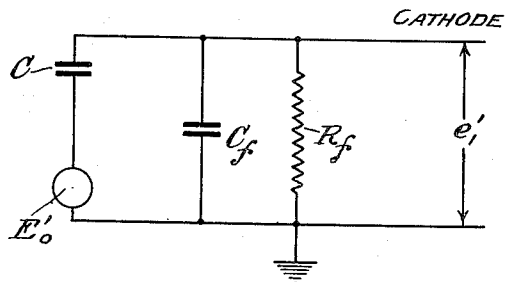


Fig. 3.

EQUIVALENT CIRCUIT OF COMPENSATING VOLTAGE



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REDUCTION OF LOW FREQUENCY REGENERATION AND HUM IN MULTISTAGE AUDIO AMPLIFIERS

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6 Claims. (Cl. 179—171)

This invention relates to new and useful improvements in audio-frequency amplifiers.

The object of the invention is to provide a simple and effective system to control low frequency regeneration by balancing the feedback to the plate circuit of a low level amplifier.

Regeneration at low frequencies arising from a plate impedance common to several stages is one of the most troublesome problems encountered in audio-frequency amplifiers. Such regeneration arises from the fact that amplified currents in the final stage of the amplifier will produce a voltage across the internal impedance of the power-supply system. If stages of lower power level use the same power supply system, this voltage developed across the internal impedance will then be inserted in the plate circuits of these low-level stages. The result is regeneration that causes either a modification of the amplification characteristics, or low frequency oscillations (motor-boating). Troubles of this sort are especially severe in the case of high-gain amplifiers having a good low frequency response.

The usual remedies for regeneration arising from a common plate impedance are to make the low frequency response of the amplifier poor and to employ decoupling filters. If these fail, separate power supplies are used for the high and low level parts of the amplifier.

In accordance with the present invention the feedback to the plate circuit of a low-level amplifier stage is balanced by an equal and opposite feedback developed across the cathode biasing resistor of the succeeding amplifier stage. This balancing system can be applied in addition to other means normally used to control low-frequency regeneration, and when properly adjusted will give a very great reduction in the net feedback.

In the drawings

Fig. 1 diagrammatically illustrates those elements of an embodiment of the invention which are necessary for a clear understanding thereof;

Fig. 2 an equivalent circuit of normal regeneration; and

Fig. 3 an equivalent circuit of the compensating voltage developed according to the present invention.

Fig. 1 shows three stages of a multi-stage audio frequency amplifier. T_1 , T_2 and T_3 are amplifying tubes in the first, second and final stages of the amplifier. Additional intermediate stages may be inserted between T_2 and T_3 . The cathode of tube T_2 is biased to ground over resistor R_r , and the resistor is shunted by the customary bias

bypass condenser C_r . P is a power supply system for the tubes of all stages and comprises a transformer 1 and a full-wave rectifier 2. 3 is the customary smoothing filter and 4 is the output transformer of the amplifier.

The amplified currents of the final or output stage T_3 develop a voltage E_o across the internal impedance Z_c of the power supply system P . This voltage, after reduction to a value E_o' by the decoupling filter 5 finds its way over path 8, and coupling resistor R_c into the plate circuit of the low level first amplifier tube T_1 . The result is a feedback voltage over coupling condenser C_c between grid 6 and cathode 7 of tube T_2 in the succeeding intermediate stage with consequent regeneration and possibly motor-boating.

In accordance with the present invention the voltage E_o' that produces the regeneration, is used to develop across cathode biasing resistor R_r of tube T_2 a voltage equal and opposite to that developed between grid and cathode of tube T_2 by the normal regeneration process. Since the bias resistor R_r is in series in the circuit from grid 6 over grid leak resistor R_{g1} , ground conductor 9, bias resistor R_r , and cathode 7 of tube T_2 , the two feedbacks will exactly cancel each other, entirely eliminating the feedback effect to the anode of T_1 .

The balancing process is accomplished by the connection of a condenser C between feedback path 8 and a point between cathode 7 and resistor R_r .

The equivalent circuit by which a feedback potential E_o' produces a voltage e_1 between grid and ground in the coupling network between tubes T_1 and T_2 of Fig. 1 is given in Fig. 2 (assuming the internal impedance Z_c of E_o' is negligible compared with R_c). A straight-forward calculation of voltage relations gives

$$e_1 = E_o' \frac{R_p}{R_c + R_p} \frac{1}{1 + \frac{R_r}{R_{g1}} + \frac{1}{j\omega C_r R_{g1}}} \quad (1)$$

The equivalent circuit by which the feedback potential E_o' produces a compensating voltage across R_r is given in Fig. 3. A solution of the voltage relations in this circuit yields

$$e_1' = E_o' \frac{C}{C + C_r} \frac{1}{1 + \frac{1}{j\omega(C + C_r)R_r}} \quad (2)$$

The tendency for the feedback E_o' to affect

stage T₁ will be eliminated when the circuit elements satisfy the relations

$$C_f = C \left[\left(1 + \frac{R_c}{R_p} \right) \left(1 + \frac{R}{R_{s1}} \right) - 1 \right] \quad (3)$$

$$C_c = (C + C_f) \frac{R_f}{R_{s1} + R} \quad (4)$$

where

R_p = plate resistance

$R = \frac{R_p R_c}{R_p + R_c}$ = resistance formed by R_p and R_c in

parallel and the remaining notation is as shown in Fig. 1. In the case of pentode tubes $R_p \gg R_c$, and these equations are approximately

$$C_f = C \frac{R_c}{R_{s1}} \quad (3a)$$

$$C_c = (C + C_f) \frac{R_f}{R_{s1} + R_c} = C \frac{R_f}{R_{s1}} \quad (4a)$$

When Equations 1 and 3 are satisfied, then $e_1' = e_1$ and the balance is complete and independent of frequency.

