

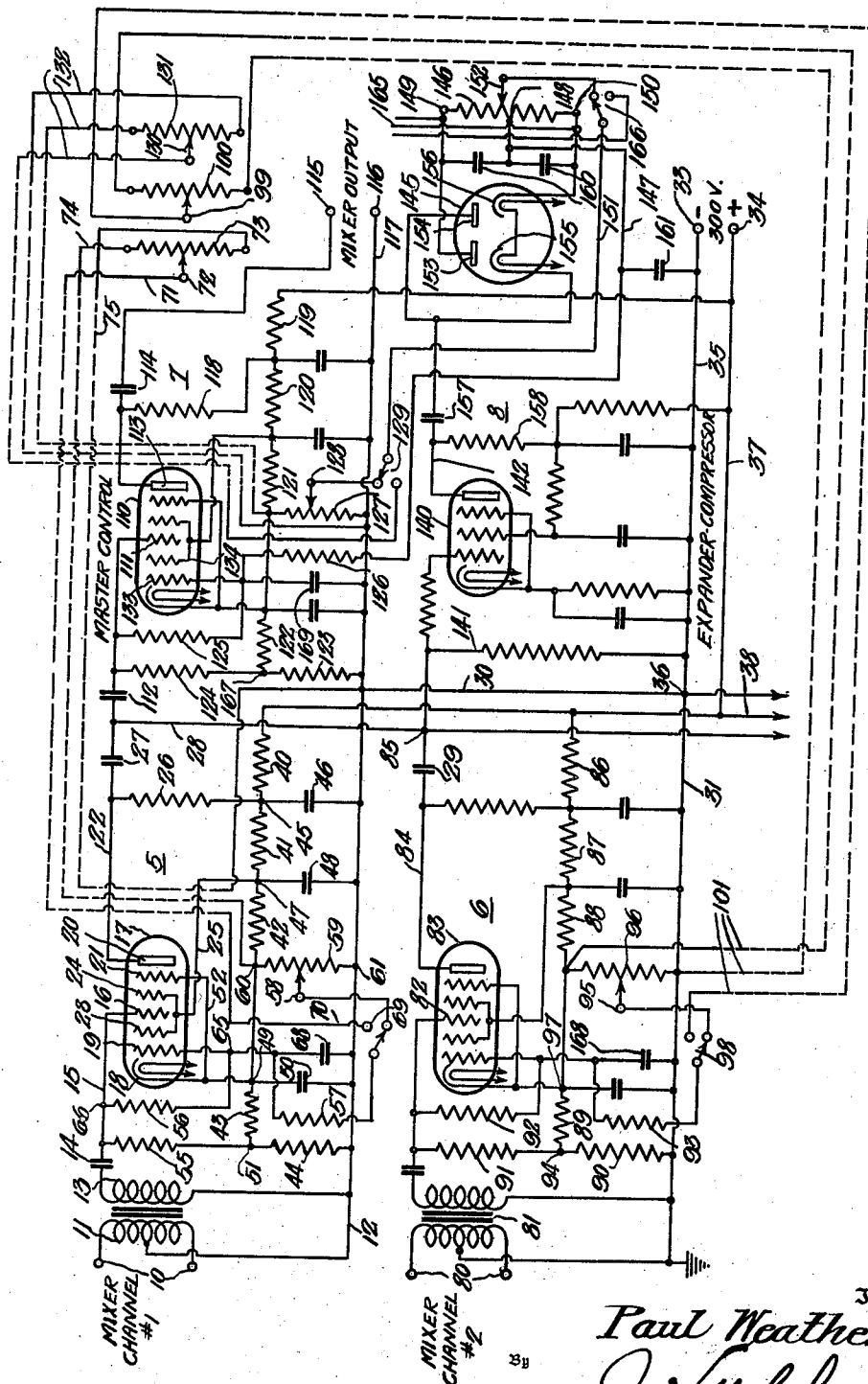
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VARIABLE GAIN SIGNAL AMPLIFYING SYSTEM

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VARIABLE GAIN SIGNAL AMPLIFYING
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The present invention relates to variable gain signal amplifying systems, and has for its object to provide an improved variable gain signal amplifier having a gain control circuit providing quiet operation and a wide range of control without signal distortion.

It is also an object of the present invention to provide a variable gain signal amplifier having at least one gain controlling stage in which an inner and an outer control grid are interposed between the cathode and anode, together with a screen electrode interposed between the inner and outer control grids and between said grids and the anode, whereby the gain of the amplifier stage may effectively be controlled by a variable biasing potential on both control grids, through a wide range without distortion of alternating current signals on the outer control grid.

More particularly, it is a further object of the present invention, to utilize and take advantage of certain inherent and desirable operating characteristics of a variable mu control grid as the inner grid in a gain controlling circuit, together with an additional control grid for applied signals to be controlled, as in a tube at present provided by a commercial type known as the RCA 6L7 pentagrid mixer amplifier.

It is also an object of the present invention, to provide a gain or volume controlling circuit wherein a variable gain controlling potential applied to the inner or first grid of a mixer tube of the type above referred to, may be varied over a relatively wide range, and a biasing potential for the outer or signal grid may be varied over a lesser range in predetermined relation thereto.

It is a further object of the present invention to provide an improved volume or gain control circuit in a variable gain signal amplifier having a multiple grid gain control tube, which permits the joint control of biasing potential on an inner and an outer control grid in predetermined mutual relation to each other, to provide a wide range of volume control without distortion.

It is also a further object of the present invention, to provide a variable gain signal amplifier having a mixer amplifier tube therein provided with a variable-mu inner grid and direct current biasing potential varying means therefor, an outer control grid and means for applying to said grid the signals to be amplified, and further provided with a screen electrode between said control grids and between the output anode and said control grids, together with means for controlling the screen grid potential, whereby a wide range of effective control of gain may be obtained.

It is also a still further object of the present invention, to provide a variable gain signal amplifier having a gain controlling tube and inner control grid and an outer signal grid biasing

means including a gain controlling circuit, which may be extended to a remote point and controlled by simple volume control means without introducing distortion and noise.

