Nov. 9, 1937. C. M. SINNETT 2,098,405

DYNAMIC AMPLIFIER

Filed Sept. 30, 1935

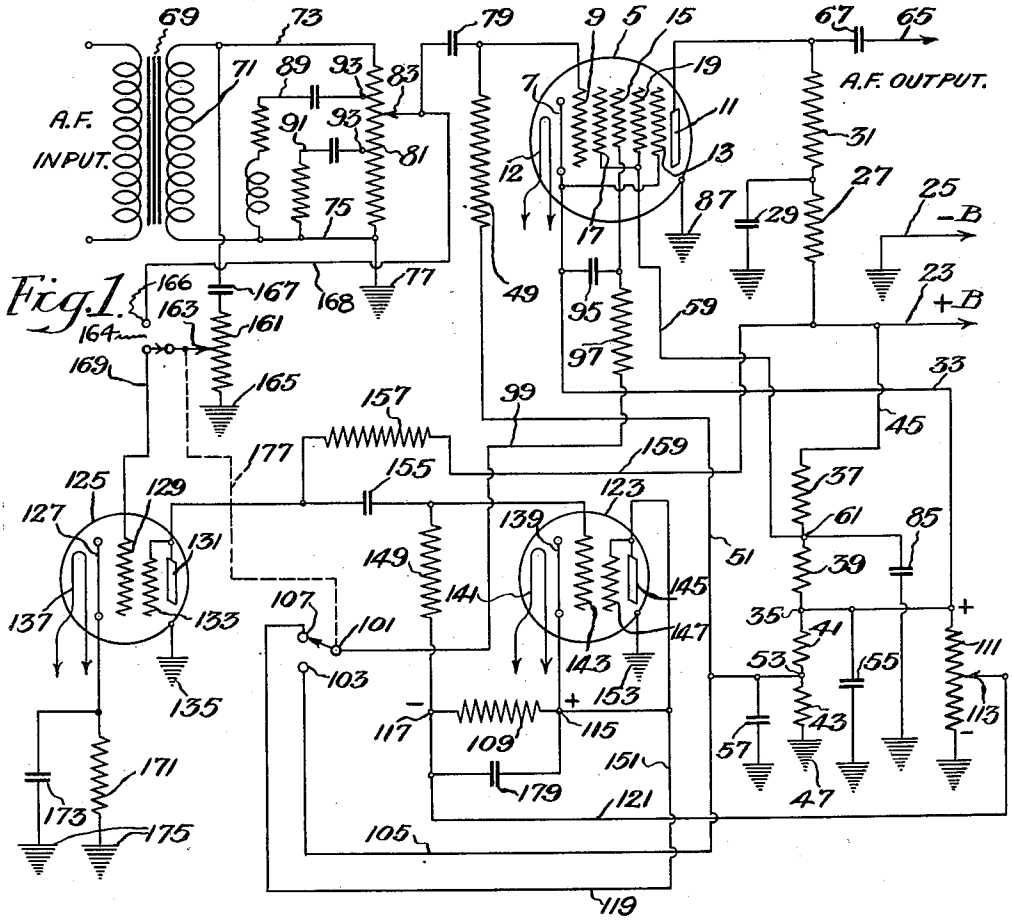


Fig. 1.

Fig. 2.

Witnesses

George L. Jepson

Inventor

Chester M. Sinnett

by P. R. Goldsborough

Attorney

Patented Nov. 9, 1937

2,098,405

UNITED STATES PATENT OFFICE

2,098,405

DYNAMIC AMPLIFIER

Chester M. Sinnett, Westmont, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application September 30, 1935, Serial No. 42,982

12 Claims. (Cl. 178—44)

The present invention relates to dynamic electric signal amplifiers for use in audio frequency circuits and the like to expand the volume range or amplitude of signals transmitted therethrough.

