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UNSYMMETRIC GAIN CONTROL DEVICE

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Fig. 1

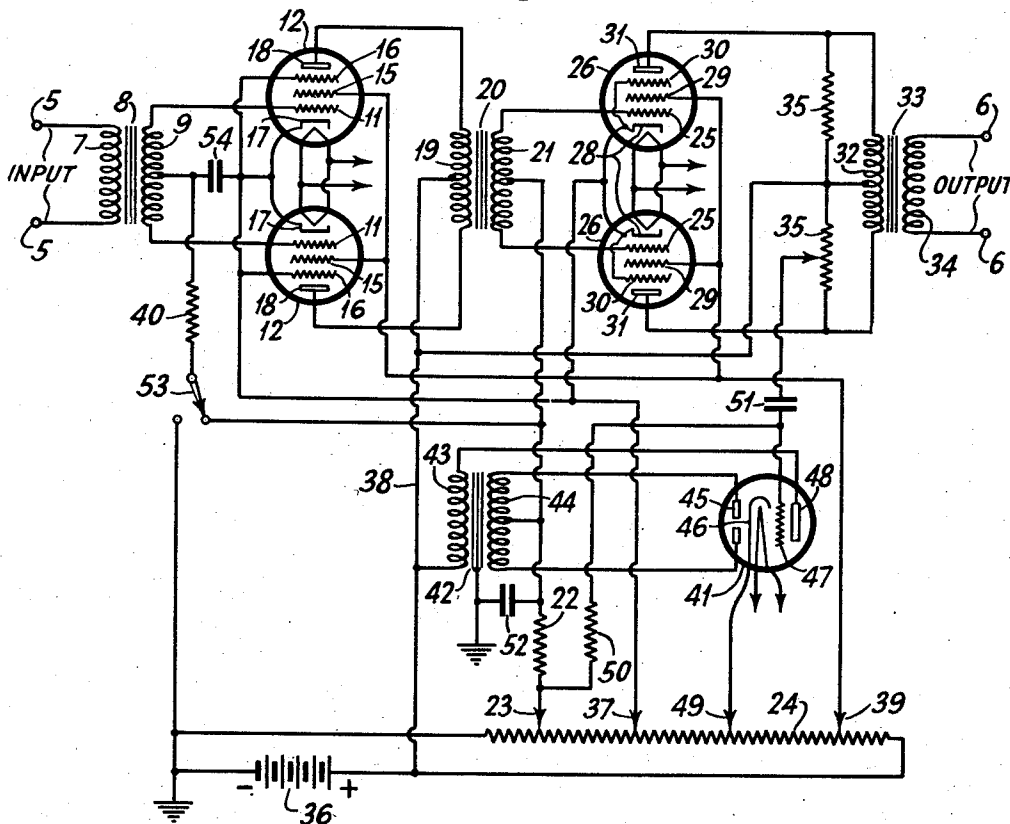
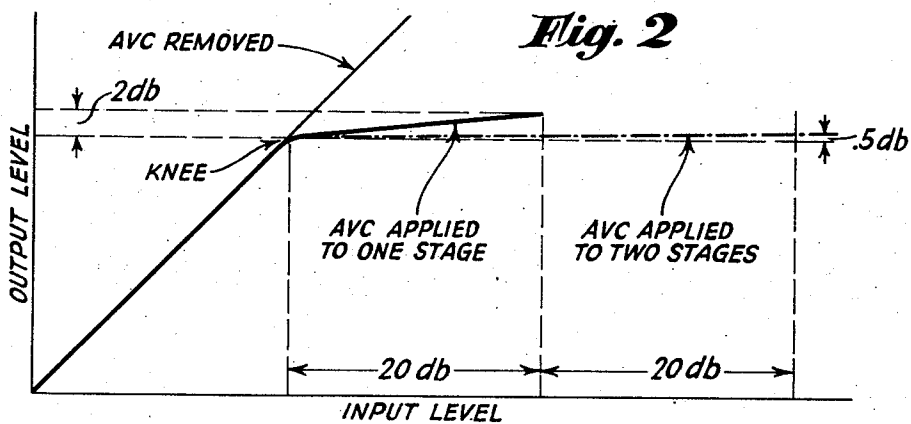


Fig. 2



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UNSYMMETRIC GAIN CONTROL DEVICE

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Application September 29, 1938, Serial No. 232,273

7 Claims. (Cl. 179—171)

This invention relates to gain control devices and has particularly to do with a system having a timing circuit for automatically governing the dynamic level range in audio frequency circuits.

