Aug. 28, 1945. W. R. KOCH 2,383,867

POWER OUTPUT AMPLIFIER CIRCUIT

Filed Jan. 13, 1943

Fig. 1.

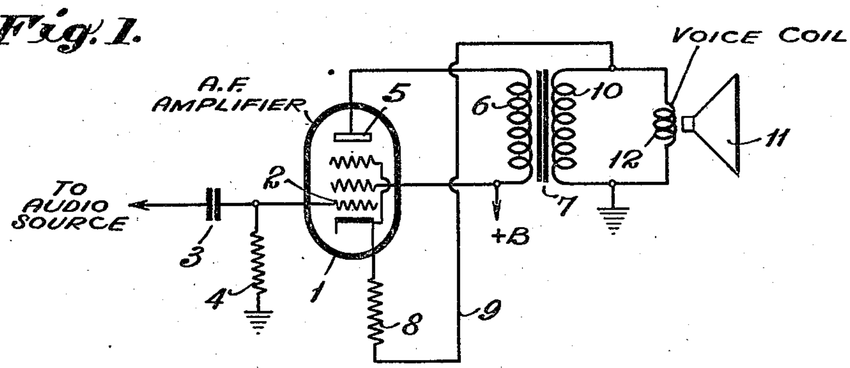


Fig. 2.

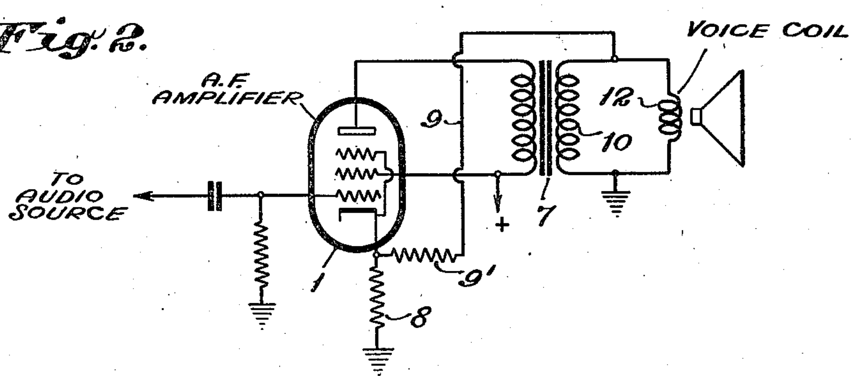
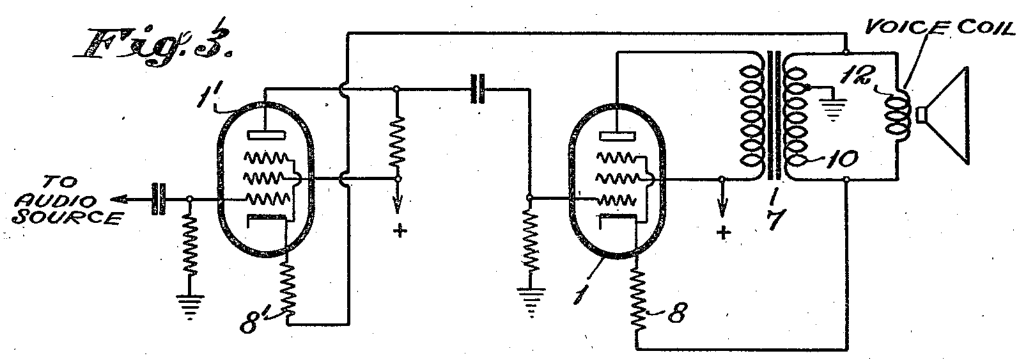


Fig. 3.



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POWER OUTPUT AMPLIFIER CIRCUIT

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10 Claims. (Cl. 179—171)

My present invention relates to audio amplifier circuits, and more particularly to an improvement in the power output amplifier circuit of a radio receiver.

It is customary to omit the large bypass condenser across the cathode resistor of the power output tube of compact radio receivers. This omission is made because of the fact that the receiver cost is increased when the bypass condenser is employed. Additionally, it is found that hum disturbance is increased when a large bypass condenser is connected across the cathode resistor of the power output tube. The problem becomes increasingly acute as the size of the receiver decreases. For example, with radio receivers of so-called "dwarf" size, there would be a disproportionate relation between the cost of the power output tube cathode resistor bypass condenser and the cost of the rest of the system. Practical experience with this economy measure, however, has demonstrated that there is a loss of audio amplification, and the maximum power output of the receiver is not secured. This is due to the fact that audio degeneration exists at the power output tube due to the cathode-to-ground impedance. In the case of radio receivers which are sufficiently small, such reduction in audio output is a serious disadvantage.

