Nov. 18, 1941. T. M. SHRADER 2,262,865

VOLUME CONTROL CIRCUITS

Filed Nov. 12, 1938

Fig. 1

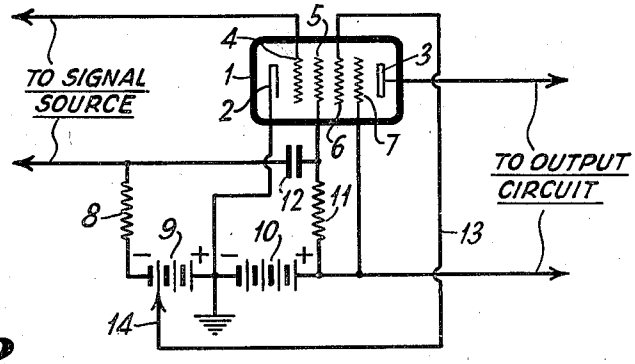


Fig. 2

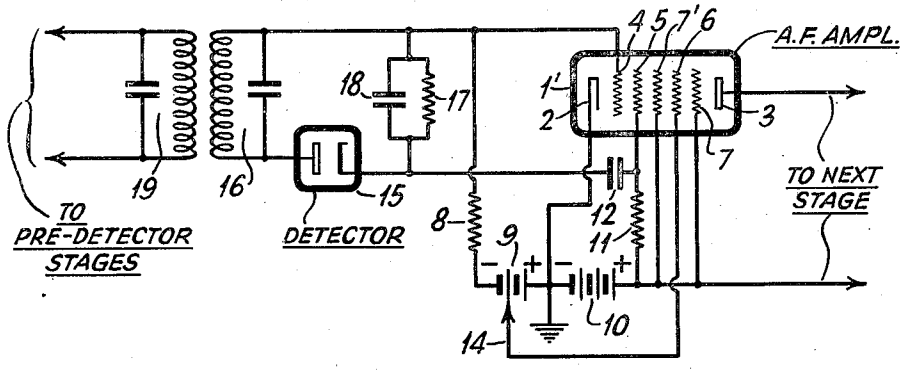


Fig. 3

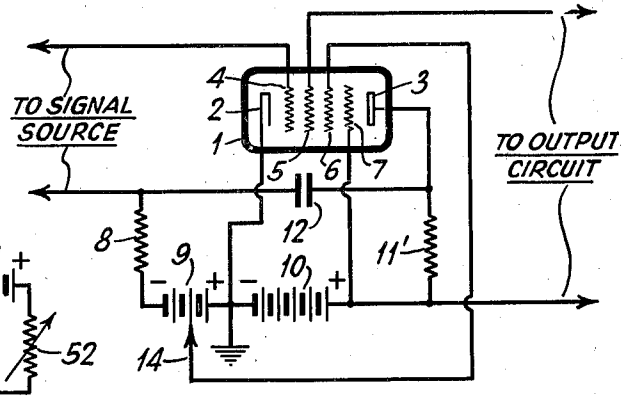
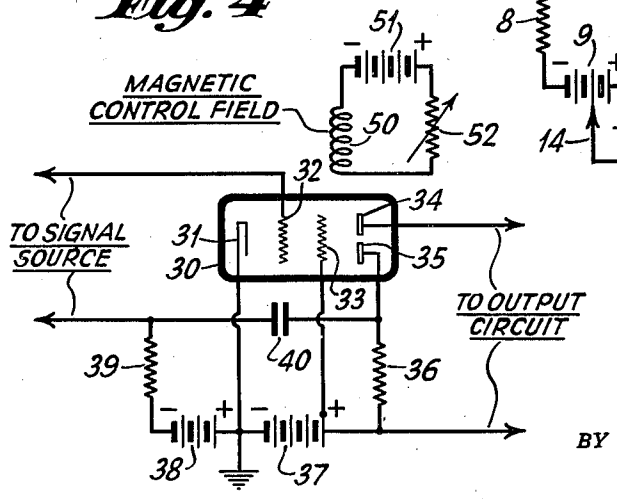


Fig. 4



INVENTOR.
TERRY M. SHRADER
BY
ATTORNEY.

Patented Nov. 18, 1941 2,262,865

UNITED STATES PATENT OFFICE

2,262,865

VOLUME CONTROL CIRCUITS

Terry M. Shrader, West Summit, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application November 12, 1938, Serial No. 240,027

9 Claims. (Cl. 179—171)

My present invention relates in general to volume control circuits, and more specifically to volume control circuits for audio amplifiers.