My invention has particular utility in microphone circuits and amplifiers and may be associated with modulators for radio transmitters, or with public address systems, or sound recorders. Gain control is generally required in such systems and quite frequently it is necessary to compress the volume range within narrower limits than those actually occurring in the rendition of speech and musical programs.

The gain control device herein disclosed is an improvement upon a gain control device as covered in my copending application, U. S. Patent No. 2,221,541 issued November 12, 1940.

Gain control devices as designed in accordance with the disclosure of my aforesaid copending application had the draw-back that they were somewhat complicated and involved the use of a number of electron discharge tubes and other equipment which, according to the instant application, have been found to be unnecessary. The results attained, however, in the improved arrangement appear to be at least equal to those of the former arrangement.

The successful application of an automatic gain control device to the problems of monitoring a broadcast program involves the use of time delay circuits which will operate to rapidly attenuate a high level audio peak and afterwards to restore the normal gain in the circuit at a gradual rate.

Accordingly, it is an object of my invention to provide a system of automatic audio gain control in which perceptible wave form distortion is avoided.

It is another object of my invention to provide a very simple system of gain control apparatus which may be actuated solely in response to variations in an output component of audio frequency energy derived from a push-pull amplifier.

It is another object of my invention to provide a system of the class above indicated in which severe changes of accent, emphasis, or expression of speech and program are avoided.

It is a still further object of my invention to provide a means for automatic gain control in which high level surges are instantly dealt with by reducing the gain in the amplifier circuit so as not to overload the equipment following the control apparatus.

Other objects and advantages of my system will become apparent in the following detailed

description when read in view of the accompanying drawing, in which—

Figure 1 shows diagrammatically a preferred circuit arrangement including volume control means for application to certain portions of an audio frequency amplifier system; and

Fig. 2 shows diagrammatically the operating characteristic of the gain control device.

By way of review of the state of the art as represented, for example, in my copending application aforementioned, it may be well to present the following facts as a preliminary to the more detailed description of the instant invention as will be hereinafter presented.

Up until quite recently it has been the practice to depend wholly upon manual gain control in monitoring a program for radio broadcasting.

Whether the gain control is manual or automatic, it is, of course, essential that audible wave form distortion be avoided. If a high level peak suddenly occurs following a low level passage, the gain control can not be applied manually with sufficient promptness to give satisfactory results. According to my invention, however, it is possible to apply the gain reduction almost instantaneously in response to the high level peak and, paradoxical as it may seem, a distortion which accompanies this gain reduction is insignificant because it takes place in so short a period of time as .005 second and the human ear cannot recognize an effect lasting for so short a period. It is found desirable, however, following the application of a sudden suppression of a high level peak to restore the normal level of amplification by slow degrees. The gain recovery is, therefore, accomplished without audible distortion. The entire program is thus compressed within suitable limits of volume range, considering the particular sound reproducing equipment to be employed, and the transmitter or other circuits involved.

