Feb. 17, 1942. E. W. HEROLD 2,273.107

AUTOMATIC GAIN CONTROL CIRCUIT

Filed March 30, 1939

Fig. 1

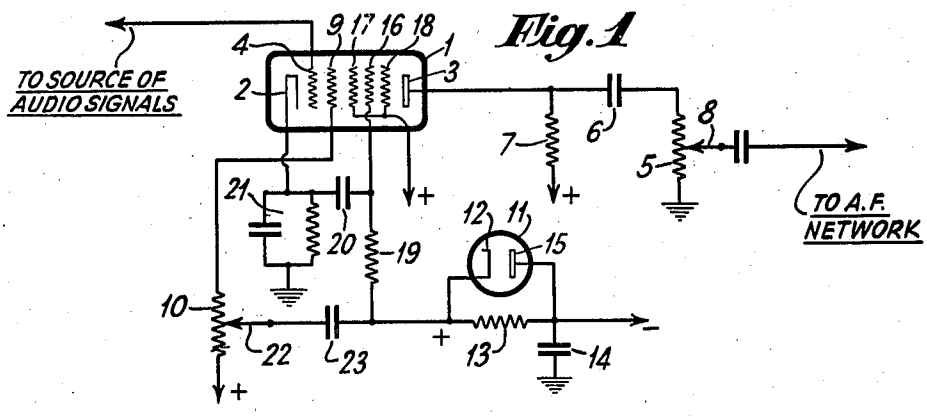


Fig. 2

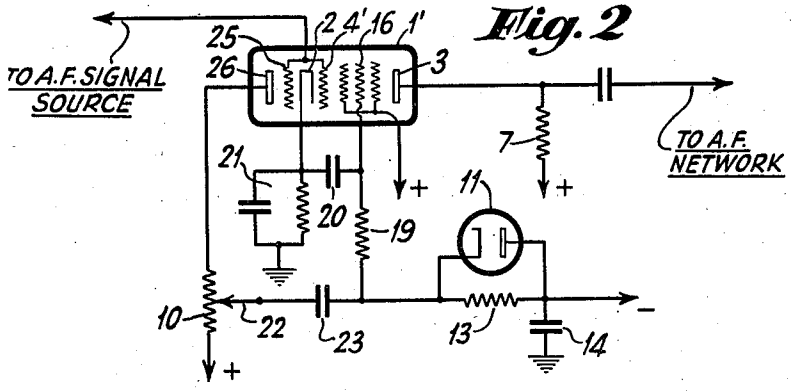


Fig. 3

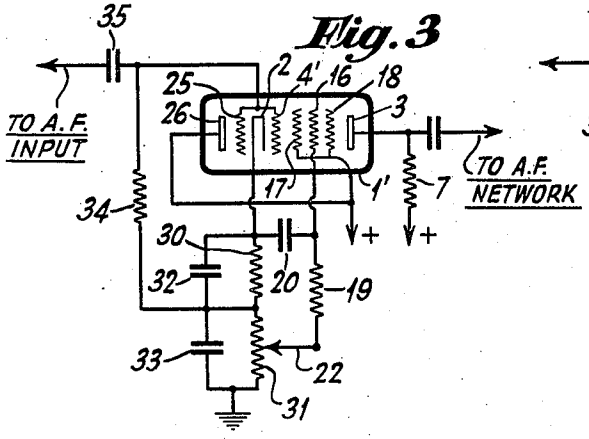
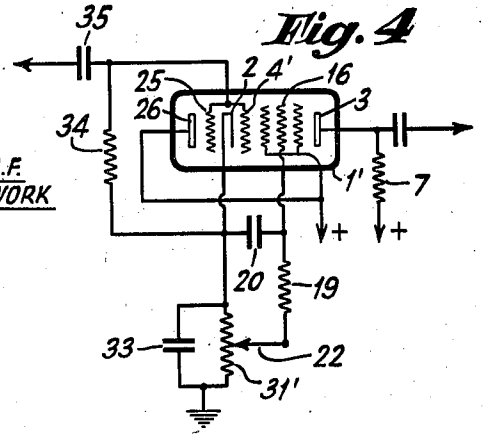


Fig. 4



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AUTOMATIC GAIN CONTROL CIRCUIT

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4 Claims. (Cl. 179—171)

My present invention relates to automatic gain control circuits, and more particularly to automatic audio volume expansion or compression arrangements.

It has been customary in the reproduction of sound to compress, or contract, the volume range of the audio frequencies at the transmitting or recording end of an audio reproduction system. Such volume range compression has necessitated the employment of automatic volume expanders at the reproducing end of the system. In general, automatic expansion has been achieved in the past by rectifying a portion of the audio input energy, and then applying the resulting direct current voltage to an audio amplifier stage so as to increase its gain when the audio input intensity increased. In order to obtain sufficient expansion, it has been necessary to employ separately the portion of the audio input energy utilized for expansion. Ordinarily, at least three tubes are required; an expander, or controlled, tube, an expander voltage amplifier and a rectifier. In general, then, automatic expanders in the past have required a number of tubes, and their utilization has been expensive.