It is an object of the present invention to provide an improved system for volume range expansion of electrically amplified orchestra and other music, with pleasing effect, and without distortion from normal radio broadcast programs and phonograph records as normally recorded.

It is a further object of the present invention to provide a volume range expansion system which includes an improved electric discharge mixing or volume control device having a simplified control circuit in connection therewith.

It is a still further object of the present invention to provide an improved volume range expansion system for audio frequency signals which permits the signal level and the degree of expansion to be adjusted independently. It has been found that volume range expansion may be effected without appreciable signal distortion, through the medium of a variable gain amplifier having separate grid electrodes for signal amplification and gain control as a mixer device, for the rectified and audio frequency components of the controlling and amplified signal.

The invention will, however, be better understood from the following description when considered in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, Figure 1 is a schematic circuit diagram of a variable gain amplifier and variable range volume expander system embodying the invention, and

Fig. 2 is a similar schematic diagram showing a modification of the circuit of Fig. 1.

Referring to Fig. 1, an audio frequency electric discharge amplifier device 5 is provided with an equi-potential cathode 7, a control grid 9 adjacent thereto, an output anode 11, a suppressor grid 13 adjacent to the anode, and a second control grid 15 provided with a screen structure comprising two grid elements 17 and 19 interconnected to effectively shield the grid 15 from the first control grid and from the anode and suppressor grid. Both the control or signal grid 9 and the control grid 15 are interposed in spaced relation to each other in the electronic stream or space path of the tube between the cathode and the anode. The cathode is provided with a heater 12.

The grid structures 17 and 19 may be considered as a screen grid for the second control grid 15. Direct current, grid biasing, screen grid and anode operating potentials are derived from a suitable source (not shown) having positive and negative output leads represented by the positive supply lead 23 and the negative ground lead 25. The positive supply lead 23 is connected to the anode 11 through a filter resistor 27 provided with a suitable bypass condenser 29 and an anode output resistor 31.

The cathode 7 is operated above ground or negative —B potential by connection through a lead 33 with a tap point 35 on a bleeder resistor comprising sections 37, 39, 41 and 43. The bleeder resistor is connected through a lead 45 between the positive supply lead 23 and ground indicated at 47. The control grid 9 is connected through a grid resistor 49 and a lead 51 with a more negative tap point 53 on the bleeder resistor, whereby the potential drop in the section 41 of the bleeder resistor is applied between cathode and signal grid to provide a fixed negative biasing potential on the latter. The sections 41 and 43 are bypassed to ground through a suitable bypass capacitor 55 and the section 43 is further bypassed by a capacitor 57. The screen grid 17—19 is connected through a lead 59 with a more positive tap point 61 than the cathode tap 35.

As an audio frequency amplifier, signals are applied across the grid resistor 49 and are amplified in connection with the signal or first control grid 9 and the output anode 11, from which the amplified signals are derived across the output resistor 31 and may be applied to any suitable output circuit, represented by the output lead 65, through a suitable coupling capacitor 67.

The audio frequency signals to be amplified may be derived from any suitable source such as an audio frequency detector of a radio receiver or from a phonograph pickup device, (not shown) and may be applied to the amplifier device 5 through a suitable coupling device such as an audio frequency coupling transformer 69. In the present example, the secondary 71 of the transformer is provided with output leads 73 and 75, the latter being grounded as indicated at 77. The leads 73 and 75 may be taken to represent any suitable audio frequency signal channel, the signals through which are to be amplified and expanded in volume range.

The signal grid 9 of the amplifier is coupled to the audio frequency circuit 73—75 through a coupling capacitor 79 and a volume control potentiometer 81 connected to the leads 73 and 75 in shunt across the secondary 71. The mov-

able volume control tap 83 of the potentiometer is connected with the coupling capacitor 79. The audio frequency circuit return to the cathode is effected through the bypass capacitor 55 and the cathode lead 33. The latter capacitor, therefore, is preferably of relatively high capacity such as 10 microfarads, for example to provide relatively low audio frequency impedance. The bypass capacitor 57 is also preferably of a similar value thereby preventing degenerative coupling between the control grid and the anode through the resistor sections 41 and 43. It will be noted that the screen grid lead 59 is also provided with bypass capacitor to ground as indicated at 85 thereby to provide a steady screen potential and in conjunction with the resistor sections 37 and 39 to provide an effective filter for the screen structure.