Referring now to the drawing, I show a gain control circuit interposed between input terminals 5 and output terminals 6. The input terminals are connected to the primary winding 7 of a transformer 8 which preferably has a split secondary, with winding 9. This winding feeds the input signal to the control grids 11 of two push-pull amplifier tubes 12. The tubes 12 are preferably of the pentode remote cut-off type having screen grids 15 and suppressor grids 16, the latter being connected to the cathodes 17. The anodes 18 are connected to opposite terminals of the primary winding 19 of a coupling transformer 20. This transformer has a secondary winding 21 having a mid-tap connected

through a resistor 22 to a tap 23 on a potentiometer 24. The terminals of the secondary winding 21 are connected to the respective control grids 25 of two additional push-pull amplifier tubes 26 constituting a second stage of amplification. The tubes 26 are likewise preferably of the pentode remote cut-off type comprising each a cathode 28, the aforementioned control grid 25, a screen grid 29, a suppressor grid 30 and an anode 31. The anodes 31 of the tubes are connected respectively to the terminals of a transformer primary winding 32 having a center tap. This primary 32 is appropriate to an output transformer 33 which also has a secondary 34 connected to any suitable utilization circuit. In order to adjust the gain of an auxiliary amplifier 41 to a satisfactory normal level, and also in order to improve the fidelity of the push-pull amplifier 26, two resistors 35 are placed in shunt respectively with the two paths of the transformer primary 32.

A source of direct current potential 36 is applied across the potentiometer 24, the negative terminal of which is preferably grounded. Leading directly off from the positive terminal of the source 36 is a conductor 38 which connects with the mid-tap on the transformer primary winding 19 and also to the mid-tap of the transformer primary winding 32. Anode potential is thus supplied to the push-pull tubes 12 and 26. All of the cathodes of these tubes are connected to a tap 37 on the potentiometer 24, this tap being positioned to receive a slightly positive potential relative to ground for biasing the tubes.

Suitable positive potentials for the screen grids 15 and 29 are obtained from a tap 39 on the potentiometer 24.

In order to apply a normal no-signal bias potential to the control grids 11 and 25, I preferably employ a biasing circuit which may be traced from ground through a high resistor 22 having a value of several megohms and through the secondary windings 21 to grids 25, also through a resistor 40 and the secondary windings 9 to the grids 11 of the tubes 12 respectively. This biasing circuit is, however, subject to gain control action by means of a double diode rectifier amplifier tube 41 in combination with a transformer 42 having a primary winding 43 and a secondary winding 44, the latter having a center tap connected to the biasing circuit above traced. The terminals of the secondary winding 44 are connected respectively to each of the two diode rectifier anodes 45 within the tube 41. This tube also comprises a cathode 46 which may be of the indirectly heated type, an amplifier control grid 47 and an amplifier anode 48. The cathode 46 is connected to the potentiometer 24 at a tap 49 which is positioned to receive a more positive potential than that of the tap 23. The anode 48 is connected to the positive terminal of the source 36, this connection being made through primary winding 43. The control grid 47 is negatively biased as by means of grid resistor 50, connected to potentiometer tap 23.

Control grid 47 receives audio voltage from the output of tubes 26 by way of a tap on potentiometer 35. The direct current path from the plate supply of tubes 26 is blocked by condenser 51. The amplifier section of tube 41 feeds into the primary 43 of transformer 42. The center tapped secondary of this transformer supplies audio voltage to the diode rectifier sections of tube 41. The resultant rectified output D. C. voltage thus appears across the resistor 22, the

pulsations being smoothed out by condenser 52. An initial bias on tube 41 diode rectifier elements is created by the position of tap 49 on the potentiometer 24. Rectification thus can not set in until the audio voltage peaks at the diode plates exceed this initial bias. The purpose of this arrangement is to prevent rectification and the consequent control action which would otherwise occur at abnormally low input signal levels. Because of the initial bias, rectification starts at a definite input level, and further increase of input level causes an extremely rapid bias increase. The relative rate of bias increase with input level increase is a direct function of the initial bias. This makes possible the sharp knee on the control curve shown in Fig. 2.

The rectified biasing voltage applied to grids 25 of tubes 26 increases very suddenly when the signal applied to the input terminals reaches a sufficient level. The time constant of the circuit supplying the bias is determined by the value of the charging resistance in relation to the capacitance of the condenser 52. The charging resistance is the sum of the diode resistance and the section of transformer secondary winding 44 which supplies the audio peak. The discharge time, following an audio peak is determined by the time constant of the condenser 52 and the discharge resistor 22. This time constant is many times greater than the charging time constant. The gain, therefore, is restored to normal at a relatively slow rate.

