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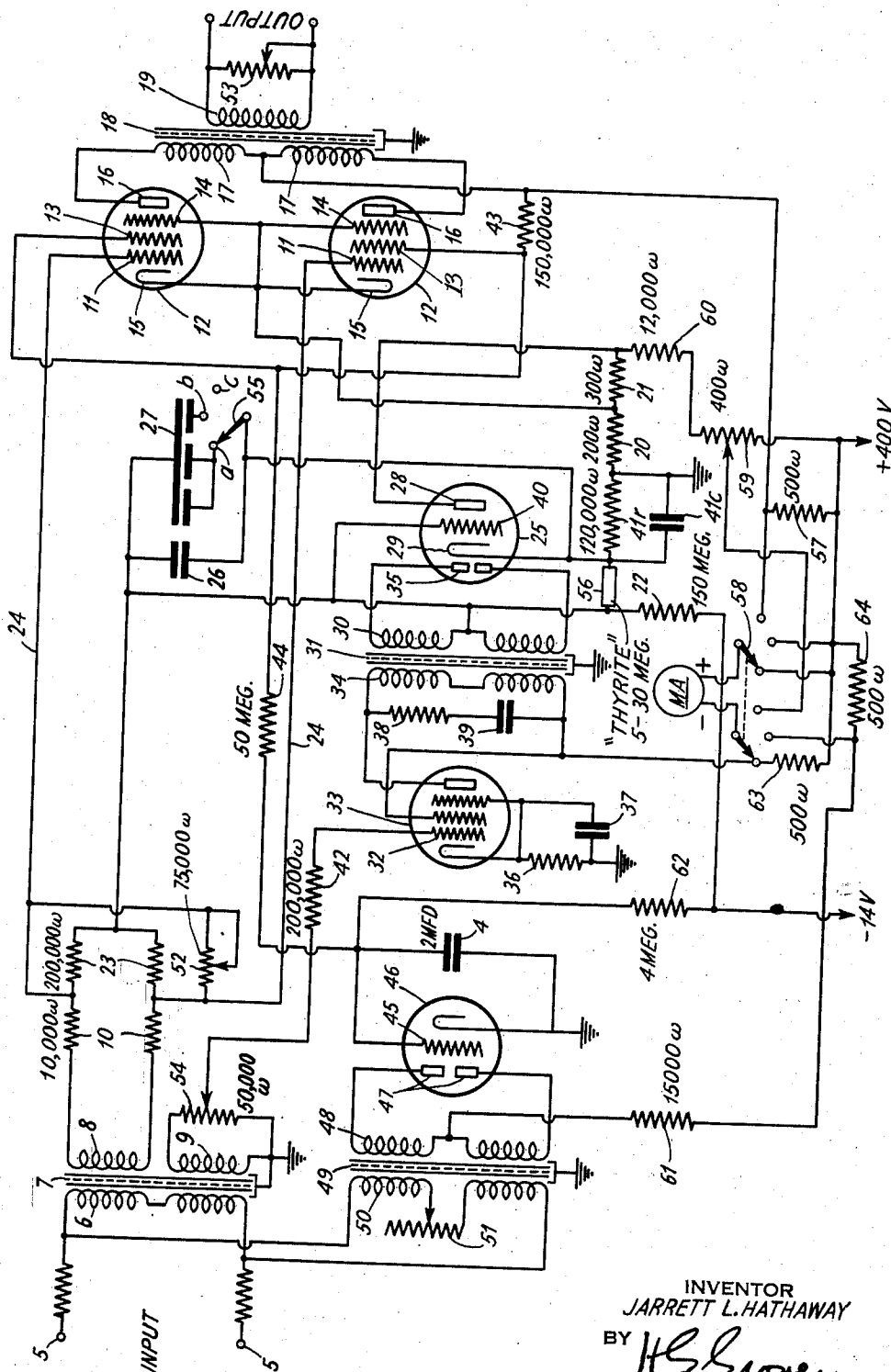
J. L. HATHAWAY