In the past, amplifiers have been provided with signal grids of the variable mu type. Upon this grid was impressed the signal voltage; and the gain control bias was also applied to such grid. However, and particularly at audio frequencies, there exists the problem of designing the signal grid so as to impart a characteristic to the amplifier whereby the very high signals can be handled without considerable distortion and high plate current. In one attempted solution of this difficulty the amplifier is provided with an auxiliary gain control grid (so-called hexode tube) while the signal is applied to the usual signal grid. The same difficulties are encountered in this case; in addition, distortion, due to kinks in the mutual conductance curve of the tube, is produced when the signal is applied to a grid located further away from the cathode than the gain control grid.

Now I have discovered a method of overcoming the aforesaid problem, and it is one of the main objects of my present invention to provide a means for utilizing the method; the latter including the steps of degenerating the signal input circuit of an amplifier, as the signal amplitude increases, to decrease the output of the amplifier, and concurrently decreasing the current flow through the output circuit of the latter.

Another important object of this invention is to provide a wave transmission tube which is so constructed that degeneration can be introduced into the wave input circuit to prevent overswinging of the wave input electrode and reduce distortion; the electron flow to the output electrode of the tube being reduced substantially at the same time to provide an auxiliary effective control over the output intensity of the tube.

Still another object of my invention is to provide an audio amplifier which includes a tube having a signal grid, an output electrode, an electron diversion electrode and a control means; the control means acting to regulate the distribution of electrons between the diversion electrode and the output electrode, and the current flow through the circuit of the diversion electrode providing signal voltage which is fed back to the signal grid in degenerative phase.

Still other objects of my invention are to improve generally the simplicity and efficiency of audio amplifier gain control circuits, and more especialy to provide audio volume control circuits which are reliable in operation and economical to manufacture and assemble.

The novel features which I believe to be characteristic of my invention are set forth in 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 an audio amplifier embodying one form of the invention,

Fig. 2 shows a modification,

Fig. 3 illustrates a further embodiment,

Fig. 4 shows still another form of the invention.

Referring now to the accompanying drawing, wherein like reference characters in the different figures denote similar circuit elements, there is depicted in Fig. 1 a wave amplifier network employing a hexode type tube 1 which is provided with a cathode 2, a plate 3 and four successive grids, 4, 5, 6 and 7. The cathode is established at a fixed potential, for example at ground potential. The source of wave, or signal, energy (not shown to preserve simplicity of disclosure) is connected from signal grid 4 to ground through a path including a resistor 8 in series with the grid bias source 9. The output, or plate, electrode 3 is connected to the grounded cathode through a path including the output, or utilization, circuit (not shown) and the positive potential source 10.

Grid 5, the electron-diversion electrode, is connected to the positive terminal of source 10 by a resistive impedance 11. The condenser 12 connects the electrode end of impedance 11 to the grid end of resistor 8. Since the impedance 11 is unbypassed at signal frequencies, there will be developed signal voltage across the impedance when current flows through the latter. Such signal voltage will be impressed upon grid 4 in degenerative phase to the signal voltage from the signal source. Hence, the function of electrode 5 is to introduce degeneration into the signal input circuit of the amplifier. Grid 7 acts as a screen grid electrode, and is connected to the positive terminal of source 10. The grid 6, disposed between electrode 5 and plate 3, has applied to it a direct current potential of variable magnitude thereby to regulate the distribution of electrons between electrode 5 and plate 3. For example, grid 6 is shown connected by lead 13 and adjustable tap 14 to source 9. It will be clear that as the tap 14 is adjusted to the negative terminal of potential source 9, the electrode 6 will become increasingly negative and thereby cause more electrons to flow to electrode 5 than to plate 3.

If the negative potential applied to grid 6 is of sufficient value to cause all of the electrons, normally flowing to the plate 3, to flow to electrode 5, the result will be that the signal input

circuit will be highly degenerated. The degenerative signal voltage introduced into the signal input circuit may be said to "buck out" most of the input signal voltage thereby preventing over-swinging the signal grid 4. Furthermore, it is to be noted that when grid 6 has a bias sufficiently high to cut off the plate current flow, the combined action of the degenerative feedback and the cut-off of plate current will result in reducing the volume to zero. When substantially no bias is applied to grid 6, the electron flow to electrode 5 is low, and is preferably very low for maximum gain, and hence very little degeneration is introduced into the signal input circuit. Furthermore, the plate current flow in the last named case will be a maximum, and, therefore, the volume of the amplifier will also be a maximum. The signal, of course, is very small when maximum gain is needed, so there is no over-swinging of the signal 4. Not only does the introduction of degeneration prevent over-swinging of the signal grid, but distortion is prevented by virtue of the degenerative feedback as is well known by those skilled in the art. It will, therefore, be appreciated that the present volume control method embodies the dual regulation of plate current as well as degenerative feedback to the signal input circuit.