An amplifier embodying the invention is particularly adapted for use in mixing circuits for microphones and other signal sources to be connected with a common signal amplifying channel. For example, in sound picture and theatre sound pickup from a plurality of points on a set or stage, it is advantageous to extend the mixing and gain controlling circuits to a central control point, and a circuit embodying the invention is particularly adapted for this use, as effective remote control at any distance may be provided without transmitting the signals to the remote point and without introducing noise into the signal circuits through the remote control extension circuits.

It may therefore be considered as a still further object of the present invention to provide an improved signal mixing system for microphones and signal pickup devices of that character, wherein individual gain controlling circuits are provided for signal mixing and master volume control, each embodying a multiple control grid amplifier tube and a gain control network of the type referred to, which is exclusive of the signal channel, whereby the control potentials on the several tube grids may be changed in predetermined relation to each other without introducing distortion and noise.

In connection with a system of the above character, it is advantageous to provide for volume expansion and compression, and it is, therefore, a still further object of the invention to provide an improved variable gain signal amplifier embodying gain or volume control in each of a plurality of signal channels, at least one of which is under control of a signal rectifier device having an output circuit and means therein for adjusting the output potential for expansion or compression of a received signal, the expansion and compression being provided in one stage and with one control device.

In a preferred embodiment of the invention, a plurality of mixer channels for microphone pickup are provided, in each of which a tube of the pentagrid mixer amplifier type, as hereinbefore referred to, is provided, together with means for controlling the application of potentials to the control grids and screen grid in predetermined mutual relation to each other, whereby the gain through each channel is smoothly variable without noise and without extending the signal conveying circuits for remote operation.

In addition, a main master control channel is provided for the several mixer channels having a similar type of gain control adapted also for remote control operation in the same manner, and

an expander-compressor channel, the control circuits of which provide for both expansion or compression of signals passing through the main master control channel. The circuits of the expander-compressor channel are also extensible to remote points without introducing signal distortion.

It is a further object of the present invention, to provide, in mixer systems of the type above referred to, a grid biasing and potential supply network in the several mixer channels and master control channel, which permits a rapid change of volume control adjustment without permitting the resulting circuit potential variations to pass through the amplifying system as noise impulses.

In carrying the above object into effect, the grid bias or potential changes on the amplifier tubes are caused to occur at a sufficiently small rate and without breaking the conductive grid bias connections, so that no portion of any generated wave front resulting therefrom will pass through the signal coupling system of the various mixing channels or main master control channel.

Furthermore, in carrying out this and other objects of the invention, the plate voltage on any amplifier tube in the system is prevented from changing abruptly, and it may also be said to be an object of the present invention to provide in connection with a pentagrid mixer amplifier tube or the like, gain controlling circuits and means which coordinate and vary the potentials on a gain controlling grid, a signal input grid and a screen grid simultaneously for each change in gain, thereby to provide a wide range of control, and in connection with a single control means adapted for remote control without introducing signal distortion or noise.

The invention will be further 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, the figure is a schematic circuit diagram of a multiple channel signal mixing and volume controlling system embodying the invention.

Referring to the drawing, two signal mixer channels 5 and 6, representing any suitable number of mixer channels, are provided in connection with a master control channel 7 for the combined output of the mixer channels, and an expander and compressor channel 8, for controlling at least one of the channels, such as the master control channel, to expand or compress the signals transmitted therethrough.

Each of the signal mixer channels may be of similar construction and management and may include similar circuit elements and connections.

Referring particularly to the first mixer channel, the signal input terminals are indicated at 10 in connection with a center tapped primary winding 11, connected at its center tap with the ground lead or chassis connection 12 of the control system and of the channel. The secondary 13 of the transformer is connected at its low potential side, also to ground and at its high side through a coupling capacitor 14 with a grid lead 15 connected to the outer control grid 16 of a double control grid amplifier tube 17. The tube is preferably a pentagrid mixer amplifier tube as shown, having a cathode 18, an inner or first control grid 19, a screen grid, an output anode 20, and a suppressor grid 21. The screen grid 21 comprises two sections 23 and 24 for screening

the control grids from one another and from the anode. A common output connection 25 is provided for the screen grid.

Signals applied to the outer control grid 16 are amplified in accordance with the gain established by the biasing potentials applied to the control grids and by the screen grid potential, and the amplified output is taken from the anode 20 through an output circuit 22 in which there is provided an output coupling resistor 26 in connection with a coupling capacitor 27. A common mixing or output bus connection 28 is provided for the various mixer channels, to which the output circuits are coupled as indicated, the output capacitor of the second channel being indicated at 29, whereby the combined output of the various channels is applied to the common bus connection 28 as the high potential side of the mixer combined output circuit. The ground lead 12, being the low potential side of the mixer channel, is likewise connected to a ground bus 30 to which the corresponding ground bus 31 of the second channel and other channels (not shown) are connected.

The anode, screen grid and biasing potentials for the entire system comprising the various mixer channels, master control and expander-compressor channels are derived from a suitable supply source of rectified or direct current provided at terminals indicated at 33 and 34. The terminal 33 is the negative supply terminal and is connected through a ground lead 35 to the ground bus 30 as indicated at 36. The terminal 34 is the positive potential supply terminal and is connected through a lead 37 with a positive B potential supply bus 38 for the various mixer channels.

The different operating potentials are derived from a potential divider or bleeder network in each channel, which may be described for channel 5 as comprising a series of resistor sections 40, 41, 42, 43 and 44 connected in the order named between the positive potential supply bus 38 and the negative ground connection 12 and the negative bus 30. The supply potential of 300 volts, in the present example, is applied across the potential divider network and the various potentials for the tube electrodes in each channel are derived from suitable taps thereon. In the present example the taps are made between adjacent sections extending from the more positive end of the bleeder circuit to the more negative end. The anode supply connection is made at a positive supply terminal 45 between the sections 40 and 44 and this connection is provided with a suitable filter capacitor 46 to ground.

Next in order and between the sections 41 and 42 at a positive supply terminal 47, the screen grid 23—24 is connected and provided with a suitable filter capacitor 48 from that terminal to ground. The next connection is made for the cathode, with a terminal 49 between the resistor sections 42 and 43 and this is also provided with a filter capacitor 50 to ground. The remaining terminal 51 between the resistor sections 43 and 44 is in effect a potential tap point between the cathode or cathode terminal 49 and ground.

