June 17, 1941. J. A. WORCESTER, JR 2,246,158

AMPLIFIER

Filed Aug. 17, 1939

Fig. 1.

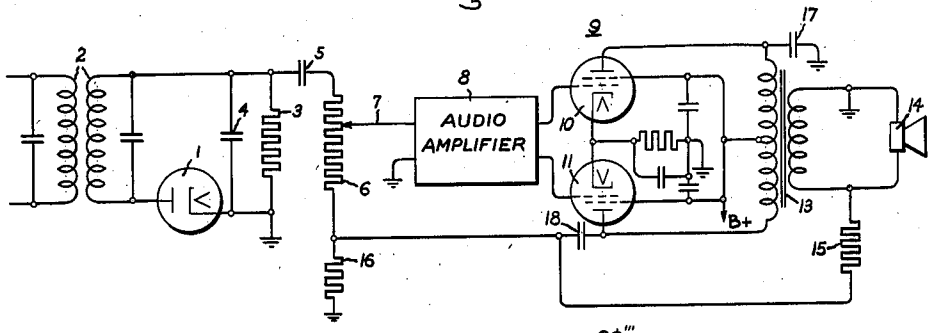


Fig. 2.

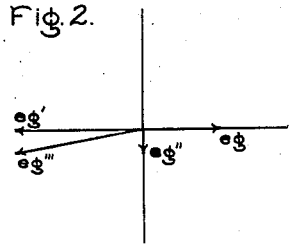


Fig. 3.

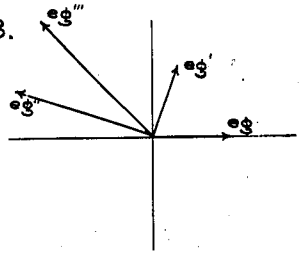


Fig. 4.

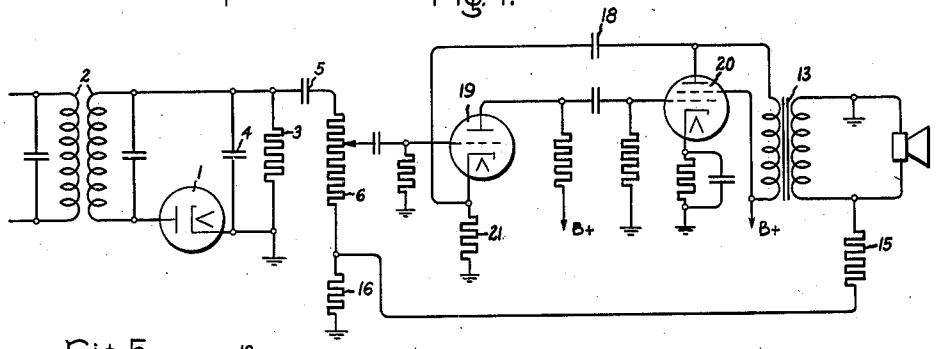
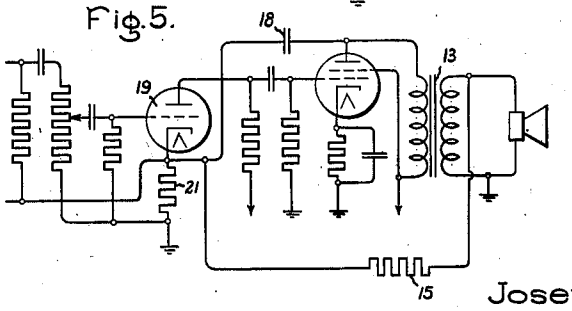


Fig. 5.



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2,246,158

AMPLIFIER

Joseph A. Worcester, Jr., Bridgeport, Conn., assignor to General Electric Company, a corporation of New York

Application August 17, 1939, Serial No. 290,611

7 Claims. (Cl. 179—171)

My invention relates to amplifiers such as are commonly used in radio receivers and it has for one of its objects to effect certain improvements therein with respect to means for securing degeneration in such amplifiers.

Commonly, the audio frequency amplifiers in radio receivers are provided with degeneration circuits to improve the frequency response characteristic, reduce hum, distortion, and for other reasons. Due to the phase shift which occurs in such amplifiers at high frequencies such circuits are likely to become regenerative at those frequencies. One of the objects of my invention is to provide improved means for avoiding such regeneration.

Another object of my invention is to provide means whereby, particularly at the higher frequencies, two voltages are supplied from the output of the amplifier to the input thereof having such phase relations that the resultant voltage is degenerative even though one of the two voltages becomes regenerative.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention, itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 represents an embodiment of my invention; Figs. 2 and 3 represent certain vector diagrams relating to its operation and Figs. 4 and 5 illustrate modifications.