The full-line curve shown on Fig. 2 indicates the control action afforded by the remote cut-off tubes 26 only. This full-line curve illustrates the possibility of compressing the output volume range above the amplitude level of the knee in the characteristic to within about 2 decibels while the input level varies over a range of 20 decibels. If the control action were to be removed, then the output level would tend to vary in direct proportion to the input level, as shown by the light-line extension of the steep slope above the knee.

From the diagram it will be seen that the tubes 12 may be subjected to volume control simultaneously with the control of tubes 26, if desired. For this purpose a switch 53 is provided, and when set in the position shown the grid return circuit for the tubes 12 is extended from the grids 11 through transformer windings 9 and 10, thence through resistor 40 and switch 53 to the mid-tap of transformer secondary 44 from which a rectified control voltage is derived. When automatic volume control is not to be applied to tubes 12, then the switch 53 is set so as to ground the grid return circuit, or, if desired, to impress thereon any suitable D. C. bias, such as may be obtained from a given tap on the potentiometer 24. In this condition the tubes 12 act merely as amplifiers.

I have found it advantageous, however, to control the bias on the grids of successive tube stages 12 and 26 so that the rate of bias increase in these two stages is radically different. Accordingly, the bias potential is applied to tubes 12 at a relatively slow rate by virtue of the time required to charge condenser 54 through resistor 40. Also the discharge time of condenser 54 is somewhat slower than that of condenser 52. Thus both in gain reduction and gain recovery the tubes 12 are more slowly controlled. This action alleviates part of the control required in the unsymmetrically timed circuits associated with tubes 26. However, the rapid gain control action afforded by tubes 26 in cutting down sudden high peaks is always avail-

able. The dot-and-dash line in Fig. 2 shows the resultant control characteristic curve which is obtained when the switch 53 is set for controlling the gain in tubes 12 along with tubes 26, and when the input signal is a steady tone. Here the output volume range above the amplitude level of the knee in the characteristic curve may be compressed to within half a decibel for an input range of 40 decibels.

If desired, resistance coupling may be employed between the two push-pull stages in place of transformer 20, provided constants are so chosen as to permit grids 25 to reduce gain at a sufficiently rapid rate for good control action.

More than two successively controlled stages may be employed, using the same rectified voltage to affect the gain control. Time constants may be the same in all, or different, as described above. In the case of differently timed circuits the slower timed circuits may be located either ahead or behind the circuit which acts to cut gain rapidly.

The diode rectifier in tube 41 may be half wave instead of full wave, as shown. If half wave rectification is used, one of the diode plates is disconnected from the transformer terminal of secondary 44 and connected to the opposite end of the secondary 44. Such an arrangement is found desirable in certain applications.

It is within the scope of my invention to apply the teachings thereof to other embodiments than those herein shown and described. The invention itself, therefore, is limited only in accordance with the claims.

I claim:

1. A gain control system applicable to a two-stage push-pull discharge tube amplifier, said system comprising a discharge tube having a cathode, a control grid, an anode, and an anode rectifier device adjacent the cathode; a source of direct current operating and biasing potentials common to said amplifier and said tube, a grid biasing circuit connected to the control grids of said push-pull amplifier and to said direct current source, said circuit being branched to the grids of successive stages, means including a time constant device in the biasing circuit branch of the preceding stage for retarding the control action of that stage in relation to the control action on the subsequent stage, a transformer having a primary winding in the output circuit of said discharge tube and a secondary winding the terminals of which are connected in circuit between the cathode and the anode rectifier device of said tube, a connection from said secondary winding to said biasing circuit; and a time constant device included in said biasing circuit between the rectifier device and the cathode of said discharge tube, said time constant device being characterized in that it provides rapid gain reduction and slow gain recovery in said amplifier only in response to audio wave peaks above a given amplitude level as delivered by said amplifier.