Accordingly, it may be stated that it is one of the main objects of my present invention to provide a simple and economical method of constructing a radio receiver utilizing no bypass condenser across the cathode resistor of the power output tube, but wherein greater gain and higher maximum output power is secured at no increase in cost.

Another important object of the invention is to provide a method of introducing positive regeneration into an audio amplifier stage to cancel negative feedback due to an unbypassed cathode resistor of the stage, and the positive regeneration being derived from the voice coil of the audio reproducer.

Another object of this invention is to compensate for degenerative effects produced upon the omission of the customary bypass condenser across the cathode resistor of an audio power output tube, the compensation being accomplished by simply connecting the cathode resistor to the voice coil circuit of the reproducer, and the impedance of the voice coil being so chosen that the voltage from the voice coil will be sufficient to balance out the degenerative voltage developed across the unbypassed cathode resistor.

Still another object of my invention is to provide an audio amplifier whose output tube has an unbypassed cathode resistor, there being introduced positive feedback to offset, in part or in full or in more-than-full, the negative feedback due to the unbypassed cathode resistor.

Yet another object of the invention is to provide a regenerative audio feedback from the voice coil circuit of a radio receiver to the unbypassed resistor in the cathode circuit of the power output tube, and there being utilized at least one attenuating resistor such that the desired alternating current voltage is introduced into the cathode circuit while maintaining the necessary direct current resistance for proper bias.

Yet another object of the invention is to provide an unbypassed cathode resistor in each of a plurality of cascaded audio amplifier tubes, there being provided an intermediate tap on the secondary of the transformer feeding the voice coil of the audio reproducer, and the voltage on one side of the intermediate tap being introduced into the first of the audio amplifier tubes, while that on the other side of the tap is introduced into the cathode circuit of the power output tube so that degeneration by both cathode resistors is compensated for.

Still other objects of my invention are to improve generally the economy, simplicity and efficiency of radio receivers of small size, and more especially to provide a power output stage for a radio receiver which has high gain and low manufacturing cost.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention, itself, however, as to both its organization and method of operation, will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit embodying the invention;

Fig. 2 illustrates a modification;

Fig. 3 shows still a further modification.

Referring, now, to the accompanying drawing, wherein like reference numerals in the different figures indicate similar circuit elements, the numeral 1 in Fig. 1 designates an electron discharge tube amplifier. This tube is by way of illustration indicated as being of the pentode type. Of course, the present invention is not limited to any particular type of tube, since triodes, tetrodes, or other types of tubes well suited for audio amplification may be employed. The control grid 2 of tube 1 is shown connected through the audio coupling condenser 3 to a lead which is indicated as being adapted for connection to any desired audio signal source. While specifically my invention is adapted for use in a radio receiver system of the midget or compact type, yet it is not restricted thereto. My invention contemplates any source of audio signals. It is to be understood that the coupling condenser 3 may be connected to the output electrodes of a prior audio amplifier tube. The direct current return resistor 4 is connected from grid 2 to ground.

Plate 5 is connected through the primary winding 6 of audio output transformer 7 to a point of positive potential +B. The source of positive potential is not shown, and may be any desired point on a battery source, or one on the usual power supply network of an alternating current-operated receiver. The negative terminal of the power supply is returned to ground. The screen grid of tube 1 may also be connected to the +B potential point, as shown in Fig. 1. The cathode resistor of the audio tube 1 is indicated by numeral 8, and is shown connected to ground through a path which comprises the lead 9 and the secondary winding 10 of transformer 7. Hence, the lower end of coil 10 is indicated as being grounded. The audio reproducer is schematically indicated by the numeral 11, and it is to be understood that the schematic representation is adopted because the construction of the reproducer is very well known to those skilled in the art.

The voice coil 12 of the reproducer is represented as being connected in shunt across the transformer secondary 10. As is well known to those skilled in the art, the reproducer diaphragm 11 is actuated in response to the movements of the voice coil 12. It is again emphasized that the representation in the figure is purely schematic, and that usually the voice coil 12 will be wound around the rear portion of the diaphragm so as to be mobile therewith.