The suppressor grid 21 is connected to the cathode in the usual manner as indicated by the connection 52. The two control grids 16 and 19 are connected with tap points on a second or grid bias potential divider network as distinguished from the main operating potential voltage divider network for the anode, screen grid and cathode. This series potential divider circuit comprises

three resistor sections indicated at 55, 56 and 57 connected in the order named, between the terminal 51 on the first network and a movable contact 58 in connection with a potentiometer resistor 59 connected substantially in parallel with the resistor sections 43 and 44 between the cathode terminal 49 and ground. The terminals of the potentiometer resistor are indicated at 60 and 61.

The circuit arrangement described provides a voltage divider for the two control grids, to establish on them, with respect to the cathode, variable biasing potentials having a predetermined mutual relation to each other. The movable contact 58 may be moved along the potentiometer 59 between the cathode and ground, thereby increasing the negative potential applied to one end of the grid bias potential or voltage divider, while the opposite end of the bias network is fixed at a predetermined tap point 51 which is intermediate between the cathode and ground. This tap point is preferably slightly more negative than the cathode by an amount sufficient to provide a predetermined minimum negative bias on the control grids.

On the bias potential divider, the inner control grid 19 is connected at the first tap point designated at 65, between the resistor sections 56 and 57, whereby it is more completely under control of the movable contact 58, to change the bias potential thereon, than the outer or signal grid which is connected, in effect, between the resistor sections 55 and 56 at a terminal 66, being thereby separated from the fixed connection 51 by the resistor section 55 and from the inner control grid 19 by the resistor section 56.

Both resistors 55 and 56 are connected at the common terminal 66 with the grid input lead 15, and the total resistance between the lead 15 and the cathode is made sufficiently high so that the signal voltage is not appreciably attenuated.

The relative resistances of the resistors 55, 56 and 57 is such that the resistor 56 is relatively high in resistance with respect to the resistor 55, whereby the negative potential applied to the outer signal grid 16 varies through a limited range as the contact 58 is moved between the terminals 60 and 61, while the negative potential applied to the inner control grid 19 is varied through a much wider range, the potential on this grid being determined by the relation between the resistance of the resistor 57 and that of the resistor 56, both of which are relatively large in resistance value with respect to the resistance value of the resistor 55.

In the present embodiment of the invention, the resistors referred to have values as given in the tabulation below:

Resistor	Resistance in ohms
40	47,000
41	150,000
42	33,000
43	1,200
44	33,000
55	56,000
56	1.2 meg.
57	800,000
59	250,000

The resistor network for the main bleeder is such that a relatively high resistance of substantially 200,000 ohms is interposed between the screen grid connection at the terminal 47 and the supply bus 38, so that the voltage regulation is relatively poor on the screen grid while the capacitor 48 is relatively small, so that the time

constant of the voltage change on the screen grid is relatively rapid.

The main bleeder resistor or potential divider provides at the terminals 60 and 49, a positive potential with respect to ground or the terminal 61, of substantially 40 volts, while the relative resistance values of the resistors 43 and 44 are such that the intermediate terminal 51 for the control grid bias potential divider is substantially 2 volts negative with respect to the cathode 18 and the terminal 49.

From the resistance values given, it will be seen that the contact 58, movable along the potentiometer resistor 59, serves to carry the movable end of the grid bias potential divider with respect to the fixed tap 51, above it in a more positive sense or direction to the terminal 60, and below it in a more negative sense or direction to the terminal 61, whereby the negative biasing potential on both grids may be slightly reduced below the two volts established at the terminal 51, the inner control grid being reduced below two volts to a greater degree than the outer or signal grid, by reason of the fixed relation between the resistors 55, 56 and 57. This relation is maintained when the contact is moved in the opposite direction in the more negative range toward the terminal 61, comprising a potential change of substantially 38 volts. Since the resistor 55 is substantially $\frac{1}{20}$ of the value of the resistor 56, and substantially $\frac{1}{15}$ of the resistance of the resistor 57, the voltage at the terminal 56, as applied to the outer control grid, while increasing and decreasing appreciably in response to movement of the contact 58, does not vary through the extremely wide range applied to the inner gain control grid.

The bias potential relation between the two grids is such that the bias potential on the outer signal grid is increased and decreased in proportion to the signal volume applied thereto from the input terminals 10, since the control is electronic and the control of gain affects the output from the control tube 22 and does not affect the amplitude of the potential applied to the outer signal control grid. Therefore, it is desirable to increase the biasing potential on the outer control grid as the negative bias is increased on the inner control grid, to reduce the gain of the amplifier stage and to restore the output volume or amplitude to a predetermined desired level.

It will be noted that a coupling capacitor, indicated at 68, is connected between the inner control grid terminal 65 and the negative ground lead 12, thereby providing a time delay or regulating effect upon the inner control grid as the contact 58 is moved, to obtain a larger control action and a smoother response without noise. In the present example, where a tube of the RCA 6L7 type is used, the inner grid is of the variable-mu type and the control action is materially improved by the use of the coupling capacitor between the grid and ground. As shown, this capacitor may have a value of substantially .25 mfd.

While the contact 58 is movable along the resistor 59 between the terminals 60 and 61, to provide a wide range of gain control on the inner grid and a lesser degree of bias control on the outer signal grid, it will be noted that the opposite end of the grid bias potential divider is connected through a fixed conductive connection with the cathode, comprising the resistors 56, 55 and 43, whereby any operation of the contact connection or change of potential normally tending to produce noise in connection with sensitive

grid circuits, is reduced substantially to zero because of the fixed conductive connection and the smoothing action of the series circuit acting in conjunction with the capacitor 68. The operation is such that the effect of the grid bias change is rendered slower in action so that no portion of a wave front tending to be set up thereby, will pass through the coupling capacitor 27 or other coupling device leading to the mixer or output bus 28.