By means of the volume control device 81—83, the amplitude of the signal potential applied to the amplifier may be controlled independently of other controls preceding it and directly at the amplifier, as means for establishing a desired initial signal amplitude or volume. In any case, the volume control device for the amplifier 5 is interposed between the control grid 9 and the signal source, which, in this case, is the secondary of the transformer 69 and the circuit leads 73 and 75.

The device 5 is a variable gain amplifier and is of the mixer type wherein two control grids are utilized in the electronic stream and are effectively shielded from each other to reduce coupling to a minimum. The present amplifier being of the pentode type provides a relatively high gain and the gain is directly controllable by the application of a direct current biasing potential to the second control grid 15. In the construction of the tube, the control or signal grid 9 is the inner grid, while the second control grid 15 is the outer grid. The tube is enclosed in a metallic casing which is suitably grounded as indicated at 87. This tube is preferably of the type now being placed on the commercial market and known as the RCA 6L7 type or pentagrid mixer amplifier.

While this tube is normally adapted for mixing two separate signals by electronic coupling, it has been found that it may be utilized to advantage in a volume expander amplifier circuit by placing the signals to be amplified and controlled on the inner or signal grid 9 operated at a suitable fixed bias, for minimum distortion as a normal amplifier, and controlling the amplification wholly by varying the bias on the outer control grid between upper and lower negative values with respect to cathode to provide an amplification factor between unit and a maximum value. In the case of the tube mentioned, this may be as high as 13 in the circuit shown. For volume range expansion, the outer control grid bias is increased to a negative value such that unity amplification is obtained and negative bias is reduced in accordance with increased signal amplitude to provide increasing gain with increased signal amplitude.

The volume control means 81—83 is preferably provided with tone compensating means such as the series circuits indicated at 89 and 91 in connection with spaced taps 93, for attenuating signals in certain frequency ranges with reduced volume adjustment. As such tone compensating means may be employed in any suitable manner and are well known, further description is believed to be unnecessary.

The outer control grid 15 is bypassed directly to cathode through a filter capacitor 95, and biasing potential therefor is supplied through a series filter resistor 97 and a bias supply lead indicated at 99. The lead 99 may be connected through a switch arm 101 with a contact 103 and a lead 105 connected with the tap point 53 on the bleeder resistor whereby the same fixed negative biasing potential may be applied thereto as is applied to the signal grid 9 as derived from the resistor section 41. With this connection, the amplifier operates in any normal manner to amplify signals without volume range expansion. For the tube shown, this may be approximately 10 volts negative bias, for normal operation of the device as an amplifier.

The switch 101 is provided with a second contact 107 for connecting the control grid 15 further in series with a resistor 109 across which are developed direct current potentials variable with signal amplitude, and in series with a third resistor 111 across which a direct current potential is provided which may be selected by an adjustable potentiometer tap 113. The resistor 109 is provided with positive and negative terminals 115 and 117 respectively, the positive terminal being connected with the switch point 107 through a connection lead 119 and the negative terminal being connected with the movable tap 113 through a connection lead 121.

The resistor 111 is connected at one end with the cathode lead 33 and the terminal 35 while the opposite end is grounded thereby providing a connection through it to the cathode and impressing across it the potential existing between the terminal 35 and ground in the bleeder resistor.