2,221,541

GAIN CONTROL DEVICE

Filed Jan. 22, 1936

3 Sheets-Sheet 1



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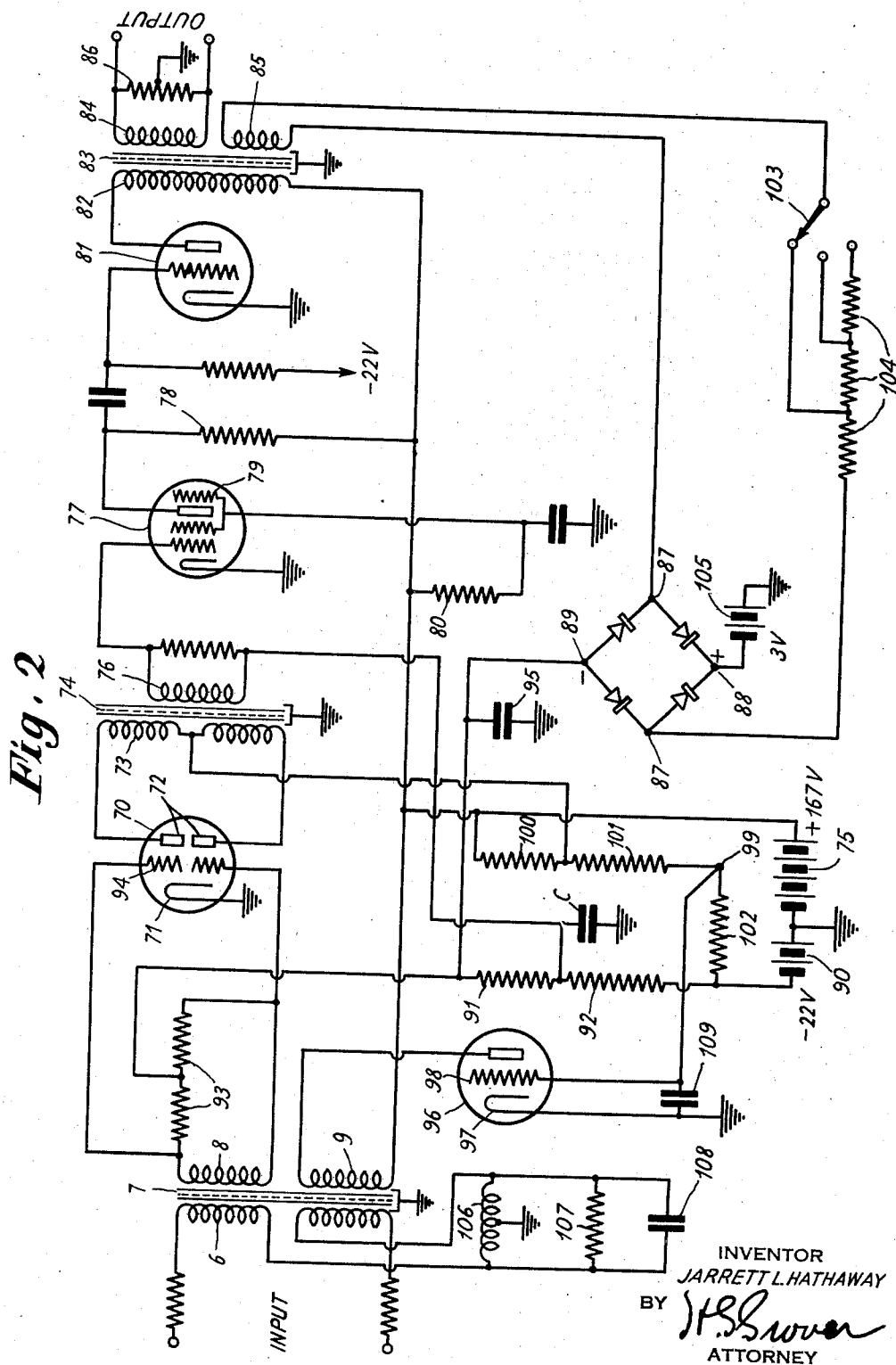