In Fig. 2 there is shown the invention applied to an audio amplifier which may embody a tube 1' of the 6A8 type. The difference between this type of tube and that shown in Fig. 1 resides in the fact that an auxiliary screen grid electrode 7' is disposed between the gain control grid 6 and the electrode 5. Furthermore, the electrode 5 in the 6A8 type tube actually consists of a pair of spaced side rods, as those skilled in the art well know. Such a tube has the advantage of having the electrode 5 draw very low current when no bias is applied to electrode 6. The audio signal input source is shown as comprising a diode detector 15, and the anode thereof is connected to the cathode through a path which includes resonant input circuit 16 and the resistive load impedance 17, the latter being shunted by a signal carrier bypass condenser 18.

The signal grid 4 of tube 1' is connected to the anode end of load impedance 17, whereas the cathode end of impedance 17 is connected to condenser 12. Grid 4 is connected to the negative terminal of source 9 through resistor 8. The numeral 19 may designate the resonant output circuit of any desired type of predetector network. For example, circuits 19 and 16 may consist of the tuned primary and secondary circuits of the output intermediate frequency transformer of a superheterodyne receiver. The plate 3 may be coupled to one or more stages of audio frequency amplification followed by any desired type of reproducer. Since the operation of this modification of the invention is the same as described in connection with Fig. 1, it is not believed necessary to describe the circuit in any further detail.

The present invention is not restricted to the utilization of one of the intermediate grids as the degenerative electrode. For example, in Fig. 3 there is shown a modification of the circuit of Fig. 1 wherein the plate 3 has the impedance 11' connected in circuit therewith, the feedback condenser 12 connecting the plate end of impedance 11' to the signal input circuit. The electrode 5 is connected to the output circuit, while the gain control grid 6 is connected by adjustable tap 14 to potential source 9. In the present arrangement as the grid 6 assumes an increasingly negative potential less electrons are permitted to flow to the plate 3 and thereby provide less degenerative signal voltage across impedance 11'. In that case there will be more electrons flowing to the electrode 5 than to plate 3. On the other hand as the grid 6 is adjusted in potential to approach ground potential the flow of electrons to plate 3 is increased, and the degenerative action is also increased. It will, therefore, be seen that with maximum negative bias on grid 6, in the case of the circuit of Fig. 3, the volume is a maximum.

In Fig. 4 there is shown a modification of the invention wherein in place of an electrostatic control electrode disposed within the tube envelope, there is employed a magnetic control field outside of the amplifier tube envelope. In this case the tube 30 is provided with a cathode 31, a signal grid 32 and a screen grid 33. A pair of anodes, or plates, 34 and 35 may be spaced from each other, but located in a position to have electrons from cathode 31 shifted from one to the other of the plates depending on the intensity of the external magnetic control field. The plate 34 may be connected to the output of the utilization network, whereas plate 35 may be connected by impedance 36 to the positive terminal of the positive potential source 37.

As explained above, the signal grid 32 may be maintained at a desired negative bias with respect to ground through the biasing potential source 38 and resistor 39, and condenser 40 may provide the feedback path for the degenerative signal voltage developed across impedance 36. The magnetic control field may be provided by any means known to those skilled in the art. By way of illustration such a means is shown as embodying a coil 50 arranged in series with a current source 51 and a variable resistor 52. Proper location of coil 50 with respect to the electron stream flowing within the tube to the plates will enable the manipulator readily to shift the electron stream from one of the plates 34 to the plate 35. Assuming, for example, that for maximum volume of the amplifier the electron stream flows mainly to plate 34, resistor 52 can be adjusted to cause the electron stream to shift to plate 35 when the output of the amplifier is to be reduced. When the electron stream is shifted to plate 35 then the current flow in the output circuit of the amplifier is a minimum, and the degenerative feedback to the signal input circuit is a maximum. If desired, a horseshoe magnet, rotated manually outside the tube envelope, may be used.

It is to be noted in each of the circuits shown that the direct current return path for the signal grid is through a fairly high impedance; the signal return path is through (as 12—11—10 in Fig. 1) a series arrangement of condenser, resistor and current source having a fairly low impedance. Again, in place of using the adjustable bias source 9 in each of Figs. 1, 2, 3, the conventional automatic volume control (AVC) network can be used to provide AVC bias for grid 6. Those skilled in the art are fully acquainted with such AVC circuits; such an arrangement used with this invention will improve the volume control action of a radio receiver.

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 depart-

ing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In an amplifier of the type including a tube provided with at least an electron emission source, an input electrode and an output electrode; the method including impressing waves upon said input electrode, developing amplified wave voltage at said output electrode, diverting electrons flowing from said source to said output electrode, deriving from the diverted electron flow a wave voltage, combining the derived wave voltage and impressed waves in phase opposition, and concurrently regulating the relative amplitudes of said derived voltage and amplified voltage in opposed senses.