Referring to the drawing, I have shown therein the audio frequency portion of a conventional radio receiver, this portion comprising a detector including a diode 1, which is connected in series with the secondary winding of a transformer 2 and a diode load resistance 3, the latter being shunted by the usual condenser 4. This circuit is the usual diode detector circuit of a radio receiver to which currents of radio frequency, such as the received signal currents, or if the receiver be one of superheterodyne type, the intermediate frequency currents, are supplied through transformer 2. These currents are rectified by the diode 1 to produce a direct current potential upon resistance 3 having therein the audio frequency modulations of the carrier wave. These audio frequency variations are supplied through a condenser 5 to an audio frequency volume control potentiometer 6 from whence they are supplied through a tap connection 7 to the input circuit of an audio amplifier 8. Currents amplified by the amplifier 8 are additionally amplified by push-pull amplifier 9 including electron discharge devices 10 and 11. The output circuit of these discharge devices includes an audio frequency transformer 13 the secondary winding of which is connected across the voice coil of a loud speaker 14.

The amplifier 9 is energized from a suitable source of potential, which is connected between ground and the intermediate point on the primary winding of transformer 13, this point being indicated at B+ on the drawing. This source, of course, may also supply the potential to the screen grids of discharge devices 10 and 11 as well as operating potential to the discharge devices of amplifier 8.

As previously stated, it is now common practice in radio receivers to utilize degeneration in connection with such amplifiers in order to improve the frequency-response characteristic, reduce distortion, and to reduce the reproduction of such hum currents as may be produced in the system from the power supply source where such source is derived by rectifying potentials from a commercial alternating current circuit, such as the ordinary house lighting circuit. To this end resistances 15 and 16 are included, the resistance 16 being connected between resistance 6 and ground and the resistance 15 being connected between the ungrounded terminal of resistance 16 and the ungrounded terminal of the voice coil of loud speaker 14. Potential is thus supplied from the voice coil of loud speaker 14 through resistance 15 to resistance 16, which is connected between the grid and cathode of the first discharge device in amplifier 8, this potential being supplied to this amplifier in degenerative phase.

In such systems, however, due to certain shunt capacities employed in amplifiers 8 and 9, such as the capacities which are connected between the anodes and cathodes of the various discharge devices, one of which is indicated at 17 on the drawing, phase shift occurs at high frequencies, this phase shift being sufficient at those frequencies to cause the potential supplied through resistance 15 to resistance 16 to be shifted in phase sufficiently to become regenerative. This is not desirable for a number of reasons, one being that it increases the response of the amplifier to extremely high frequencies thereby rendering the amplifier undesirably sensitive to noise currents.

To avoid such regeneration, in accordance with my invention, a second voltage is supplied from the output of the amplifier to the input of the amplifier of such phase that the resultant of the

two voltages is degenerative even at the high frequencies. In Fig. 1 this second voltage is supplied to the resistance 16 through condenser 18. This condenser 18 may comprise the condenser normally connected between the anode of discharge device 11 and ground after the manner of condenser 17.

In accordance with my invention this condenser is connected to ground through resistance 16. It has such a value that its impedance is high at all frequencies to be amplified relative to the resistance of resistance 16 so that no substantial phase shift in the voltage supplied through it occurs by reason of change in its reactance with frequency. At low frequencies its reactance is so high that the voltage supplied therethrough is insufficient greatly to influence the phase of the resultant of the two voltages. At high frequencies, however, its reactance, although still high relative to the resistance of resistor 16, is sufficiently low that its voltage very materially affects the phase of the resultant of the two voltages and it is in such a direction that this resultant voltage is maintained in degenerative phase even at the higher frequencies.

This operation of the system may be better understood from an inspection of Figs. 2 and 3. Fig. 2 represents the condition which exists at low frequencies. In this figure e_g represents the signal voltage supplied by the detector 1 to the input of amplifier 8; e_g' represents the voltage supplied to resistance 16 through resistance 15, this voltage being 180 degrees displaced from the signal voltage e_g; e_g'' represents the voltage supplied through condenser 18 from the anode of device 11. Of course the voltage on the anodes of discharge devices 10 and 11 are 180 degrees displaced with respect to each other but this voltage is taken from the anode of the device from which the voltage is in lagging phase with respect to the voltage e_g'. The resultant of the two voltages e_g' and e_g'', is indicated at e_g'''. Owing to the large impedance of condenser 18 at low frequencies, e_g''' is not greatly different either in phase or magnitude from e_g'.

Fig. 3 represents the condition which exists at high frequencies. It will be seen that the voltage e_g' supplied through resistance 15 is now shifted to a position where it lags the signal input voltage e_g by less than 90 degrees. It thus has a regenerative component and tends to increase the amplification at high frequencies. The voltage e_g'' is still in the quadrature relation with respect to e_g' but is now greatly increased due to the lower reactance of condenser 8 at the high frequencies. The resultant of these two voltages e_g''', has thus not shifted in phase to the extent that e_g' has shifted and is still in degenerative phase even at the highest frequencies to be amplified. In fact in this way any likelihood of a regenerative condition existing at high frequencies is eliminated.