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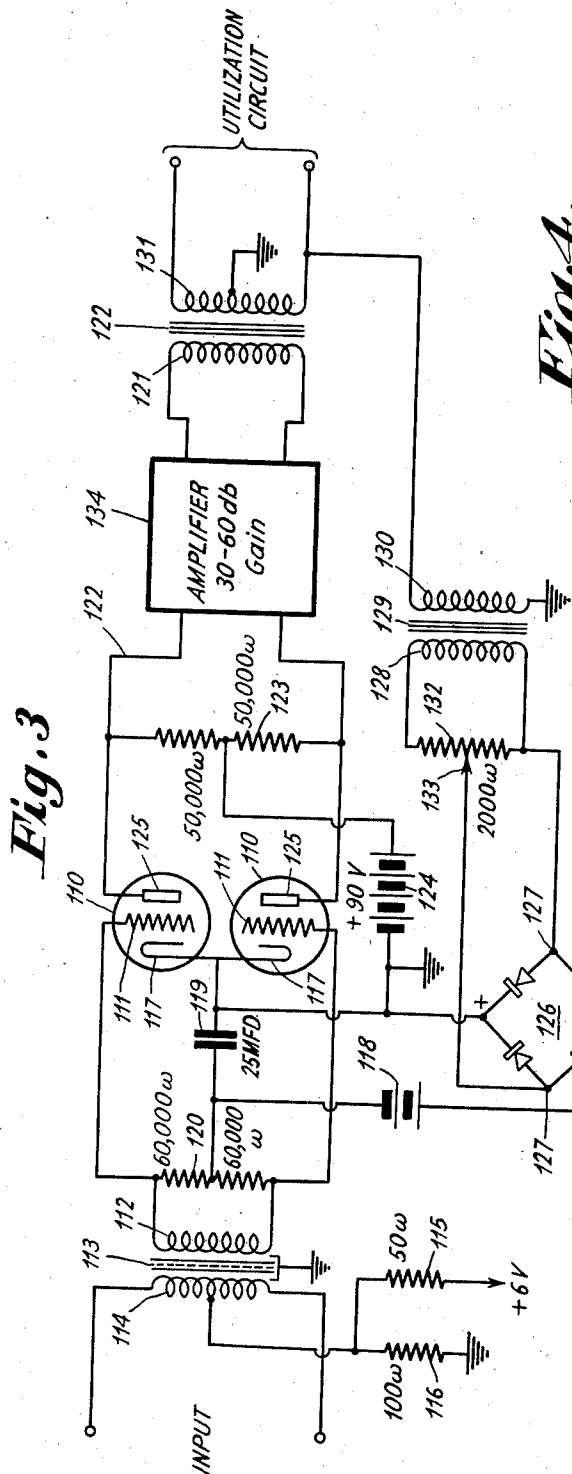
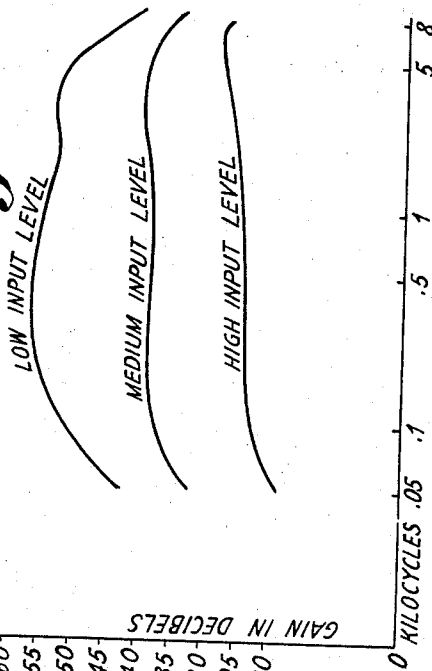
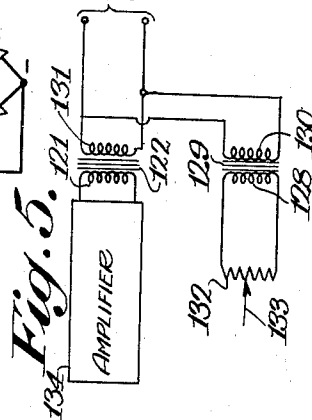