2. In a gain control system applicable to a two-stage push-pull discharge tube amplifier having the usual electrodes including gain control electrodes, a discharge tube having an amplifier section and a double diode rectifier section, means operative to control the amplifier section of said tube in response to audio wave peaks derived from the output of said push-pull amplifier, a transformer having its primary in circuit between output electrodes of said amplifier section, said transformer having a center-tapped secondary the mid-terminal of which is negatively biased with respect to the cathode of said discharge

tube, the outer terminals of said secondary being connected respectively to the anodes of said double diode rectifier section, and means responsive only to those of said audio wave peaks which surpass a given amplitude level for enabling said discharge tube in cooperation with said transformer to apply a rapid gain reduction control voltage and a relatively slow gain recovery control voltage to said gain control electrodes of said push-pull amplifier, and means including a time constant device in circuit with the gain control electrodes of the first stage in said amplifier for delaying the control action thereon in reference to the control action applied to the subsequent stage.

3. In combination, a discharge tube provided with a grid-controlled amplifier section and a diode rectifier section, a push-pull discharge tube amplifier system having an output circuit the voltage in which is available for control of the amplifier section in said discharge tube, a transformer having a primary winding connected in circuit with the space current path of said discharge tube amplifier section and a secondary winding the terminals of which are in circuit with the space current path of said discharge tube diode rectifier section, an automatic volume control circuit for said push-pull amplifier system, the last mentioned circuit being connected to a mid-tap on said secondary winding, and a time constant device included in said automatic volume control circuit and characterized in that it provides a gain reduction in said push-pull amplifier system which is substantially instantly responsive to audio wave peaks above a given amplitude level in the output of said push-pull amplifier system, and a much retarded gain recovery following such gain reduction.

4. The combination set forth in claim 3 and including branches in said automatic volume control circuit for controlling two stages in said push-pull amplifier system, and means including a separate time constant device in the branch to one of said stages whereby both the gain reduction and the gain recovery in said stage are delayed with respect to the corresponding gain reduction and recovery of the other stage.

5. The combination set forth in claim 3 and further characterized in that said time constant device includes a capacitor shunting a highly resistive impedance in circuit between said automatic volume control circuit and ground.

6. An automatic volume control circuit arrangement for controlling a push-pull amplifier, comprising a grid biasing circuit appropriate to said amplifier, means for amplifying an output component of said amplifier, a transformer having a primary fed with energy derived from said amplifying means, a diode rectifier having anodes connected to the terminals of a secondary on said transformer and a cathode in circuit with a mid-tap on said secondary, a source of operating and biasing potentials common to said push-pull amplifier, its grid biasing circuit and said amplifying means; said grid biasing circuit including said secondary mid-tap and running thence through a resistor to a point of suitable bias potential on said source, and a capacitor in shunt with said resistor; the combination of said resistor and capacitor constituting a time constant means such that it renders said grid biasing circuit operative to suddenly reduce the gain of said push-pull amplifier after the output component thereof has reached a given amplitude level, and to slowly increase the gain in response to a

subsequent reduction of said output component to a value below said given amplitude level.

7. An automatic volume control circuit arrangement for controlling a two-stage push-pull amplifier, comprising, in combination, an electronic amplifier under control of output energy from said push-pull amplifier, a transformer having a primary winding influenced by output energy from said electronic amplifier and a secondary winding, a mid-tap on said secondary winding, said mid-tap being capacitively coupled directly to ground and being directly connected to the input side of said push-pull amplifier, an electronic diode rectifier having direct anodal connections with the terminals of said secondary winding, and a bias-

ing source in circuit between the cathode-side of said rectifier and the mid-tap of said secondary winding, and means including two time constant devices in said volume control circuit arrangement, one of said devices being operative to provide a substantially instant gain reduction in said push-pull amplifier in response to wave peaks of said output energy only above a predetermined amplitude level, and to provide a relatively slow gain recovery thereafter, while the other of said time constant devices is operative to retard the control action on one amplifier stage with respect to the other.

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