As the bias potential on the inner grid is varied between the limits provided by the potentiometer 59, the screen grid 23—24 is caused to vary between 18 and 50 volts. An increase in negative bias on the grid 19 causes the screen grid voltage to change in a direction to permit handling greater input signals without distortion.

The screen voltage divider network is so chosen that the correct operation voltages are obtained for all values of gain. Also these values of resistance are so chosen that signals originating on the first or inner control grid are degenerated without causing appreciable degeneration of signals originating on the outer or second grid control. Thus steep wave fronts impressed on the inner grid by changing its bias suddenly are further prevented from being impressed upon the following stage with enough intensity to cause noise.

It will therefore be seen that the potential divider network shown, provides for the control of the inner and outer grids and the screen grid by the simultaneous control of biasing potentials and operating potential in predetermined mutual relation to each other, whereby noiseless gain control of a relatively wide range is provided without introducing distortion or noise.

It will be noted that a switch 69 is provided in the connection between the gain control contact 58 and the resistor section 57, whereby the resistor 57 may be connected to the contact 58, or selectively to an extension lead 70 extending to a remote point as indicated by the dotted connection 71, and a corresponding movable contact 72 on a remotely located potentiometer device 73 corresponding to the potentiometer resistor 59. The latter is connected in parallel with the device 73 through extension leads indicated at 74 and 75 extending, with the lead 71, back to the terminals 60 and 61, respectively.

When the switch is thrown to connect the resistor 57 with the extension lead 70, it will be seen that remote control of the gain is obtainable at the contact 72, and that in so extending the circuits referred to, the signal transmission circuit is not in any way extended or subjected to the influence of extraneous signals tending to cause noise. The control of gain is otherwise the same as described in connection with the potentiometer contact 58.

An advantage of this system lies in the fact that the extension leads to the remote control point need not be shielded or prevented from picking up stray signals, and may be extended to any desired length with ordinary conductors. The resistor 57 and the by-pass capacitor 68 serve as a filter between the extension lead 71 and the inner control grid 19, the resistor 57 being of relatively high resistance; such as 800,000 ohms, as previously pointed out, and the capacitor 68 being of substantially .25 mfd.

Any suitable number of mixer channels similar to the channel above described, may be connected with the ground, plate supply and signal bus lines 30, 38 and 28 respectively. A second channel is

represented by the channel 6, which is provided with the same circuit elements and connections therefor as the channel 5 and operates in the same manner. Therefore, the channel 6 will be described briefly only by reference to the various elements and circuits whereby it may be referred to the description of the channel 5 for comparison therewith.

The channel input terminals are indicated at 80 and are connected through the input transformer 81 with the outer or second control grid 82 of the amplifier tube 83. The output anode circuit 84 is coupled through the capacitor 29 with the channel output bus lead 28 as indicated at 85.

Operating potentials are derived from a voltage divider series circuit comprising the resistors 86, 87, 88, 89 and 90, connected serially between the bus leads 30 and 38 and corresponding to the resistors 40 to 44 inclusive of the first channel.

The inner and outer control grids are connected through the grid resistor circuit comprising the resistors 91, 92 and 93 connected in series between a terminal 94 on the plate supply voltage divider circuit and a tap 95 on a shunt resistor 96 providing a potentiometer between the cathode terminal 97 on the main or anode voltage divider circuit and the ground lead or negative supply lead 31.

A switch 98 is interposed in the last named connection between the grid voltage divider circuit element 93 and the potentiometer contact 95, for the purpose of switching over to remote control of gain in the channel by a remotely located control element comprising a potentiometer device indicated at 99—100. The remote control lead connections are indicated at 101.

With the switch in the position shown, the control of gain through the second mixer channel 6 is obtained by operation of the contact 95, while, for remote control, the switch is turned to the alternate contact to control gain by adjustment of the contact 99 at the remote control point.

The signals applied to the main bus wire 28 are applied to a common output utilization means such as the usual amplifier channel, through a master control channel which may be similar to the mixer channels in regard to its circuit elements and connections, thereby simplifying the equipment necessary for a complete mixer and master control unit.

In the present example, the master control channel indicated at 7, as hereinbefore referred to, comprises a multiple control grid amplifier tube 110 having an outer control grid 111 coupled to the mixer bus lead 28 through a coupling capacitor 112, and having an output anode 113 coupled through any suitable means such as a coupling capacitor 114 with a mixer output high potential terminal 115, the low potential terminal 116 being connected to the ground bus 30 and anode potential return circuit through a ground lead 117.

The output anode is provided with operating potential through an output coupling resistor 118, and the electrodes of the tube are connected in the same manner as the mixer channels with the main anode and screen grid supply bleeder comprising resistors 119—123 and control grid supply bleeder comprising resistors 124—126. The gain control potentiometer is indicated at 127 and is provided with a gain control contact 128 having a control switch 129 for providing a connection with a corresponding control contact 130 on a remote control potentiometer 131.

the contact and potentiometer being connected with the potentiometer 127 and the switch 129 through suitable extension leads indicated at 132. The control and operation of the inner control grid indicated at 123, the outer control grid 111 and the screen grid 134 is the same as that described in connection with the mixer channel 5, whereby the control of gain from the mixer bus lead 28 for all channels may be controlled at the amplifier or remotely as desired.

With the arrangement shown, the control potentiometers 72-73, 99-100 and 130-131 may each have a resistance of 250,000 ohms and may be placed at any suitable point by extending the lead connections therewith, to control at one point, the mixing of the various signals from microphone pickup circuits on a location or stage, for example, and the desired mixing may be effected together with control of the output from the mixing circuits at any desired point such as that at which the performance involving the sound pickup is to be viewed. The extension leads and controls may thus be placed at the rear of a theatre or in the balcony at any suitable point, without extending any of the sensitive sound signal conveying circuits or providing coupling therewith, while complete and effective control is obtained through the medium of simple control elements and circuits.

Provision is also made for volume or gain expansion and compression by an expander-compression channel 8, as hereinbefore referred to, which is connected with the mixer bus lead 28 to amplify and rectify a portion of the signals applied to the mixer bus and to utilize the resulting rectified current to control the gain of the master control channel.