Fig. 4.



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GAIN CONTROL DEVICE

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8 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.

Audio gain control was found in the very early stages of broadcasting to be very essential in order to produce modulation of a radio wave at a reasonably high level and without distortion. Such gain control was at first entirely manual in operation. The gain was not changed so rapidly as to cause appreciable wave form distortion. Later on in the development of the art, automatic gain control devices were tried in the modulator circuits. As a rule, these devices in their operation involved a time lag prior to the reduction or increase in the gain. It was found, however, that the time delays could not satisfactorily be fixed at such values as would escape perception by the human ear. It was not possible to attenuate a sudden high level audio peak. Furthermore, the rate of gain recovery usually possessed the same time delay element as the rate of gain reduction. At best such devices were limited in operation and could not be used on high quality circuits.

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 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.

Still another object of my invention is to provide a system of the class described in which a relatively slow increase in the gain may be obtained following a sudden reduction of gain in response to a high level passage.

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

scription thereof when read in view of the accompanying drawings in which:

Figure 1 shows diagrammatically a preferred circuit arrangement having volume control means applied to certain portions of an audio frequency amplifier system;

Fig. 2 shows a modification of my invention;

Fig. 3 shows still another modification of my invention;

Fig. 4 represents graphically the frequency response characteristics of a typical gain control system as illustrated in certain of the embodiments of my invention herein shown; and

Fig. 5 shows a modification of one portion of the circuit arrangements of Fig. 3.

Before describing the circuits in detail, it may be well at the outset to call attention to the fact that automatic audio gain control as practiced in the broadcasting art and as used, particularly in microphone-modulator circuits is based on the broad fundamentals of manual control, that is: after average gain has been adjusted manually for a particular program, gain variation is made such as to raise the low level passages and to reduce the excessively high level passages.

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 can not 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 Fig. 1, I show in the circuit diagram thereof an amplifier having connected therewith a suitable automatic gain control device. The input terminals 5 are connected to the primary winding 6 of a transformer 7 which preferably has two secondaries 8 and 9. The

secondary 8 feeds energy across two resistors 10 (say of 10,000 ohms each) to the control grids 11 of a set of push-pull amplifier tubes 12. The tubes 12 are "super-control," preferably of the pentode type having screen grids 13 and suppressor grids 14, the latter being connected to the cathodes 15. The anodes 16 are connected to opposite terminals of the primary winding 17 of an output transformer 18. This transformer has a secondary winding 19 connected to any suitable utilization circuit.

A source of direct current potential is applied between the cathodes 15 and the anodes 16 through the primary windings 17 of the transformer 18. In the diagram this source is represented as having a value of substantially 400 volts above a grounded zero level. The same or another source includes a biasing potential of approximately -14 volts below the zero ground potential. The cathodes 15 are preferably maintained at a somewhat positive potential with respect to ground, this being accomplished by the insertion between the cathodes and ground of a resistor 20.

In order to apply a normal no-signal bias potential to the control grids 11, I preferably employ a biasing circuit which may be traced from ground through resistors 41r and 56, and thence to the circuit including resistors 23, each of which is connected to a control grid 11 through conductors 24. A further biasing source is applied from its -14 volt terminal through resistor 22, having a value of, say 150 megohms. The positive side of this source is grounded, as is the negative side of the 400 volt direct current source whose positive terminal only is shown in the drawings. The -14 volt biasing source compensates for leakage to the grid circuit from the high potential source; hence a normal zero potential across the resistor 56 is produced. The overall bias, due to this compensating resistor 22 and the space current of tube 25 through resistor 41r is such as to produce a bias of approximately -4 volts on the control grids 11 of the tubes 12 when no signal is coming in.

The tubes 12, being "super-control" tubes, are such that amplification is a function of the grid bias over a wide usable range. The bias is made to vary automatically as a function of the signal level in order to accomplish automatic gain control. Higher bias created by higher signal level causes lower amplification. This bias change with signal level variation is made rapid for increasing signal level but the recovery rate is slow when the signal level decreases. The unsymmetrical rate of gain change is achieved by a rectifier time delay circuit which comprises capacitors 26 and 27 and a resistor 56. The time required to charge the condenser 26 plus a portion of the condenser 27 and to establish a given bias on the grids 11 of the tubes 12 with respect to their cathodes 15 is dependent upon the product of the capacitances by the impedance of one-half of the secondary winding 30 on a transformer 31 plus the resistance of the rectifier anode space path in the tube 25. Suitable values for these components have been found such that the charging time is less than .005 second. The discharge rate of the capacitors 26 and 27 is dependent upon the product of their capacity by the resistance value of the resistor 56 shunted by the resistor 22.