With the switch 101 moved to the contact 107 as shown, the gain or outer control grid 15 is connected in series through the filter resistor 97, thence through the leads 99 and 119, through the resistor 109 and the lead 121 to the movable contact 113 and through the portion included between the contact 113 and the positive terminal thereof to the cathode through the lead 33. There are, therefore, in series between the outer control grid and the cathode, a filter resistor and two sources of biasing potential, one of which is adjustable and the other of which is variable in accordance with signal variations.

The latter source of biasing potentials is provided by a rectifier device 123 connected to the signal source or signal circuit 73—75 through a buffer amplifier device 125. The amplifier device 125 comprises a cathode 127, a control grid 129, an output anode 131 and a suppressor grid 133 connected with the anode. The device is preferably of the metallic shielded type, the metallic shielding being connected to ground as indicated at 135 and the cathode is provided with a suitable heater indicated at 137.

The rectifier device may be of any suitable type but is preferably of the diode type and may be provided by an electric discharge device having a cathode 139 provided with a heater 141, a grid electrode 143, an anode 145 and a suppressor grid 147, the latter being connected with the anode.

In the present example, the cathode is connected with the positive terminal 115 of the resistor 109 and the control grid 143 is connected through a grid resistor 149 with the negative terminal 117 of said resistor.

The suppressor grid and anode are also connected through a lead 151 to the cathode and

the terminal 115. This device is also preferably of the metal shielded type, the metal shield being grounded as indicated at 153. Both the devices 123 and 125 may be provided by a metal tube now appearing on the commercial market and known as the RCA 6C5.

The device 123 is utilized as a rectifier with the grid 143 as the anode, and is coupled to the amplifier device 125 through a coupling capacitor 155 and an anode output resistor 157 for the latter. The anode 131 and the suppressor grid 133 of the amplifier are utilized as a combined anode electrode as shown. The resistor 157 is the positive supply source 23 through a supply lead 159. With this arrangement, the rectifier device 123 is resistance coupled to the amplifier device 125 across the resistor 149 as the input resistor between the diode anode electrode 143 and the cathode electrode 139.

The resistor 109 is the diode rectifier output impedance and the direct current component of the signal, rectified by the diode, is provided at the terminals 115 and 117. It will be seen that the polarity of the terminals will be as indicated, thereby introducing into the series circuit between the control grid 15 and the cathode 7 of the amplifier mixer tube 5, a potential opposing that established by the fixed source 111. A signal serves therefore, to reduce the negative bias initially established on the grid 15 and to cause the amplification of the device 5 to increase with increase in signal strength thereby to provide volume range expansion, the degree of which depends upon the amount of signal admitted to the rectifier.

The amount of signal admitted to the rectifier or the degree of expansion is controlled independently of the volume control device 81—83 for the signal amplifier 5, by a potentiometer device comprising a resistor element 161 having a movable contact 163. The input potentiometer is grounded at one end as indicated at 165 and connected through a coupling capacitor 167 at the opposite end with the high side of the audio frequency circuit represented by the lead 73. It is, therefore, connected substantially in parallel with the secondary 71 of the transformer 69 and the movable contact 163 is connected through a lead 169 with the control grid 129 of the buffer amplifier 125.

The cathode of the amplifier is provided with a series bias resistor 171 having a bypass capacitor 173 to ground 175. Since the grid 129 is connected conductively to the potentiometer device 161, the self biasing potential is applied to the grid 129.

Operation of the contact 163 serves to increase the signal applied to the grid 129 as the contact 163 is moved in an upward direction as viewed in the drawing. The amplified signals received on the grid 129 are amplified and applied to the rectifier 123 for controlling the amplifier mixer device 5 as hereinbefore described.

The contact 163 may be connected with the switch 101 in such a manner that, as the contact 163 is moved to the minimum input position adjacent to the ground end of the resistor 161, the switch arm is moved to the contact 103 thereby placing the amplifier device 5 under normal operation without volume range expansion. This connection for operating the switch is indicated by the dotted connection 177.