In small radio receivers, and in general in audio amplifier systems where all the components are greatly reduced in size, the usual electrolytic condenser across the cathode resistor 8 is omitted. If the bypass condenser is employed the cost of the system is materially increased, and even brings up hum disturbance because of the increased amplification. However, the omission of the bypass condenser across resistor 8 introduces degeneration due to the cathode-to-ground impedance. The degeneration cuts down the audio amplification and the maximum power output. When such a condenser is connected across the cathode resistor the amplification is increased because degeneration is reduced, and for this reason hum in the plate circuit of the preceding tube becomes more audible. Such a resistance-capacitor combination does not change impedance very rapidly with frequency, so that if the capacitor is small enough so that it will not remove degeneration for hum frequencies, the middle audio frequencies will not be benefited by it to any appreciable degree. Because of the more rapid change of response with frequency in the output transformer at the low frequency end of its range, and the phase shift occurring there, the voltage introduced into the cathode circuit by the transformer will cancel out the voltage introduced there by the space current of the tube only over the medium frequency range, but not at the low or hum frequency region. According to my invention greater gain is provided at higher maximum output power, with substantially no increase in cost.

It is merely necessary to connect the lower end of the cathode resistor 8 to the voice coil circuit by lead 9. Considerable increase in gain and power output are secured. The voice coil connections are made so that the audio voltage introduced into the cathode circuit of tube 1 by the voice coil 12 is of opposite direction to that caused by the cathode current flowing through cathode resistor 8. If, now, the impedance of voice coil 12 is properly chosen, the audio voltage from the voice coil, applied over lead 9 to the cathode circuit of tube 1, will be just sufficient to balance out degenerative feedback developing across the unbypassed resistor 8. It will, therefore, be seen that I have provided a method of producing positive regeneration in the cathode circuit of the power output tube 1 to cancel the negative audio feedback voltage due to the cathode resistor 8.

Where the voice coil impedance is too high, the circuit shown in Fig. 2 may be employed. In this circuit the lead 9 is connected to the cathode end of loading resistor 8, whose lower end is grounded, through a bias resistor 9'. In actual tests a power output stage of the type shown in Fig. 2 gave a 2:1 improvement in sensitivity and power output. There was employed in the circuit a power output tube of the 5OL6GT type and a voice coil which had a resistance of 12 ohms. With a slightly lower voice coil resistance, the circuit of Fig. 1 would have been superior.

In the circuit of Fig. 1, the voice coil impedance is deliberately chosen so that the audio voltage fed back to the cathode circuit is just sufficient to give the desired amount of feedback to balance out the degenerative voltage. When a higher resistance voice coil is used, the resistor 9' of Fig. 2 functions as a bias resistor so that only the desired alternating voltage is introduced into the cathode circuit, and the necessary direct current resistance to produce a proper bias is maintained. The attenuation occurs through resistors 9' and 8 forming a voltage divider. Resistor 9' could have a value of 150 ohms, and resistor 8 a value of 560 ohms. It should be noted that the hum is not regenerated, not only because the output transformer 7 does not pass the hum frequencies efficiently, so that only small amplitudes of these frequencies get back to the cathode circuit, but also because their phase is shifted so that they do not cancel the voltage produced in the cathode by the space current of the tube.

In Fig. 3 I have shown a further variation of the circuit of my invention. Here the winding 10 has an intermediate tap provided thereon. The voltage across one portion of the tapped coil is fed in regenerative phase to the cathode circuit of one audio tube, while the voltage across the other portion of the coil is applied regeneratively to the cathode circuit of a second audio tube. In Fig. 3 the power output tube 1 has its unbypassed cathode resistor connected to the lower end of voice coil 12. The cathode resistor 8' of the preceding audio amplifier tube 1' is connected to the upper end of voice coil 12. Hence, the usual bypass condensers across resistors 8 and 8' are omitted, and the audio feedback thereto from the voice coil feed winding compensates for the degeneration produced by the unbypassed cathode resistors. Condenser-resistance coupling is used between the tubes.

If desired, the audio voltage developed across the impedance of the voice coil may be introduced solely into an audio stage preceding the power output stage.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In combination with a power output stage of the type having a tube provided with an unbypassed cathode resistor, a reproducer having a voice coil, means coupling the voice coil to the tube output electrodes, additional means, including solely said coil in series with said resistor in the space current path of the tube, whereby alternating voltage developed across the coil is applied directly to the tube input electrodes in phase and magnitude such as to compensate for degenerative effects produced by the unbypassed resistor.