The equations assume that the impedance Z_c' is small compared with the coupling resistance R_c of the amplifier, and also that the screen grid bypass condenser C_{sg} is of adequate size to return substantially all of the screen current directly to the cathode. In practical amplifiers, these assumptions are almost perfectly realized, and to the extent that this is the case, the balance is independent of frequency.

In a typical example, one might use the values of 0.50 megohm for coupling resistor R_c , 0.5 megohm for grid leak resistor R_{g1} , 1700 ohms for bias resistor R_f and 4.2 mfd. for bias bypass condenser, i. e., the same values that would be selected on the basis of usual considerations. The required value of balancing condenser C and coupling condenser C_c are then computed by Equations 3 and 4, respectively. The resulting numerical values are (assuming that R_p is infinite): $C = 4.2$ mfd., and $C_c = 0.014$ mfd.

It will be seen, therefore, that my novel arrangement of eliminating regeneration caused by a common plate impedance is both simple and effective. It requires the addition of only one new circuit element, a condenser C of reasonable size, together with control of the proportions of certain other circuit components. This balancing arrangement will reduce the regeneration by 30 to 40 db. without difficulty, and even greater reduction can be achieved by careful adjustment of circuit constants.

A system such as herein described for reducing regeneration arising from a common plate impedance is also effective in reducing the hum voltage that an incompletely filtered power-supply system will introduce into an amplifier stage. This is so because the balancing arrangement acts to prevent voltage E_o' existing in the power-supply system P from producing a potential between the grid and cathode of the tube T₂. Thus the above discussion, although carried out on the assumption that E_o' is a regeneration voltage, actually applies equally well when this is a hum voltage, and the hum will be reduced to the same extent as regeneration.

What I claim is:

1. In a multi-stage audio frequency amplifier, an amplifier tube in each stage having a cathode and an anode, a path over which both the sup-

ply voltage and a voltage developed by amplified currents in the final stage are fed to the anode of the tube in the first stage, a cathode biasing resistor for the tube of the second stage, and means for developing across said resistor a voltage equal and opposite to said first mentioned voltage to balance the latter, said means including two condensers of predetermined value connected in series with one another between the two sides of said voltage feeding path, and a connection from the common junction point of said condensers and the cathode of said second stage tube.

2. In a multi-stage audio frequency amplifier, an amplifier tube in each stage having a cathode and an anode, a power supply system for all said tubes, a path over which a voltage developed by amplified currents in the final stage across the internal impedance of said power system is fed back to the anode of the tube in the lowest level stage, a cathode biasing resistor for the tube of the intermediate stage succeeding the last mentioned tube, and means for developing across said resistor a voltage equal and opposite to said first mentioned voltage to balance the latter, said means including two condensers of predetermined value connected in series with one another between the two sides of said voltage feeding path, and a connection from the common junction point of said condensers and the cathode of said intermediate stage tube.

3. In a multi-stage amplifier, an amplifier tube in each stage, a power supply system for all said tubes, a feedback path to the anode of the tube in the first stage over which is transmitted the voltage developed by amplified currents in the final stage across the internal impedance of said power system, a decoupling filter in said path, a connection including a coupling condenser between the tube in the first stage and the tube in the second stage, a biasing resistance for the tube in the second stage, and means including a condenser for developing across said biasing resistance a voltage equal and opposite to said first mentioned voltage to balance the latter, said last mentioned condenser being connected from the positive side of said path of said power system to the cathode end of said biasing resistance, whereby the feedback voltage reaching said anode of said first stage tube and passing through said coupling condenser is effectively balanced out.

4. In a multi-stage audio frequency amplifier, an amplifier tube in each stage having an anode, a cathode and a grid, a power supply system for all said tubes including a transformer and a rectifier, a path from said power supply system to the anode of the tube in the first stage and over which is transmitted the voltage developed by amplified currents in the final stage across the internal impedance of said power system, a decoupling filter and a coupling resistance in said path, a connection including a coupling condenser between the anode of the tube in the first stage and the grid of the tube in the second stage, a connection between the cathode and grid of the second tube including a grid leak and a biasing resistance, a bias bypass condenser shunted across said biasing resistance, and a balancing condenser connected from the connection between the biasing resistance and the cathode of the second tube and the positive anode-feeding side of said feedback path developing across said biasing resistance a voltage equal and opposite to

said first mentioned voltage to balance the latter.

5. In a multi-stage amplifier, an amplifier tube in each stage having an anode, a cathode and a grid, a power supply system for all said tubes, a path from said power supply system to the anode of the tube in the first stage, a connection including a coupling condenser between the anode of the tube in the first stage and the grid of the tube in the second stage, a connection between the cathode of the second tube and ground including a biasing resistance, and a condenser connected between the biasing resistance and said path developing across said biasing resistance a voltage equal and opposite to the hum voltage of the power supply system to balance the latter.

6. In a multi-stage amplifier, an amplifier tube in each stage, a common power supply system for all of said tubes, a feedback path from the power supply system to a lower level tube over which parasitic voltage developed across said system is transmitted to the grid of said lower level tube, a connection between the cathode and grid of said lower level tube including a grid leak, a biasing resistance and a bypass condenser shunted across said biasing resistance, and a balancing condenser connecting the cathode of said tube and the feedback path, developing across said biasing resistance a voltage equal and opposite to said parasitic voltage to balance the latter.

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