The portion of the input signal appearing across the terminals of the secondary winding 9 of the transformer 7 is applied to the grid 32

of the pentode amplifier tube 33. This tube is connected in the conventional pentode manner and serves as an audio frequency amplifier feeding energy into its output circuit which includes the primary winding 34 of the transformer 31. The secondary 30 of this transformer is connected to the anodes 35 of a full wave diode rectifier tube 25. The self-biasing resistor 36 and by-pass condenser 37 are inserted in circuit between the cathode of tube 33 and ground so as to enable this tube to function in the usual manner. A series-connected resistor 38 and capacitor 39 serve to improve the frequency characteristic of the transformer 31 and, at the same time, to decrease the transformer secondary impedance so that the charging time of the condensers 26 and 27 can be reduced to a satisfactory low value.

The rectified voltage appearing across the resistor 56 due to the action of the diode rectifier portion of the tube 25 is applied negatively to the grids 11 of the amplifier tubes 12 and simultaneously to the grid 40 of the tube 25 which renders the amplifier portion of this tube less conductive and lowers the potential on the cathode 29. The amplified direct current voltage output of this tube then appears across the resistor 41r. Greater signals make the cathode 29 less positive. The rate of this voltage change across the resistor 41r is dependent upon its value with respect to that of the capacitor 41c as well as on the impedance between the cathode 29 and anode 28 in the amplifier section of the tube 25. These values are such as to give a very small time delay in reducing the gain in the amplifier tubes 12. The voltage variation across the resistor 41r and capacitor 41c referred to ground is added to the original diode rectifier D. C. voltage. It is the sum of these two which furnishes the varying bias on the grids 11 of the tubes 12, although it should be noted that the maximum biasing potential from the direct current amplifier section of the tube 25 is small in magnitude, say 8 volts, and that after tube 25 is biased to cutoff by its diode rectifier, that the diode rectifier voltage only is the source of higher bias on grids 11. This last effect may produce as great a bias as -40 volts.

The control grid circuit between the transformer secondary 9 and the grid 32 includes a resistor 42 which serves to prevent the possibility of grid current on the tube 33 causing wave form distortion in the voltage output of the transformer 7. A resistor 43 is inserted between the high positive voltage supply lead to the anodes 16 and the leads to the screen grids 13.

A tap off the screen grid lead connects through a 50 megohm resistor 44 to a control grid 45 of a twin amplifier tube 46, the function of which is to act as an absorption device having a variable impedance dependent upon the strength of the input signal. It will be understood, of course, that if the impedance of the amplifier tubes 12 is varied through the control action upon their control grids 11, the current flow in the screen grid circuits is also varied and this varies the potential drop across the resistors 43 and 44, and 62. The values of the resistors 44 and 62 are so high that an appreciable time delay occurs before the variations of voltage swing upon the screen grid can be applied to the control grid 45 of the tube 46. The tube 46, therefore, acts as a variable resistor which is by-passed to ground by a time delay condenser 4 whose value is preferably 2 microfarads. The anodes 47 are connected to opposite terminals of the secondary 75

winding 48 on a transformer 49. The primary winding 50 of this transformer is connected in parallel with the input leads to the transformer primary 6. Under a condition of low input signal volume the tube 46 is substantially biased to cut-off. No shunting action takes place and the secondary winding 48 of the transformer 49 is substantially open-circuited. The transformer primary 50 under these conditions offers a substantially infinite impedance and there is no loss of power through this primary circuit. When, however, the tube 46 becomes conductive due to the control action upon its grid 45, a certain amount of the input energy is dissipated through the transformer 49 to the tube 46, thereby reducing the volume which is applied to the transformer 7. The variable shunting action of this circuit occurs at a slow rate of speed, due to the delay action of the large condenser 4 in the high resistance circuit composed of resistors 62 and 44, and acts to adjust the average signal level supplied to the grids of tubes 12. Control action in tubes 12, as stated, is extremely rapid for increasing signal input level, and slow for decreasing signal level. Since transformer leakage normally increases at the higher audio frequencies, the shunting action of tube 46 is not reflected through to the primary side to as great an extent as on the lower frequencies. Therefore, the effect is to increase high frequency response on high level signals. For low level signals the high frequencies therefore fall off thus preventing excessive amplification of the hiss of microphones or other high frequency noises. The low frequency response characteristic is also controlled to some degree by the variable shunting action of tube 46 through transformer 49. Without termination on the secondaries 48 a low frequency reactive shunting loss is caused by the primary 50. With termination this reactive shunting loss becomes negligible compared with the shunting loss of tube 46.