2. In a radio receiver of the small type wherein the audio power output stage includes a tube having input and output electrodes, a reproducer voice coil coupled to the output electrodes and an unbypassed bias resistor common to the input and output electrodes; the improvement which is characterized by means for applying audio voltage developed directly across the voice coil directly upon said input electrodes in regenerative phase thereby to compensate for degeneration produced by the bias resistor.

3. In an audio amplifier, a tube provided at least with a cathode, a signal grid and a plate, means applying audio signal voltage to the grid, an unbypassed resistor in the space current path of the tube and being connected between said cathode and ground, a reproducer having a voice coil coupled to the plate, and regenerative feedback means applying audio voltage across at least a portion of the voice coil to the said tube thereby to compensate for degeneration introduced by said unbypassed resistor, means grounding one end of said voice coil, and said feedback means comprising a resistor of constant resistive magnitude connected in series between the cathode end of the unbypassed resistor and the ungrounded end of the voice coil.

4. In an audio amplifier, a tube provided at least with a cathode, a signal grid and a plate, means applying audio signal voltage to the grid, an unbypassed resistor in the space current path of the tube and being connected between said cathode and ground, a reproducer having a voice coil coupled to the plate, and regenerative feedback means applying audio voltage across at least a portion of the voice coil to the said tube thereby to compensate for degeneration introduced by said unbypassed resistor, said voice coil having a resistance of constant magnitude so chosen as to provide said compensation.

5. In an audio amplifier, a tube provided at least with a cathode, a signal grid and a plate, means applying audio signal voltage to the grid, an unbypassed resistor in the space current path of the tube and being connected between said cathode and ground, a reproducer having a voice coil coupled to the plate, and regenerative feedback means applying at least a portion of the audio voltage across the voice coil to the said tube thereby to compensate for degeneration introduced by said unbypassed resistor, an additional audio amplifier preceding said tube, said additional amplifier having an unbypassed cathode resistor, and means applying audio voltage across a second portion of the voice coil to the additional amplifier.

6. In an audio amplifier provided with at least two tubes arranged in cascade, a reproducer voice coil coupled to the output of the last tube, a separate unbypassed bias resistor in the space current path of each tube, means establishing an intermediate point of the secondary of the transformer feeding the voice coil at a relatively fixed alternating potential, means applying audio voltage developed between one end of the secondary and said point to one bias resistor in a regenerative sense, additional means applying audio voltage developed between the opposite end of the secondary and said point to the second bias resistor in a regenerative sense.

7. An amplifier for audio frequency currents, including an electronic tube having at least a cathode, a control grid and an anode, and including a voltage reducing transformer with a primary winding in circuit with said anode, and a secondary winding of constant resistive magnitude in circuit with said cathode with polarity to cause regenerative amplification.

8. An amplifier for audio frequency currents, including an electronic tube having a cathode, one or more grids and an anode, means for securing bias voltage for the control grid of said tube comprising a resistor in circuit between the cathode of said tube and the negative terminal of the anode voltage supply source, and means including an impedance transforming output device of constant resistive magnitude for introducing in series with said bias producing means, audio frequency voltages of substantially equal amplitude and opposite phase to those appearing across said resistor because of variations in space current of said tube.

9. In an audio amplifier, a tube provided at least with a cathode, a signal grid and a plate, means applying audio signal voltage to the grid, an unbypassed resistor in the space current path of the tube and being connected between said cathode and ground, a reproducer having a voice coil coupled to the plate by a transformer, and regenerative feedback means applying audio voltage across at least a portion of the transformer secondary to the said tube thereby to compensate for degeneration introduced by said unbypassed resistor, an additional audio amplifier preceding said tube, said additional amplifier having an unbypassed cathode resistor, and means applying audio voltage across a second portion of the transformer secondary to the additional amplifier.

10. In an audio amplifier provided with at least two tubes arranged in cascade, a reproducer having a voice coil, a transformer coupling the output of the last tube to the voice coil, an unbypassed bias resistor in the space current path of each tube, means establishing an intermediate point of the transformer secondary at ground potential, means applying audio voltage developed between one end of the secondary and said ground point to one bias resistor in a regenerative sense, additional means applying audio voltage developed between the opposite end of the secondary and said ground point to the second bias resistor in a regenerative sense.

WINFIELD R. KOCH.