It may be stated, therefore, that it is one of the main objects of my present invention to provide, in general, automatic gain control of a wave amplifying network, wherein the network comprises a multi-electrode tube capable of acting simultaneously as a wave amplifier, and as an amplifier of wave energy which is to be utilized for rectification to provide a gain control voltage for the first-mentioned wave amplifier section.

Another important object of this invention is to provide in an automatic audio expansion network a tube having electrodes grouped in two sections; one of these sections cooperating to provide an audio amplifier, whereas the other section functions to amplify audio energy for subsequent rectification whereby expansion control voltage is provided for the audio amplifier section.

Another object of this invention may be stated to reside in the provision of an audio gain control network which employs a multi-electrode tube capable of simultaneously amplifying the audio energy, and utilizing a portion of the audio input energy for expansion or compression control.

Still other objects of my invention are to improve generally the simplicity and efficiency of audio volume expander or compressor circuits, and more especially to provide audio expander circuits which are not only reliable and efficient in operation, but are economically manufactured and assembled in audio reproducer networks.

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 embodiment of an automatic audio expander network constructed according to my invention,

Fig. 2 illustrates a modified arrangement,

Fig. 3 illustrtaes a further modification adapted for use in an automatic compression network,

Fig. 4 illustrates a modification of the invention, as shown in Fig. 3, applied to audio expansion control.

Referring now to the accompanying drawing, wherein like reference characteristics and the different figures designate similar circuit elements, there is shown an electron discharge tube 1 which may be of the type commercially known as a 6A7 or 6A8. Such a tube comprises a cathode 2 and an output electrode 3. Between these two electrodes there are disposed in successive order, in the electron stream emitted from cathode 2, five control electrodes. The grid, or control, electrode 4 is connected to any desired source of audio signal energy. Such audio source may be, by way of illustration, the output circuit of the detector of a radio receiver employed in broadcast reception. However, it is to be clearly understood that the audio source may, also, be the electrical pick-up of a phonograph record reproducer, or any of the preceding audio amplifier tubes of such a reproducer network. Again, the audio source may comprise the photo-electric pick-up of a talking moving picture system, and it may even be the microphone of a public address system. In general, let it be assumed that there is impressed upon the grid electrode 4 audio energy derived from any desired source.

The cathode 2, input grid 4 and plate electrode 3 cooperate to provide an audio amplifier, and the amplified audio voltage is developed across the potentiometer resistor 5. One end of the resistor 5 is grounded, while its opposite end is connected to the plate electrode 3 by an audio coupling capacitor 6. The plate electrode 3 is connected to any desired source of positive po-

tential through a plate resistor 7. The potentiometer is provided with an adjustable slider 8, and the audio voltage developed across resistor 5 may be regulated as to magnitude by adjustment of the slider 8 along the resistor 5. It is to be clearly understood that the output audio voltage will be impressed upon one or more amplifier stages, and finally reproduced in any desired type of audio reproducer.

In order to effect expansion of the volume range it is essential to increase the gain of the audio amplifier as the intensity of the audio input energy increases. Assuming that the audio input energy impressed on the control electrode 4 has previously been compressed, in any manner well known to those skilled in the art, then it becomes essential to expand the audio volume range in order properly to secure contrast between the soft and loud sounds. For example, if music is being reproduced and the musical sounds are derived from a record employing compression in the recording, it becomes necessary to utilize expansion during audio amplification at the reproducing end of the system so that the proper contrast between pianissimo and fortissimo may be secured. Since these facts are well known to those skilled in the art, it is not believed necessary to provide any further explanation of the principles underlying compression and expansion of volume range.

The gain control of the audio amplifier is provided by a portion of the audio input energy to the audio amplifier. It is desirable to amplify the control energy prior to its rectification. Hence, the second control electrode 9 is employed as a plate, or anode, electrode, and the load resistor 10 is arranged in circuit with anode 9. Resistor 10 is connected to a source of positive potential. It will, therefore, be seen that the audio energy impressed on electrode 4 develops audio output voltage both across the output resistor 7 and the output resistor 10, both electrodes 9 and 3 functioning as audio amplifier output electrodes.

The audio voltage developed across output resistor 10 is impressed upon a rectifier 11, and the latter may be of the diode type. The cathode 12 of the diode is connected to ground through a path which includes the diode load resistor 13 and the condenser 14. The diode anode 15 is connected to the junction of condenser 14 and load resistor 13, the junction point, additionally, being connected to a source of negative direct current potential so as to provide an initial negative bias for the gain control electrode 16 of tube 1.