The input energy which is shunted off through the transformer 49 and absorbed in the tube 46 may be controlled in amount by the use of a rheostat 51, preferably interconnecting two of the terminals of the divided primary winding 50.

In order to manually adjust the normal output level a rheostat 52 is connected across the conductors 24. This rheostat has preferably a resistance value in the neighborhood of 75,000 ohms from end to end. A shunting resistor 53 may also be used for attenuation, if desired, in connection with the terminals of the transformer secondary 19. This resistor may be of approximately 800 ohms in value, depending upon the impedance values of other portions of the circuit.

The extent to which the gain control is used can be varied by the use of a rheostat 54 in connection with the terminals of the transformer secondary 9. Since one terminal of this secondary is grounded the voltage swing will appear at the opposite terminal. In order to secure the maximum degree of gain control the movable contactor on the rheostat 54 should be in the uppermost position, whereas if it is moved toward the grounded end the minimum or no gain control will be obtained.

The rate of gain recovery following high level passages may be adjusted by the use of a three-position switch 55 having steps a, b and c. Different values of capacitance are thereby shunted across the resistor 56. Step a adds two sections of .1 mfd. each, in capacitor 27, to the .05 mfd. value of capacitor 26, making a total of .25 mfd.

Step b connects only one .1 mfd. section of capacitor 27 in parallel with capacitor 26, making a total of .15 mfd. Step c cuts out the capacitor 27 entirely, leaving only the .05 mfd. capacitor 26 in circuit. The capacitance values stated are, of course, merely by way of example. If adopted in combination with the other circuit constants herein suggested, then the average rates of recovery to be expected are as follows: step a, 1.5 decibels per second; step b, 2.5 decibels per second; and step c, 7 decibels per second.

The resistor 56 which is in shunt with the capacitors 26 and 27 may be of the conventional fixed value type, although this gives an uneven and undesirable rate of recovery of gain after high level signals. With an ordinary linear resistor in the position of 56 after high level signals have caused a maximum gain reduction, the rate of gain recovery is very slow compared to that following medium or low level signals. This is just the reverse of the desired recovery action. The desired action is closely achieved, however, by utilizing a special non-linear resistor of variable value which is an inverse function of the terminal voltage. The material known as "Thyrite" has this characteristic and functions to give a more rapid gain recovery rate following extremely high level signals than following medium or low level signals. "Thyrite" as well known in the trade is a conglomerate substance composed of finely comminuted particles of conductive material imbedded in a non-conductive binder. The characteristics of this substance have been fully disclosed in Patent #1,822,742, granted September 8, 1931, to K. B. McEachron. In the particular embodiment shown, such a Thyrite resistor preferably has a value of 5 megohms resistance with a 40 volt drop thereacross and approximately 30 megohms resistance with no voltage drop.

The various adjustments which have been mentioned for obtaining proper output level, proper gain control and proper timing of the gain control may be performed to the best advantage with the aid of a milliammeter MA which is here shown connected through a double pole three-position switch 58. In the first position of this switch the milliammeter is connected in shunt with a 500 ohm resistor 63 which is in circuit between the 400 volt supply source and the anode of the tube 33. In this position therefore the milliammeter registers approximately the amount of current impressed upon the transformer 31. In the intermediate position of the switch 58 the milliammeter is connected across a 500 ohm resistor 64 and is in circuit with the plate supply lead of the twin amplifier tube 46 through resistor 61 and transformer secondary 48. In this position of the switch 58 it is therefore possible to note the variations in the amount of input energy which is diverted and absorbed in the tube 46.

In the third position of the switch 58 the milliammeter is connected in reversed polarity for indicating plate current in the tubes 12. The 500-ohm resistor 57 provides a bucking voltage which may be balanced by the voltage drop to the movable tap on the potentiometer 59 so as to obtain a zero setting of the milliammeter with no signal input.

It is preferable that all of the transformer cores be grounded and that grounded electrostatic shields between the windings of certain of the transformers, principally transformers 7 and 31 should be provided.