From the foregoing description, it will be seen that a variable gain amplifier tube 5 is provided with electrode means whereby it may operate as a mixer amplifier to control the signal gain. The inner or first control grid 9 of the tube receives the audio frequency signal, directly under control of a separate and independent volume control means for the signal. By varying the bias potential on the outer or signal control grid 15, the audio frequency gain of the amplifier stage may be increased with decrease in bias potential, which is initially adjusted by means of the contact 113 for substantially unit amplification.

A portion of the input signal from the audio frequency circuit 73—75 is taken therefrom preceding the audio frequency volume control means and is supplied to a volume amplifier 125 which serves to isolate the load of the rectifier device 123 from the audio frequency transmission circuit, thereby minimizing distortion of the signal by operation of the rectifier. The rectified voltage derived from the rectifier device across the rectifier or diode output resistor 109 is applied, through a filter system comprising the resistor 97 and the bypass capacitor 95, to the outer or second control grid 15.

As the input signal is increased, this rectified potential increases in opposition to the potential initially established on the grid 15 and increases the gain on the amplifier device 5 proportionately. Likewise, as the signal strength decreases, the rectified voltage decreases, thereby increasing the bias potential on the control grid 15 and permitting the gain to decrease. In this manner additional dynamic volume control is obtained over that normally present when the amplifier device operates independently with the switch arm 101 in the position 103.

For producing a pleasing effect in musical reproduction with volume range expansion particularly in the production of orchestra music both from phonograph records and radio signals, it is desirable that the gain of the amplifier mixer device 5 having a more rapid build-up or increase of amplification and a slower decay or reduction of amplification, and this is provided by the circuit in connection with the control grid 15 as follows: with increasing signal strength, the volume provided by the rectifier output resistor tends to change the bias upon the grid 15 through the resistor 97 causing the capacitor 95 to be charged at a predetermined rate. With the capacitor 95 of .5 microfarad and a resistor 97 of approximately 500,000 ohms, the build-up time is substantially .2 second and has been found to be a preferred time lag in response for most pleasing reproduction of music, such as orchestra music.

When the signals are decreasing in volume and the voltage across the output resistor 109 is decreasing, the capacitor 95 discharges not only through the resistor 97 but also through the resistor 109, the two being in series for this condition of operation and the decay time is, therefore, increased and in the present example to substantially .5 second, with a resistor 109 of substantially 200,000 ohms shunted by a stabilizing .5 microfarad. By adjusting the values of the resistors 97 and 109, and the capacitor 95, the time of build-up and decay may be adjusted for any preferred volume expansion effect.

For normal operation of the system described, with a fixed potential of substantially 10 volts on the inner of signal control grid 9, and the contact 113 adjusted to apply a negative potential to the other or gain control grid 15 of approximately 18 volts to provide substantially

unity amplification, the contact 163 is then adjusted to provide a degree of volume expansion such that with the maximum signal potential to be received through the circuit 73—75, the resulting bias potential on the gain control grid 15 may be that necessary for maximum amplification or gain. For example, zero bias potential on the grid 15 may produce maximum gain, in which case the rectified signal potential across the resistor 109 is substantially equal to and the adjusted potential provided by the source 111. Lesser degrees of expansion may be obtained by adjustment of the contact 163 of the expansion control device 161 to correspond to a lower signal potential.

A system, in accordance with the invention, has the advantage that the signal channel is not loaded or otherwise affected by the signal rectifier and gain control means to cause signal distortion, since the rectifier device is isolated from the signal channel by a buffer amplifier of the electric discharge type, and the gain control means comprises a control grid inserted in the electronic stream of the signal amplifier independently of the signal control grid and effectively shielded or screened therefrom and from the output anode. Furthermore, both the signal volume and the degree of expansion are independently adjustable whereby the degree of expansion may be maintained for various signal levels established by the volume control means and the same range of expansion may be obtained for low volume adjustments as for high volume adjustments for the signal volume control device.