2. In a signal transmission network provided with a tube having an electron emission source, an input electrode, an output electrode, and an auxiliary electrode; the method which includes establishing said input electrode at a negative potential relation to said emission source, impressing signals upon said input electrode, deriving at said output electrode amplified signals, deriving a signal voltage from electron flow to said auxiliary electrode, impressing said derived signal voltage upon the input electrode, and controlling the distribution of electrons from said source between said output electrode and said auxiliary electrode.

3. In a signal amplifier, a tube provided with a cathode, a negative signal grid, an output electrode and a positive auxiliary electrode arranged to receive electrons from said cathode, a signal source coupled between the cathode and signal grid, means operatively associated with the auxiliary electrode to develop signal voltage and impress it in degenerative phase upon said signal grid, an output circuit connected to said output electrode, and means for simultaneously controlling the electron flow to said output electrode and regulating the electron current flow to said auxiliary electrode thereby to control the magnitude of said degenerative voltage.

4. In a signal amplifier, a tube provided with a cathode, a signal grid, an output electrode and an auxiliary electrode arranged to receive electrons from said cathode, a control electrode disposed in said tube between said output electrode and auxiliary electrode, a signal source coupled between the cathode and signal grid, means operatively associated with the auxiliary electrode to develop signal voltage and impress it in degenerative phase upon said signal grid, an output circuit connected to said output electrode, and means including said control electrode for regulating the electron current flow to said auxiliary electrode thereby to control the magnitude of said degenerative voltage.

5. In a signal amplifier, a tube provided with a cathode, a signal grid, an output electrode and an auxiliary electrode arranged to receive electrons from said cathode, a signal source coupled between the cathode and signal grid, means operatively associated with the auxiliary electrode to develop signal voltage and impress it in degenerative phase upon said signal grid, an output circuit connected to said output electrode, and means for regulating the electron current flow to said auxiliary electrode thereby to control the magnitude of said degenerative voltage, said regulating means comprising a device external of said tube and being constructed to produce a magnetic field of variable intensity.

6. In a signal amplifier, a tube provided with a cathode, a negative signal grid, an output electrode and a positive auxiliary electrode arranged to receive electrons from said cathode, a signal source coupled between the cathode and signal grid, means operatively associated with the auxiliary electrode to develop signal voltage and impress it in degenerative phase upon said signal grid, an output circuit connected to said output electrode, and means for simultaneously controlling the electron flow to said output electrode and regulating the electron current flow to said auxiliary electrode thereby to control the magnitude of said degenerative voltage, said first named means including an impedance connected between said auxiliary electrode and the cathode, and a path of low impedance to signal voltage connecting the signal grid to a point on said impedance.

7. In combination with a source of audio signal voltage, a tube provided with a cathode, an output electrode and at least three cold electrodes arranged in succession in the electron stream therebetween, said source being coupled to the cathode and the first of said cold electrodes, an output circuit coupled between the cathode and output electrode, an impedance element in circuit with the second cold electrode, means for establishing the latter and output electrode at a positive potential, means for feeding degeneratively to said first cold electrode audio voltage developed across said element, and means for varying the potential of the third cold electrode over a range of negative potential values thereby to control the distribution of electrons between the output electrode and said second cold electrode.

8. In combination with a tube provided with at least a cathode, signal input electrode and output electrode, a signal input circuit coupled to the input electrode, a signal output circuit connected to the output electrode, means, responsive to electrons diverted from the electron stream flowing between cathode and output electrode, for developing signal voltage, means applying the developed signal voltage to said input electrode in degenerative phase relative to the signal voltage from said input circuit, and a single means for simultaneously controlling the magnitude of said electron diversion and the intensity of the electron stream to said output electrode.

9. In combination with a source of audio signal voltage, a tube provided with a cathode, an output electrode and at least three cold electrodes arranged in succession in the electron stream therebetween, said source being coupled to the cathode and the first of said cold electrodes, an output circuit coupled between the cathode and output electrode, an impedance element in circuit with the second cold electrode, means for establishing the latter and output electrode at a positive potential, means for feeding degeneratively to said first cold electrode audio voltage developed across said element, means for varying the potential values thereby to control the distribution of electrons between the output electrode and said second cold electrode, said second cold electrode being constructed to draw a small electron flow when said third cold electrode is at minimum negative potential, and a positive screen electrode disposed between said second and third cold electrodes.

TERRY M. SHRADER.

DISCLAIMER

2,262,865.—*Terry M. Shrader*, West Summit, N. J. VOLUME CONTROL CIRCUITS. Patent dated November 18, 1941. Disclaimer filed September 16, 1942, by the assignee, *Radio Corporation of America*.

Hereby enters this disclaimer to claims 1, 2, 3, 4, 6, and 8 of said patent.

[*Official Gazette October 13, 1942.*]