The control characteristics of my system as illustrated in Fig. 1 are readily appreciated when the milliammeter readings are compared under conditions which give effect to more or less control action. With the variable adjustments that are provided the system can be used either as a dynamic range compressor or as a level limiter. Assuming first that the switch 53 is set to the third position, then the milliammeter pointer may be adjusted for a zero reading with the gain control device inoperative. Then by adjusting the potentiometer 54 for maximum gain control, the milliammeter pointer will make wide swings over the instrument scale, thereby indicating operation of the device as an output level compressor. The output level can, in this manner, be readily held within 6 decibels variation for an input level variation of from 30 to 40 decibels. Over a more limited portion of the input volume range the average compression ratio can be made as high as 20 to 1. That is, for an input change of 20 decibels there is a variation of only 1 decibel of output level. This range is quite suitable for level limitation provided the input level variation is not excessive. For operation as a limiter, sufficient control must be used to place the program peaks on this highly compressed range.

Referring now to Fig. 2, I show a modification of my invention in which the circuit is somewhat simplified by the use of dry plate rectifiers in place of a thermionic rectifier. This circuit is particularly useful in connection with an amplifier system having a carbon microphone on the input side and a telephone line on the output side. Other uses may, of course, be found for the embodiment herein shown.

The circuit shows an arrangement of electron discharge tubes as used in an actual set-up where the average gain of the unit was in the neighborhood of 55 decibels. The actual momentary gain was a function of the momentary input level so that amplification varied continuously in accordance with the program input. The change of gain between input levels of -70 and -15 (referred to a 2.5 volt zero level across a 500-ohm impedance) amounted to 33 decibels. Thus when the input level was -70 decibels, the output level became -15 decibels; also when the input level was -15 decibels, the output level became +2 decibels. This automatic control action is accomplished with a minimum of audible distortion, yet peaks, say, above normal are reduced to prevent overloading of subsequent equipment. This -15 decibel input level is found to be as high as can be used without objectionable distortion. The output impedance is made sufficiently low so that a telephone line impedance has little effect on operation.

The details of the circuit are as follows: The input signals are impressed upon the primary 6 of a transformer 7. This transformer has two secondary windings 8 and 9. Energy is fed to the amplifier section from the secondary 8 to two grids 94 of a push-pull tube 70. This tube is constructed as a double triode and is the equivalent of two triode tubes operated in a push-pull manner. The cathode 71 may be grounded. The anodes 72 are connected to opposite terminals of the primary winding 73 on the transformer 74. A mid-tap on the primary 73 connects through a resistor 100, with the positive side of the direct current plate supply source 75 having a value of say 167 volts above a zero ground potential.

Output energy from the transformer 74 is fed from its secondary 76 to the control grid of a screen grid discharge tube 77. The cathode of this tube is grounded. The anode has impressed upon it a potential from the source 75 and interposed therebetween is a resistor 78. The screen grid 79 derives its potential preferably from the same source through a resistor 80. The tube 77 may be capacitively coupled to a further stage of amplification which is conventionally indicated as including the tube 81. The output from the tube 81 is conducted through the primary 82 of a transformer 83 having two secondaries 84 and 85. The secondary 84 is used for conveying the signal to a utilization device (not shown). For improving the quality of the response a resistor 86 may be connected across the terminals of the secondary 84. This resistor may have a grounded center-tap, if desired.

The secondary winding 85 is used for deriving energy for gain control purposes. This portion of the signalling energy is fed back to the terminals 87 of a full-wave oxide plate rectifier system, consisting of four uni-directional devices arranged to feed towards the positive terminal 88 and away from the negative terminal 89 which connects to the grids 94, through the resistors 93 and also to a voltage-divider 91, 92, to the negative terminal of a biasing source 90, the latter being grounded on the positive side thereof. The section 91 has a value of, say, 1 megohm and the section 92 a value of approximately 10 megohms. The interconnecting point between the two sections is by-passed to ground through the capacitor C, having preferably a value of about .3 mfd., thus effecting a time delay circuit.

A normal negative bias is impressed upon the grids of the push-pull tube 70 through the oxide rectifier from the bias battery 105 to each grid 94 and through the respective resistors 93. When the gain in this tube 70 is to be reduced in response to a high level signal, a portion of the signalling energy derived from the secondary 85 of the transformer 83 is rectified and renders the grids 94 more negative with respect to the grounded cathode 71. Hence the gain in this push-pull amplifier tube is reduced momentarily at a rate dependent upon the product of the capacity 95 and the rectifier output impedance, between terminals 88 to 89. A gradual recovery of the gain is effected by equalizing the potentials across the condenser 95 at a rate depending upon the current leakage across the dry plate rectifier from the terminal 88 toward the terminal 89.