This arrangement includes an amplifier stage comprising an amplifier tube 140, having an input circuit 141 connected at the terminal 85 on the bus 28, and having an output circuit 142 coupled to a rectifier device 145. The rectifier output resistor 146 is variably included in the bias control connection for the control grids, between the resistor 126 and the switch 129 for the manual control contacts 128 and 130. A connection whereby the resistor 146 may be included in the bias control circuit for the master control channel 7, is provided by a lead 147 connected between the resistor 126 and a tap 148 on the resistor 146 substantially mid-way between the terminals 149 and 150, and a lead 151 connected between the switch and a movable tap 152 on the resistor 146, the tap being movable along the resistor between the terminals 149 and 150 to the center tap, and on either side thereof.

The rectifier device 145 is of the type having two anodes 153 and 154 associated respectively with two cathodes 155 and 156. The output circuit 142 of the expander-compressor amplifier is coupled to the rectifier device through suitable means such as a coupling capacitor 157 and an output anode resistor 158, with the anode 154 of one of the diode rectifier elements and the cathode 155 of the other diode rectifier element in parallel. The terminals 149 and 150 of the output resistor are connected respectively with the remaining diode anode 153 and the remaining cathode 156 of the device 145.

The arrangement is such that full wave rectification is obtained and the rectified signal is applied to the output resistor 146 to provide a current flow therein resulting in establishing a potential between the terminals 149 and 150 which is dependent upon the amplitude of the

audio frequency signal with a polarity as indicated, the terminal 150 being positive and the terminal 149 being negative.

With the movable contact 152 at the mid tap 148, the rectified signal potential control voltage is out of circuit with the control grid circuit for the amplifier 110, and the control of gain is placed entirely on the manual control elements 128 or 130. As the contact 152 is moved to include a portion of the resistor 146 between the terminals 148 and 150, the lead 147 connected with the control grids becomes in the presence of signals, more negative than the lead 151, thereby having the effect of increasing the negative bias and thereby reducing the gain of the master control channel.

This has the effect of volume compression, tending to reduce the output amplitude in response to sudden increase in the amplitude of signals transmitted through the main channel, and the degree of compression may be regulated by the adjustment of the contact 152, the compression being increased as the contact is moved toward the terminal 150.

In a similar manner, as the contact 152 is moved toward the terminal 149 from the tap 148, the lead 147 becomes in the presence of signals, more positive than the lead 151, having the effect of decreasing the negative bias on the control grids of the master control amplifier and thereby increasing the gain. This has the effect of volume expansion as variations in signal amplitude are received on the rectifier, and the degree of expansion may be controlled by moving the contact 152 toward or away from the terminal 149 as a greater or lesser degree of expansion is desired for any signal level.

Thus, in one rectifier stage, both expansion and compression is obtainable and is further controllable through the operation of a single control element 152. It will be seen that, by extending the leads from the terminals 149, 150 and 152, remote control operation may be obtained for volume expansion and compression in a similar manner to that described for the mixer and main amplifier channels.

The output resistor 146 is provided with a bypass capacitor for each section as indicated at 160 and the center tap connection is bypassed to ground through a low impedance alternating current path provided by a capacitor 161.

A total resistance of substantially 1 megohm may be utilized in the output resistor 146, for satisfactory results, with a similar resistance value for remote control if utilized. The remote control leads and selector switch therefor, are indicated at 165 and 166 respectively, and may be connected in accordance with the arrangement as described for the other remote control circuits with any suitable potentiometer device of substantially the same resistance value at the remote control point.

From the foregoing description it will be seen that a variable gain signal amplifying system is provided for controlling a plurality of amplifying or mixer channels, with a common master control channel and with a volume expander-compressor channel, all adapted for gain control at a remote point, providing a wide range of control without signal distortion and adapted to provide quiet operation.

Furthermore, it will be seen that advantage is taken of the inherent operating characteristics of a multiple control grid amplifier tube in

each of the gain controlling channels wherein the inner control grid may be of the variable mu type having a long cut-off range.

In taking advantage of this control of the inner control grid, the gain controlling potentiometers, such as those shown at 59, 96 and 127, and the corresponding remote control potentiometer devices, are preferably arranged to provide a relatively rapid change in resistance between the cathode end of the potentiometer and the movable contact, whereby a relatively high resistance is inserted in circuit for a relatively small range or angle of movement of the contact and whereby the initial operating cut-off or main operating range is reached during a relatively small portion of the control range of movement, the remainder of the movement of the contact being effective to provide a slow smooth cut-off.

This arrangement is provided for the purpose of effecting the same smooth control of all tubes within the usual manufacturing limits, without matching the tubes in the control channels since manufacturing variations do not generally change the bias control characteristic beyond a certain negative value biasing potential. The bias change provided by the potentiometers is such that the tubes are brought into the operating range rapidly.

In each of the gain controlling stages, the permanent biasing connections with the main bleeder or potential supply circuit, such as at the terminal 51 of the channel 5, and the filter capacitors 50, 168 and 169, prevent the variations in biasing potential either by the expander-compressor stage or by the control contacts from being transmitted too rapidly to the control grids and from subjecting the control grids to open circuit conditions without bias in the event of any contact being imperfect in its movement over a control resistor.

While the invention has been shown and described in its present preferred form and with tubes of a present available type, it should be understood that it may be provided in connection with other types of signal amplifying channels as a single volume or gain control unit or in a similar combination to that shown for mixing control and the like, and that other types of tubes may be employed in the control circuit or circuits, with suitable control grids and operating characteristics.

I claim as my invention:

1. In a signal mixer system, the combination of a plurality of amplifier channels, means providing a common signal output mixing circuit therefor, a master volume control amplifier connected with said mixing circuit to receive and amplify the combined signal output therefrom, means responsive to changes in the amplitude of the signals applied to said mixing circuit for controlling the gain of said master volume control amplifier, and the combined signal output level therefrom, and an output circuit for said amplifier through which the mixed, amplified and controlled signals are conveyed.

2. The method of operating an amplifier including a screen grid and a plurality of control grids, which includes applying a signal to one of said control grids, applying a bias potential of the same polarity with respect to the cathode to both of said control grids, and varying the bias potential applied to one of said grids at a different rate from that applied to the other of said grids and in the same direction of potential variation,

whereby the amplifier is prevented from overloading conjointly with control of gain.