Fig. 4 represents a modification of my invention which involves an amplifier having two stages 19 and 20, both amplifiers being of the single ended type as distinct from the push-pull type shown at 9 in Fig. 1. As previously pointed out in Fig. 1 the desired lagging relation of voltage e_g'' to that of e_g' is secured by taking this voltage from the proper one of the two discharge devices 10, or 11. This selection is not available in the arrangement of Fig. 4, which does not involve a push-pull amplifier. The same result, however, may be secured by utilizing a resistance 21 between the cathode and ground of the first amplifier 19. The voltage e_g'' may then be supplied from the anode of discharge device 20 to the cathode thereof through the condenser 18 which corresponds to the condenser 18 of Fig. 1. The voltage e_g' is supplied through resistance 15 to resistance 16 in the same way as was done in Fig. 1. These two voltages then combine in the input circuit in the way that is illustrated by the vector diagrams of Figs. 2 and 3.

Fig. 5 shows a further simplification of the arrangement of Fig. 4 in that the circuits are so arranged that resistance 21 serves the purpose of both resistances 21 and 16 of Fig. 4 thus obviating one resistor. Condenser 18 is connected as in Fig. 4. Resistance 15 is, in Fig. 5, connected between the cathode of discharge device 19 and the opposite side of the secondary winding of transformer 13 from that shown in Fig. 4, the ground connection to that winding being also positioned on the opposite terminal. In this way the two voltages e_g' and e_g'' both appear upon resistance 21 in proper phase to produce the effects above explained.

While I have shown particular embodiments of my invention, it will, of course, be understood that I do not wish to be limited thereto since various modifications both in the circuit arrangements and in the instrumentalities employed may be made. I, therefore, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an audio amplifier for currents having frequencies extending over a wide range of audio frequencies, means to supply voltage from the output of said amplifier to the input thereof in degenerative phase at low frequencies in said range, said amplifier operating to shift the phase of said voltage at high frequencies in said range to a regenerative phase, and means to combine with said voltage supplied from the output a second voltage supplied from the output of said amplifier of such phase that the resultant voltage is in degenerative phase at all frequencies throughout said range.

2. The method of maintaining degeneration at high frequencies in an audio amplifier in which large phase shift occurs at such frequencies, which includes supplying from the output to the input of said amplifier two voltages, the resultant of which remains in degenerative phase when one of said voltages is supplied in regenerative phase.

3. The method of maintaining degeneration at high frequencies in an audio amplifier in which large phase shift occurs at such frequencies, which includes supplying from the output to the input of said amplifier two voltages widely shifted in phase, one of said voltages being shifted in one direction from the desired phase relation at low frequencies and the other being shifted in the opposite direction from the desired phase relation at high frequencies, and the resultant of which voltages remains in desired phase at all frequencies.

4. The method of maintaining a desired relation over a wide frequency range between the voltage supplied to the input of an amplifier for amplification thereby and a voltage supplied thereto from the output of said amplifier, where large phase shift in the amplifier occurs at high frequencies, which includes supplying to said input from the output of the amplifier, two volt-

ages whose phase shifts vary with frequency but the resultant of which remains in the desired phase relation.

5. In combination, an amplifier, an input circuit therefor, a resistance connected between said input circuit and the output of said amplifier to supply voltage from said output to the input in degenerative phase at low frequencies, said amplifier operating to shift the phase of said voltage at high frequencies to a regenerative phase relation, a condenser connected between said output and input, said condenser having sufficiently high impedance at low frequencies that only small voltage is supplied through said condenser to said input circuit and said condenser having sufficiently low impedance at high frequency that the voltage supplied therethrough to said input at high frequency is sufficiently great that the resultant of said voltage and that supplied through said resistance is degenerative at the highest frequencies to be amplified.

6. In combination, an amplifier having an input circuit including a resistance, a resistance and a condenser each connected between the output of said amplifier and said first resistance to impress voltages from said output on said first resistance in quadrature relation, the voltage supplied through said resistance being in degenerative phase at low frequencies and in regenerative phase at high frequencies, and the voltage supplied through said condenser being low at low frequencies relative to that supplied through said resistance, but sufficiently high at high frequencies that the phase of the resultant voltage on said first resistance is degenerative at said high frequencies.

7. In combination, an amplifier having a grid, a cathode and an output, said cathode being connected to ground through a resistance, an input circuit coupled to said grid, a condenser connected between said output circuit and said cathode, and a second resistance connected between said output and said input circuit, said second resistance operating to supply between said grid and cathode a voltage having degenerative phase at low frequencies and regenerative phase at high frequencies, said condenser having sufficiently low impedance at high frequencies to produce on said first resistance a voltage which combines with the voltage supplied to said input through said second resistance to produce between said grid and cathode a resultant voltage having a degenerative phase at high frequencies.

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