Gain control electrode 16 is the fourth control electrode of the tube and is disposed between the screen grid electrodes 17 and 18; the latter two grids are connected to a source of positive potential. It will be understood that the grids 17 and 18 provide an accelerating field for the electrons between grids 9 and 16 and between grid 16 and the plate electrode 3. The gain control 16 is connected to the cathode end of diode load resistor 13 by means of a resistor 19, which functions to filter out the audio pulsations in the gain control voltage. The condenser 20 by-passes audio frequency currents from the grid end of resistor 19 to the cathode 2. The cathode itself is maintained at a positive potential above ground by means of the usual self-biasing resistor network 21, and, therefore, the control grid 4 is at a normal negative bias. The magnitude of the audio voltage impressed on the control rectifier 11 is adjusted by means of the variable tap 22 adapted to slide along resistor 10, the audio coupling condenser 23 connecting the tap 22 to the cathode end of resistor 13.

To explain the functioning of the arrangement shown in Fig. 1, let it be assumed that the audio signal is applied to grid 4. The amplified audio signal voltage is developed across the output circuit of tube 1. The gain of the audio amplifier is controlled by grid 16 in a polarity sense such that the gain of the audio amplifier increases as the audio signal input intensity increases. This follows from the fact that when the audio signal voltage applied to grid 4 increases, then the audio voltage developed across resistor 10 increases thereby increasing the magnitude of the audio voltage impressed upon rectifier 11. In this way the direct current voltage across load resistor 13 increases. Since the grid 16 is connected to the cathode, or positive, end of resistor 13, an increase in direct current voltage developed across resistor 13 causes the reduction of the initial negative bias on gain control grid 16. The result of this reduction of negative bias is to increase the gain of the audio amplifier. The amount of increase in gain and thereby the amount of volume expansion may be controlled by adjustments of tap 22.

While it has been explained that tube 1 is of the 6A7 or 6A8 type, it is desirable to have the fourth grid 16 of a constant pitch winding. It is pointed out that in a 6A7, or 6A8, type of tube the second grid 9 actually consists of the rod supports usually employed for supporting the grid winding. With this type of construction the rod supports have a minimum of influence on the main electron stream flowing to the audio amplifier output electrode 3. It will, therefore, be appreciated that the tube 1 not only provides normal audio amplification, but also supplies amplification of that portion of the audio input energy which is to be used for rectification at tube 11 in order to provide the expansion control voltage for grid 16.

The present invention is not limited to the particular type of tube shown in Fig. 1, since many other multi-electrode type tubes can be utilized. For example, in Fig. 2 there is shown a tube 1' of the type commercially designated as a 6K8. This type of tube combines in one envelope the electrodes of a triode and a hexode. Thus, the cathode 2 provides an electron stream flowing through the control grid 25 to the output electrode 26, and audio signal energy is impressed on grid 25. The output resistor 10 is included in circuit with the output electrode 26. In other words, cathode 2, grid 25 and plate 26 correspond respectively, in Fig. 1, to cathode 2, grid 4 and output electrode 9. The audio amplifier section of tube 1' comprises the cathode 2, the grid 4' and the output plate 3. The gain control electrode 16 is located between the positive screen grids, as in the case of tube 1 in Fig. 1.

The remainder of the circuit elements correspond to those shown in Fig. 1. Both signal grids 25 and 4' are connected to the source of audio input energy, and both of these grids are maintained at a normal negative bias by the self-biasing network 21. It is not believed necessary to describe the detailed construction of the combined triode-hexode type tube shown in Fig. 2; it being believed merely necessary to point out that cathode 2 provides a pair of independent electron streams to a triode section and an independent hexode section. The advantage of this

arrangement is that the control energy amplifier section has minimum influence on the functioning of the gain audio amplifier section. It is to be clearly understood that in either of Figs. 1 or 2 automatic compression will be secured by merely interchanging the connections to the cathode 12 and anode 15 of diode 11. For example, if the anode 15 is connected to resistor 13 in place of cathode 12 then with an increase of audio input energy intensity there will result a decrease in the gain of the audio amplifier.

It is not essential to the operation of the present invention that independent rectifiers be employed for providing the gain control voltage. In Figs. 3 and 4 are shown circuit arrangements wherein the combined triode-hexode 1' may be utilized for providing the rectification action as well as the automatic compression or expansion. In Fig. 3 there is shown an automatic compressor circuit. In this case the plate electrode 26 is connected to the same positive potential lead connected to the positive screen grids 17 and 18. The cathode 2 is connected to ground by means of a pair of series resistors 30 and 31, resistor 30 being shunted by an audio-by-pass condenser 32, and resistor 31 being shunted by an audio by-pass condenser 33. The blocking condenser 35 connects the audio input circuit to the control grids 25 and 4' which, in turn, are connected to the junction of resistors 30 and 31 by means of grid leak 34. The gain control grid 16 is connected to the resistor 31 through the series path including filter resistor 19 and adjustable tap 22.