3. In a signal mixer system, the combination of a plurality of amplifier channels having a common signal output bus connection, a master volume control amplifier connected therewith, means responsive to changes in the amplitude of signals applied to said bus connection for controlling the gain of said master volume control amplifier in accordance with variations in said amplitude, additional gain controlling means for said mixer and master volume control amplifiers including a grid potential control network, a potentiometer device connected with said network for controlling said gain, and means providing a remote control connection for said potentiometer device.

4. In a signal mixer system, the combination of a plurality of mixer amplifier channels each comprising an amplifier tube having an outer signal grid and an inner gain control grid and a grid bias control network connected at one end with the cathode, at intermediate points with said grids, and at the opposite end with a switch, filter means in said connection with the switch, a gain controlling potentiometer connected with said network through said switch, means for applying to said potentiometer a gain controlling potential, and means connected through said switch for extending said potentiometer connection for remote control.

5. A variable gain signal amplifier adapted for remote control in a signal amplifying channel, comprising in combination, an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, and means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode.

6. A variable gain signal amplifier adapted for remote control in a signal amplifying channel comprising in combination, an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode, and means connected between one end of said network and the cathode for manually controlling said biasing potential.

7. A variable gain signal amplifier adapted for remote control in a signal amplifying channel, comprising in combination, an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last

named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode, means connected between one end of said network and the cathode for manually controlling said biasing potential, a filter in said connection, means for remotely controlling said potential, and means for selectively rendering said last named means effective as the potential controlling element in said network.

8. A variable gain signal amplifier adapted for remote control in a signal amplifying channel comprising in combination, an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the other control grid with respect to the cathode, and means connected between one end of said network and the cathode for manually controlling said biasing potential, signal rectifier means in said first named gain controlling connection for applying an additional variable gain controlling potential to said grids through said network in accordance with the amplitude of the first named signals, and means for manually controlling the polarity and magnitude of said additional gain controlling potential.

9. A variable gain signal amplifier adapted for remote control in a signal amplifying channel comprising in combination, an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode, and a potentiometer device connected between one end of said network and said cathode for controlling said biasing potential, a remote potentiometer device connected with said first named potentiometer device, and means for selectively connecting said network with said remote potentiometer device to receive a variable controlling potential therefrom.

10. A variable gain signal amplifier in accordance with claim 6, further characterized by the fact that the inner control grid is of the variable μ type and that the gain controlling means includes a potentiometer provided with a resistor element having a relatively wide range of resistance variation for a limited range of movement at the high gain controlling end thereof.

11. In a variable gain signal amplifying system, the combination of a plurality of variable gain signal mixer channels having a common signal mixer bus, and a master control signal amplifying channel connected with said bus, said mixer channels and said master control channel each

further comprising an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode, and means connected between one end of said network and the cathode for manually controlling said biasing potential.

12. In a variable gain signal amplifying system, the combination of a plurality of variable gain signal mixer channels having a common signal mixer bus, and a master control signal amplifying channel connected with said bus, said mixer channels and said master control channel each further comprising an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode, means connected between one end of said network and the cathode for manually controlling said biasing potential, means connected with said mixer bus for deriving therefrom a gain controlling potential which varies in response to variations in signal potential therein, and means for applying said controlling potential to the voltage divider network of one of said tubes to control the gain therein selectively in aiding or opposing relation to said first named biasing potential, thereby selectively to provide volume expansion and compression in one of said channels.

13. In a variable gain signal amplifying system, the combination of a plurality of variable gain signal mixer channels having a common signal mixer bus, and a master control signal amplifying channel connected with said bus, said mixer channels and said master control channel each further comprising an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, means for applying a variable biasing potential to the inner control grid to control the gain of said amplifier, said last named means including a voltage divider network, means connected between one end of said network and the cathode for manually controlling said biasing potential, means for amplifying and rectifying signals applied to said mixer bus, means for deriving a gain controlling potential from said last named means including a rectifier output resistor having negative and positive terminals and an intermediate tap, and means for variably including said resistor in circuit with said manual bias potential control means on either side of said tap whereby said last named gain controlling potential is effective in aiding or opposing relation to said first named biasing potential to pro-

vide volume expansion and compression selectively.

14. In a signal mixer system, the combination of means providing a plurality of signal amplifier channels having a common mixer bus for receiving the signal output therefrom, a master volume control amplifier channel connected with said mixer bus to control the signal output therefrom, each of said amplifier channels including an electric discharge amplifier tube having a cathode, an output anode, a signal grid, and a gain controlling grid, means in each of said channels for applying a gain controlling potential to the gain controlling grid of the amplifier tube therein, said last named means being adapted for remote control operation, means connected with said mixer bus for deriving therefrom a gain controlling potential which varies in response to variations in the amplitude of the signal potential applied to said bus, and means for applying said last named gain controlling potential to the gain controlling grid of at least one of said tubes to control the gain in the amplifying channel wherein said tube is connected, selectively in aiding or opposing relation to the first named biasing potential, thereby selectively to provide volume expansion and compression in one of said channels.

15. In a signal mixer system, the combination of means providing a plurality of signal amplifier channels having a common mixer bus for receiving the signal output therefrom, a master volume control amplifier channel connected with said mixer bus to control the signal output therefrom, each of said amplifier channels including an electric discharge amplifier tube having a cathode, an output anode, a signal grid, and a gain controlling grid, means in each of said channels for applying a gain controlling potential to the gain controlling grid of the amplifier tube therein, said last named means being adapted for remote control operation, means connected with said mixer bus for deriving therefrom a gain controlling potential which varies in response to variations in the amplitude of the signal potentials applied to said bus, said means including a signal rectifier having an output resistor across which said gain controlling potential is derived, means for applying said last named gain controlling potential to the gain controlling grid of at least one of said tubes selectively in aiding or opposing relation to the first named biasing potential, thereby selectively to provide volume expansion and compression in one of said channels, and said last named means including a tap connection on said output resistor between the terminal ends thereof, and a contact on said output resistor movable between the terminal ends on either side of said tap connection whereby the potential applied to said control grid therefrom may be varied from zero in a positive or a negative direction.