However, in certain systems it may be desirable to operate the control system from the same volume control device as the signal amplifier. For this purpose a switch 164 is provided to break the connection for the grid 129 with the contact 163 of the independent expansion control device and to provide a connection through a contact 166 and a connection lead 168 with the volume control contact 83. Variation of the volume control means, for a lower volume, for example, provides a correspondingly lesser degree of expansion. Likewise the expansion control is increasingly more effective as the volume is increased.

The series circuit for the gain control grid of the signal amplifier is particularly advantageous since the filter means for time delay operation is placed adjacent to the control grid and serially in circuit with the output resistor of the controlling rectifier and the fixed source of biasing potential for adjusting the initial amplification. This permits a more rapid increase in gain with a slower decrease in gain in response to changes in signal strength or average amplitude of the applied audio frequency signals, as is desirable for sound reproduction with volume range expansion from normally recorded and normally broadcast signals without the addition of complicated circuit means.

The control channel, including the buffer amplifier, is uniformly responsive throughout the audio frequency range and provides substantially linear amplification for the rectified signals. The circuit has the further advantage that compensated volume control means may be provided in connection with the signal amplifier independently of the volume expansion means and the latter is controlled entirely by the voltage amplitude of the signals applied to the buffer amplifier, no additional controlling signal being required, and substantially no load being placed upon the audio frequency circuit thereby, since the audio frequency signal circuit actuates only the signal and buffer voltage amplifiers.

The buffer amplifier and signal rectifier for the control circuit may be combined if desired in one device as shown in the circuit modification of Fig. 2 to which attention is now directed and in which the same reference numerals are used as in Fig. 1 for the same circuit elements.

The volume expander amplifier 5 is coupled as in the circuit of Fig. 1 to a signal input circuit and volume control through the coupling capacitor 79 and is provided with bias supply means through the grid leak resistor 49 while the output circuit includes the output coupling impedance 31 and the coupling capacitor 67.

The gain control grid 15 is provided with the filter capacitor 95 and series filter resistor 97 and the cathode 7 is provided with a variable self-bias resistor 217 also provided with a bypass capacitor 219. The circuit from the cathode 7 through the variable self-bias resistor 217 is completed through a ground connection 218, a second ground connection 215, through a diode output resistor 209 and thence to the resistor 97 through a lead 205. The initial bias on the gain control grid 15 is thereby adjusted by the resistor 217 and the resistor 209 is also variable to provide a desired opposing potential in response to signals to cause the gain of the amplifier 5 to increase with increasing signal strength.

The resistor 209 is suitably bypassed by a capacitor 213 and it will be seen that for increasing signal strength, the resistor 97 causes the capacitor 95 to charge at a predetermined rate and that, upon decrease of signal strength, the resistors 97 and 209 are in series to cause a longer time delay for response of the amplifier to decreasing signal strength.

In the present example, the diode rectifier for supplying signals to the output resistor 209 is provided in an electric discharge amplifier device 180 having a control grid 183, an output anode 185, a cathode 187, a heater therefor 189, and a pair of diode anodes 191 associated with the cathode 187.

Signals are applied to the control grid 183 from the signal supply lead 169 and are amplified in the amplifier 180. The amplified signals are applied to the diode comprising the anodes 191 and the cathode 187 through an output transformer 193 connected with the amplifier output circuit 195 in which is included a coupling capacitor 197 and coupling resistor 199. The output circuit includes the primary winding 201 of the transformer 193 and the secondary 207 is connected between the diode anodes 191 and the cathode 187 through the output resistor 209. The diode circuit comprises the leads 211 and 205. The control of the variable gain amplifier through the means shown is otherwise the same as described in connection with Fig. 1 and, accordingly, further description is beliveed to be unnecessary.