The condenser 20, connected between the grid end of resistor 19 and the cathode end of resistor 30, functions as a portion of the filter network 19—20. It will be seen that in the arrangement of Fig. 3 no diode rectifier is necessary, since plate rectification occurring in the triode section of tube 1' is utilized. The resulting cathode current change through resistor 31 is employed to increase the grid bias of grid 16 as the audio input energy increases. In other words, as the audio input voltage impressed on grids 25 and 4' increases there will be a greater flow of space current through resistor 31, and, therefore, the grid 16 will be biased increasingly in a negative polarity sense. This results in the reduction of the gain of the hexode section of tube 1' such as is desired for automatic compression.

It is desirable to design tube 1' so that the triode section is normally biased close to cut-off, while with the same bias on grid 4' of the hexode portion of the tube this latter portion is operating on a substantially linear portion of its characteristic. This is readily accomplished by utilizing a higher mu, or amplification factor, for the triode section than for the grid 4' to grid 17 portion of the hexode. Tubes made in this way can readily be devised by those skilled in the art. In the 6K8 type of tube, for example, such a difference in amplification factor exists by virtue of the difference in spacing between grid 25 and plate 26 from the spacing of grids 4' and 17. If the triode section mu is not sufficiently higher than the mu of grid 4' to grid 17 of the hexode, satisfactory operation can still be obtained by lowering the positive voltage applied to the triode section plate 26 below that of the grid 17.

The circuit arrangement shown in Fig. 4 differs from that of Fig. 3 in that grid rectification is utilized in place of plate rectification in the triode section. The signal grids 25—4' are connected to the audio signal source through the grid condenser 35 as in Fig. 3. The grid leak 34, however, in distinction to Fig. 3 is connected to the cathode thus permitting grid rectification. Resistor 31' connects cathode 2 to ground, the resistor being by-passed for audio frequencies by condenser 33. In this form of circuit the cathode 2, signal grid 25 and plate 26 provide a grid leak detector circuit. Upon a signal intensity increase, the flow of space current through cathode resistor 31' decreases due to the well known action of the grid-leak and condenser 34—35. As a result the bias of grid 16 decreases; the gain of audio amplifier section 2—4'—16—3 thereby is increased. Expansion of the audio volume range results. If the hexode section has a sufficiently low mu so as not to be cut off for the strongest signals, distortion effects will be negligible. The triode section mu should be high, as in the case of the arrangement of Fig. 3.

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 a wave transmission system, a tube comprising a cathode, an output electrode, a signal grid between the cathode and output electrode, a gain control electrode located between the signal grid and the output electrode, a second signal grid adjacent the cathode and a second output electrode; the cathode, second grid and second output electrode providing a wave detector circuit, means impressing waves on both signal grids, a load impedance in the space current path of the detector circuit connected between the cathode and a point of relatively fixed alternating potential, and means responsive to voltage variations across the load impedance for controlling the potential of said gain control electrode.

2. In an audio signal amplifier network, a tube provided with a cathode, a pair of output electrodes receiving independent electron streams from the cathode, and a signal grid located in each electron stream, an audio signal input circuit connected to the signal grids, an audio output circuit coupled to one output electrode, an auxiliary gain control electrode in the electron stream to said one output electrode, means responsive to variations in the magnitude of the electron flow to the other output electrode for adjusting the potential of the gain control electrode, said responsive means comprising an impedance connected in the space current paths to both of said output electrodes and a direct current voltage connection between a point on the impedance and said gain control electrode.

3. In a signal amplifier network, a tube having a cathode, two output electrodes, a pair of input electrodes connected to a source of signal and suitably disposed to control the electron current to said output electrodes and a gain control electrode suitably disposed to control the electron current to a first of said output electrodes, a source of direct current including suitable biasing means applied to the electrodes of said tube in such a manner that the direct current variations in electron current to said second output electrode substantially correspond to the average amplitude of said signal, a resistive impedance connected in series with the discharge paths of

both of said output electrodes, and means for applying only the direct current potential variations across said resistive impedance to said gain control electrode.

4. In a signal amplifier network, a tube having a cathode, two output electrodes, a pair of input electrodes connected to a source of signal and suitably disposed to control the electron current to said output electrodes and a gain control electrode suitably disposed to control the electron current to a first of said output electrodes, a resistance connecting said signal electrodes to said cathode in such a manner that the direct current potential of said signal electrodes corresponds to the intensity of the signal applied to them, a second resistance in the discharge paths of both of said output electrodes, and means for applying the direct current potential variations across the second resistance to the gain control electrode so as to control the electron current to the first output electrode.

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