16. A variable gain signalling amplifier adapted for remote control in a signal amplifying channel comprising in combination, an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, and means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of the amplifier device, said last named means including a voltage divider network connected between the cathode and each of said control grids pro-

viding a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode, potential supply means including a potential divider network having a positive and negative terminal, means providing a fixed connection for one end of said first named network thereon and a variable gain controlling connection thereon for the opposite end of said first named network, means providing a connection for the cathode on said network at a point more positive than said fixed connection, and means providing said variable gain controlling connection remotely from said amplifier.

17. A variable gain signalling amplifier adapted for remote control in a signal amplifying channel comprising in combination, an electric discharge amplifier device having a cathode, an inner control grid and an outer control grid, means for applying signals to be amplified to the outer control grid, and means for applying a variable biasing potential to the inner and the outer control grids in predetermined mutual relation to each other to control the gain of the amplifier device, said last named means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on the inner control grid than on the outer control grid with respect to the cathode, potential supply means including a potential divider network having a positive and negative terminal, means providing a fixed connection for one end of said first named network thereon and a variable gain controlling connection thereon for the opposite end of said first named network, means providing a connection for the cathode on said network at a point more positive than said fixed connection, means providing said variable gain controlling connection remotely from said amplifier, signal rectifier means in said first named gain controlling connection for applying an additional variable gain controlling potential to said grids through said network in accordance with the amplitude of the first named signals, and means for manually controlling the polarity and magnitude of said additional gain controlling potential.

18. A variable gain signal amplifier in accordance with claim 16, further characterized by the fact that the inner control grid is provided with a time delay filter including a portion of said voltage potential divider network and a bypass capacitor connected between said inner control grid and the negative terminal of the potential supply network.

19. A variable gain signal amplifier in accordance with claim 16, further characterized by the fact that the electric discharge amplifier device is provided with an output anode and a screen grid interposed between the outer control grid and the anode, and that the screen grid is provided with a series regulating resistor in the potential divider network whereby the potential on the screen grid varies in predetermined mutual relation to the variation in potential on the two control grids in aiding relation thereto to control gain.

20. A variable gain signal amplifying system comprising, in combination, an electric discharge amplifier tube having a cathode, an anode, an inner and an outer control grid and a screen grid interposed between said grids and between the outer control grid and the anode, a series resistor network providing a potential divider having a positive and a negative terminal and spaced taps

thereon providing connections for the anode, screen grid and cathode which are positive with respect to the negative terminal, a potentiometer resistor connected between the cathode and said negative terminal, a tap on said potential divider between the cathode and the negative terminal, means providing a variable contact for said potentiometer resistor which is movable thereon to control the gain of said amplifier tube, a second potential divider network connected between said tap and said variable contact and comprising three resistors in series, means providing a signal input circuit for the outer control grid, means providing a biasing connection for said outer control grid with said second potential divider network between two of the series connected resistors one of which is connected with the tap, means providing a bias supply connection with the inner control grid with the second potential divider network at a point between two of the series connected resistors one of which is connected to the variable contact, a filter capacitor connected between the inner control grid and the negative terminal of the first named voltage divider network, and means for deriving amplified signals from the output anode including a signal output circuit.

21. A variable gain signal amplifying system in accordance with claim 20, further characterized by the fact that the first named potential divider network includes a resistor section in series with the screen grid connection to regulate the potential on the screen grid in predetermined mutual aiding relation to variations in biasing potential applied to the inner and outer control grids by the variable contact, for mutually controlling the gain of said amplifier tube, and further characterized by the fact that the resistors in the second voltage divider network are so proportioned in resistance value that variations in potential on the inner control grid may be provided over a relatively wide range simultaneously with and in predetermined mutual relation to a lesser range of potential change on the outer control grid.

22. A variable gain signal amplifying system in accordance with claim 21, further characterized by the fact that the variable gain controlling potentiometer is provided with a tapered resistance providing a relatively wide change in resistance when the contact is moved adjacent to the cathode end of the resistor for a relatively small range of movement whereby a predetermined normal operating point for the amplifier tube may be reached by the bias change provided by movement of said contact through said range, and whereby the contact is provided with an effective wide control or operating range, thereby compensating for variations in operating characteristics existing in tubes of the same type.

23. A variable gain signal amplifying system in accordance with claim 20, further characterized by the fact that the inner control grid is of the variable- μ type and that the variable gain controlling potentiometer is provided with a tapered resistance providing a relatively rapid change in resistance when the contact is moved adjacent to the cathode end of the resistor for a relatively small range of movement whereby a predetermined normal operating point for the amplifier tube may be reached before the contact reaches an effective normal control or operating range on said potentiometer resistor, thereby compensating for variations in operating characteristics existing in tubes of the same type.

24. A variable signal amplifying system in accordance with claim 20, further characterized by the fact that the potentiometer device and variable contact therefor are provided with extensible lead connections, and means connected with said lead connections, at a remote point, whereby remote control of gain is provided for said amplifying system without extending signal conveying circuits and without noise conveying connections between the extensible circuit and the signal conveying circuits.

25. In a variable gain signal amplifying system, the combination of a plurality of variable gain signal mixer channels having a common signal mixer bus, and a master control signal amplifying channel connected with said bus, said mixer channels and said master control channel each further comprising an electric discharge amplifier tube having a cathode, an anode, an inner and an outer control grid and a screen interposed between said grids and between the outer control grid and the anode, a series resistor network providing a potential divider having a positive and a negative terminal and spaced taps thereon providing connections for the anode, screen grid and cathode which are positive with respect to the negative terminal, a potentiometer resistor connected between the cathode and said negative terminal, a tap on said potential divider between the cathode and the negative terminal, means providing a variable contact for said potentiometer, a second potential divider network connected between said tap and said variable contact and comprising three resistors in series, means providing a signal input circuit for the outer control grid, means providing a biasing connection for said output control grid with said second potential divider network between two of the series connected resistors one of which is connected with said tap, means providing a bias supply connection with the inner control grid with the second potential divider network at a point between two of the series connected resistors one of which is connected to the variable contact, a filter capacitor connected between the inner control grid and the negative terminal of the first named voltage divider network, and means for deriving amplified signals from the output anode including a signal output circuit.