I claim as my invention:

1. In a volume expander system for audio frequency signals, an electric discharge amplifier device having two independent control grids in the space path thereof, means for applying audio frequency signals to be amplified to one of said control grids, volume control means for said signals interposed in circuit between said last named means and said one of said control grids, a signal rectifier device having an output resistor,

means providing a series bias supply connection for the second control grid through said output resistor, means including a series resistor and a by-pass capacitor between the second control grid and the cathode providing a filter in said connection, a buffer amplifier including an electric discharge amplifier device coupled to said rectifier, means for applying audio frequency signals to said rectifier through said amplifier, and means for controlling the amplitude of said last named signals independently of said first named volume control means.

2. In a volume range expander system for audio frequency signals, an electric discharge amplifier device having a cathode, and two independent control grids in the space path thereof, means for applying audio frequency signals to be amplified to one of said control grids, volume control means for said signals interposed in circuit between said last named means and said one of said control grids, a signal rectifier device having an output resistor, means providing a series bias supply connection for the second control grid through said output resistor, a by-pass capacitor for said second control grid directly connected therewith and a series filter impedance in said bias supply connection between the second control grid and the cathode providing a filter in said connection, said resistors being in series for discharge of said capacitor and said output resistor providing a potential source for charging said capacitor, whereby a predetermined differing delay in response of the gain control through said amplifier device is provided for increasing and decreasing signal volume level.

3. A dynamic audio frequency amplifier comprising an electric discharge signal amplifier having a signal grid and a separate gain control grid in the space path thereof, said last named grid being provided with a screen, a signal rectifier for applying a signal variable biasing potential to said gain control grid, means for connecting said rectifier to the signal channel of said amplifier including a buffer amplifier stage, independent volume control means for said buffer amplifier and said first named amplifier, and time delay filter means providing a connection between said rectifier and said gain control grid.

4. A volume expander system comprising in combination, an electric discharge amplifier device having a pair of control grids, means for applying signals to be amplified to one of said grids more adjacent to the cathode, means for applying a predetermined fixed direct current biasing potential to the other of said control grids, means providing a time delay network in connection with said other control grid, a second signal amplifier device comprising a cathode, a control grid, an anode, and a diode anode adjacent to the cathode, means for applying signals to said last named control grid, means for applying signals derived from said anode between the diode anode and the cathode, and a diode output resistor in circuit between the time delay network and said bias supply means.

5. In a volume expander system, the combination with a signal supply circuit, of a combined amplifier and rectifier device having a control grid connected with said signal supply circuit and having an output resistor, a volume expander amplifier device having a cathode, a signal grid connected with said signal circuit and a gain control grid connected with said output resistor, a resistor capacitor filter in series between said gain control grid and said output resistor, a self-bias resistor in circuit with said last named resistors serially, and independent volume control means for said last named amplifier.

6. In an audio frequency amplifier, an electric discharge amplifier device having a cathode, a control grid adjacent to the cathode, a second control grid and an output anode electrode, means for applying audio frequency signals to said control grid, and means for applying a variable biasing potential to the second control grid thereby to control the gain of said amplifier, said means comprising a second amplifier device, means for variably applying a portion of said signals to said second amplifier device, a rectifier device for receiving amplified signals through said second amplifier device, an output resistor for said rectifier, means providing a fixed direct current biasing potential for said control grids including a resistor across which a potential is established for the second control grid, a circuit connecting said last named resistor and output resistor serially between the second control grid and the cathode, and a resistor capacitor filter connected between the second control grid and the cathode.

7. A volume range expander system for audio frequency signals, comprising an audio frequency signal transmission circuit, an audio frequency amplifier having a signal control grid connected with said circuit, volume control means in said connection, said amplifier device further having a cathode, a second control grid and an output anode, a time delay filter connected adjacent to the second control grid and comprising a capacitor connected between said control grid and cathode and a series resistor, means providing biasing potential for said second control grid included serially in circuit with said filter resistor between said grid and the cathode, and means for establishing a variable potential in opposition to said biasing potential in said circuit in response to signal strength variations, said means comprising a diode rectifier device, a diode output resistor therefor in said circuit, an electric discharge amplifier stage coupled to said diode rectifier and variably connected with said signal circuit, independently of said first named amplifier device.

8. In an audio frequency amplifier, the combination of an electric discharge amplifier and control device having a cathode, a signal control grid adjacent to the cathode, an output anode and a second control grid between said first named control grid and the anode, a signal output circuit connected with said anode, a signal input circuit connected with said signal control grid, volume control means in said last named connection, a second electric discharge amplifier device connected with said signal input circuit independently of said volume control means, independent volume control means for said second amplifier device, a diode rectifier device coupled to said second amplifier device for rectifying signals therefrom, said rectifier device having an output resistor, a capacitor connected between the second control grid and the cathode, a resistor connecting said second control grid with the rectifier output resistor whereby said resistors are in series relation to each other between the second control grid and the cathode, and means providing a fixed biasing potential for said grid in said connection.

9. In a volume range expansion system for audio frequency signals, an electric discharge amplifier having a cathode, a signal control grid, a

second control grid, means for establishing a fixed biasing potential on said first control grid, means for applying audio frequency signals to said signal control grid, means for deriving a fixed biasing potential for said second control grid from said first named means, means for applying a rectified signal potential to said second control grid in opposition to the potential applied thereto by said last named means, said means for applying a rectified signal potential including filter and bias supply resistors in series with said second control grid, and a shunt capacitor for said series circuit connected between the second control grid and the cathode, the value of said capacitor and the values of said series resistors being so related that variation in biasing potential in response to variation in rectified signal potentials are applied to said second control grid with a predetermined time delay with increasing rectified signal potential and a predetermined increased time delay with decreasing rectified signal potential.

10. In a volume range expander system for audio frequency signals, a combined electric discharge amplifier and mixer tube having a cathode, a control grid adjacent thereto, an output anode, a suppressor grid adjacent thereto and connected to the cathode, a second control grid interposed in the space path of the tube between the first control grid and the output anode, and a screen grid structure for said second control grid whereby it is electrically shielded from the other electrodes of the tube, means providing a series bias supply and control circuit between the second control grid and the cathode, a filter comprising a resistor and capacitor in combination in said circuit adjacent to the second control grid, the filter capacitor being connected between the cathode and said second control grid, a signal rectifier having an output resistor included as a time delay and bias supply impedance in said series circuit, means for applying a biasing potential to said second control grid whereby a predetermined initial low degree of amplification is obtained, and means for applying signals to be amplified to the first named control grid and to said rectifier.

11. In a volume range expander system for audio frequency signals, a combined electric discharge amplifier and control tube having a cathode, a control grid adjacent thereto, an output anode, a gain control grid interposed in the space path of the tube between the first control grid and the output anode, means providing a series bias supply and control circuit between the second control grid and the cathode, a filter comprising a resistor and capacitor in combination in said circuit, a signal rectifier having an output resistor included in said series bias supply and control circuit, means for applying a biasing potential to said second control grid whereby a predetermined initial low degree of amplification is obtained, variable means for applying signals to be amplified to the first named control grid, and variable means for applying signals to said rectifier.

12. In a volume range expander system for audio frequency signals, a combined electric discharge amplifier and control tube having a cathode, a control grid adjacent thereto, an output anode, a gain control grid interposed in the space path of the tube between the first control grid and the output anode, means providing a series bias supply and control circuit between the second control grid and the cathode, means providing a common source of biasing potential for said control grids connected with said last named circuit, a signal rectifier having an output resistor included in said series bias supply and control circuit, and means responsive to an increase in the average amplitude of audio frequency signals applied to said first named grid for causing the gain control grid potential to be changed in a positive direction.

CHESTER M. SINNETT.