26. A variable gain signal amplifying system comprising in combination an electric discharge amplifier tube having a cathode, an anode, an inner and an outer control grid and a screen interposed between said grids and between the outer control grid and the anode, a series resistor network providing a potential divider having a positive and a negative terminal and spaced taps thereon providing connections for the anode, screen grid and cathode which are positive with respect to the negative terminal, a potentiometer resistor connected between the cathode and said negative terminal, a tap on said potential divider between the cathode and the negative terminal, means providing a variable contact for said potentiometer, a second potential divider network connected between said tap and said variable contact and comprising three resistor elements in series, means providing signal input circuit for the outer control grid, means providing a biasing connection for said outer control grid with said second potential divider network between two of the series connected resistor elements one of which is connected with the tap, means providing a bias supply connection with the inner con-

trol grid with the second potential divider network at a point between two of the series connected resistor elements one of which is connected to the variable contact, a filter capacitor
5 connected between the inner control grid and the negative terminal of the first named voltage divider network, and means for deriving amplified signals from the output anode.

27. A variable gain signal amplifying system
10 in accordance with claim 26, further characterized by the fact that means are provided for amplifying and rectifying signals derived from the mixer bus connection and that the rectifying means is provided with an output resistor having
15 a tap between its terminals connected with the second potential divider network, and a variable tap connected with the variable tap of the potentiometer connection therefor, whereby the rectifier output resistor may be variably included in
20 circuit with the control grids to apply thereto a controllable portion of the voltage output in a positive or negative direction in response to variations in signal amplitude.

28. A variable gain signal amplifying system
25 in accordance with claim 25, further characterized by the fact that each of the potentiometer devices and variable contacts therefor are provided with an extensible remote control circuit, potentiometer gain control means connected with
30 each of said extensible circuits at a common remote control point, and selective switching means in circuit with each of said last named variable contacts for rendering the gain control effective at the remote control point.

29. In a signal transmission system, a variable
35 gain amplifier comprising an amplifier tube having a cathode, an anode, a positive screen grid, a gain control grid between the cathode and the screen grid, a signal control grid electrostatically shielded from the gain control grid and
40 the anode by said screen grid, means for applying signals to be amplified to the signal control grid, means providing a fixed negative biasing potential with respect to the cathode, a potential
45 divider network conductively connecting said control grids with the cathode through said last named means, and means in said network
50 for varying the negative bias potential from said source on the gain control grid over a relatively wide range of values and on the signal control grid over a relatively narrow range of values with respect to the cathode in predetermined mutual relation to each other, whereby the amplifier is prevented from overloading conjointly with gain
55 control over a wide range of signal amplitudes.

30. In a signal transmission system, a variable
gain amplifier in accordance with claim 29, further characterized by the fact that the gain control grid is of the variable μ type and that that
60 variable bias control means is a potentiometer resistor providing a relatively wide change in bias potential on said grid in a negative direction over a relatively narrow range of control movement in initiating volume reduction.

31. In a signal transmission system, a variable
65 gain amplifier comprising an amplifier tube having a cathode, an anode, a positive screen grid, a gain control grid between the cathode and the screen grid, a signal control grid electrostatically shielded from the gain control grid and the anode
70 by said screen grid, means for applying signals to be amplified to the signal control grid, means providing a fixed negative biasing potential with respect to the cathode, a potential divider network conductively connecting said control grids
75 with the cathode through said last named means, and means in said network for varying the negative bias potential from said source on the gain control grid over a relatively wide range of values and on the signal control grid over a relatively narrow range of values with respect to the cathode in predetermined mutual relation to each other, whereby the amplifier is prevented from overloading conjointly with gain control over a wide range of signal amplitudes.

32. In a signal transmission system, a variable
gain amplifier comprising an amplifier tube having a cathode, an anode, a gain control grid, a signal control grid, means for applying signals
10 to be amplified to the signal control grid, means providing a fixed negative biasing potential with respect to the cathode, a potential divider network conductively connecting said control grids
15 with the cathode through said last named means, and means in said network for varying the negative bias potential from said source on the gain control grid over a relatively wide range with respect to the cathode, means for applying a gain controlling potential to said control grid to vary the effect of said first named bias potential,
20 comprising a signal rectifier stage, and a single control element connected in circuit with said potential divider network and said rectifier for selectively increasing or decreasing the effect of said last named potential on said control grid in response to the variations in the amplitude of signals applied to said amplifier, whereby volume expansion and compression may selectively be applied to said amplifier.

33. In a signal transmission system, a variable
45 gain amplifier comprising an amplifier tube having a cathode, an anode, a positive screen grid, a gain control grid between the cathode and the screen grid, a signal control grid electrostatically shielded from the gain control grid and the anode
50 by said screen grid, means for applying signals to be amplified to the signal control grid, means providing a fixed negative biasing potential with respect to the cathode, a potential divider network conductively connecting said control grids
55 with the cathode through said last named means, and means in said network having an extensible control circuit for varying the negative bias potential from said source on the gain control grid over a relatively wide range of values and on the signal control grid over a relatively narrow range of values with respect to the cathode in predetermined mutual relation to each other, and means responsive to variations in the amplitude of signals applied to said amplifier for automatically
60 varying the bias potential on said control grids in accordance therewith, selectively in a positive or a negative potential sense, whereby volume expansion and compression may selectively be applied to said amplifier.

34. A variable gain signal amplifier adapted
for remote control in a signal amplifying channel, comprising in combination, an electric discharge amplifier device having a cathode, an in-
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ner control grid, an outer control grid and a screen grid between said control grids, means for applying signals to be amplified to one of said control grids, and means for applying a variable biasing potential to said control grids in predetermined mutual relation to each other to control the gain of said amplifier, said last named

means including a voltage divider network connected between the cathode and each of said control grids providing a greater range of voltage variation on one control grid than on the other control grid with respect to the cathode.

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