The circuit of Fig. 2 includes a variable absorption device such as the tube 96 connected with a secondary winding 9 on the transformer 7. This absorption device acts as a slow speed automatic gain control and at the same time an automatic frequency characteristic control. This frequency characteristic control action is illustrated in Fig. 4 and is due to the fact that transformer leakage increases on the higher audio frequencies and consequently the shunting action decreases. The absorption device discharge tube 96 has a grounded cathode 97 and a control grid 98 which connects to a suitable point 99 on a voltage divider between the 167 volt positive lead of the battery 75 and the -22 volt negative lead of the battery 90. The potential drop across this potential divider at the point 99 may be varied in accordance with the amplitude of the signals due to variations in the plate current in the tube 70 which in turn results in

a variation in the drop of potential between the two terminals of a resistor 100 constituting part of the voltage divider. The value of the resistor 100 may be made approximately 500,000 ohms.

Between the resistor 100 and the point 99 is a resistor 101 having a value of, say, 50 megohms. Between the point 99 and the negative terminal of the grid biasing battery 90 is a resistor 102 having a value of, say, 2 megohms. This is bypassed to ground by a condenser 109 of, say, 1 mfd. in order to establish a time delay circuit. It will thus be seen that the control action may be varied at a slow rate through the use of the tube 96 which absorbs more or less of the energy impressed upon the secondary 9 of the transformer 7. The fast gain reduction action, however, is accomplished through the use of the dry plate rectifier system which varies the bias potential supplied to the grids 94 of the tube 70. The amount of control may be adjusted through the use of a three-position switch 103 having contact points connected to different taps on a three-section resistor 104 intervening between the secondary 85 and one of the terminals 87 of the rectifier system. The three sections of the resistor 104 preferably have values of 400 ohms, 1000 ohms and 3000 ohms respectively, as successively viewed from left to right in the diagram.

The frequency characteristics of the transformer 7 may be improved by connecting in series with the two sections of its primary 6 a filter system consisting of a choke 106 having a grounded center-tap, a resistor 107 and a capacitor 108. Values of the condenser and choke inductance are such as to resonate in the frequency region of excess response.

Referring now to Fig. 3, I show still another embodiment in which, although the circuit is considerably simplified as compared with the circuits of Figs. 1 and 2, certain objects and advantages of my invention are none the less manifested. In the circuit diagram therein shown I have provided a pair of push-pull amplifier tubes 110 of the triode type although, of course, it is to be understood that screen grid tubes, pentode tubes or any other type of tubes may be employed. The control grids 111 are connected to opposite terminals of the secondary winding 112 of an input transformer 113. The primary winding 114 of this transformer has impressed upon it the input signalling energy from any desired source. Assuming that such a source is a carbon microphone, it is usual to supply a positive biasing potential to the translating circuit and such a potential has been here shown as having a value of 6 volts impressed across a 50 ohm resistor 115 and thence to a center-tap on the primary winding 114. A leakage path from the center-tap to ground is also provided through a 100 ohm resistor 116. It will be understood, although it is not shown, that the microphone itself would be grounded at a suitable point.

The input circuit to the grids 111 is provided with a normal negative biasing potential with respect to the cathodes 117, such potential being derived from a C-battery 118 connected between the negative side of an oxide rectifier and the resistors 120 which connect to the grids 111. The mid-tap of the secondary shunting resistors 120 is by-passed to the cathodes 117 by a condenser 119 of say 25 mfd.

The output circuit for the push-pull tubes 110 is fed to the input circuit of a balanced high impedance amplifier 134 having a gain of, say, from

30 to 60 decibels. A direct current source 124 supplies a suitable potential by way of a mid-tap on the resistor 123, which has two equal 50,000 ohm sections, to the anodes 125 of the push-pull tubes 110. The negative pole of the source 124 is connected directly to the cathodes 117.

The circuit diagram of Fig. 3 as thus far described is more or less conventional. I have found, however, that the circuit in its entirety provides new and improved results over what was known in the art, particularly when it includes a full wave dry oxide plate rectifier system 126 connected up in the manner shown. In this rectifier system the terminals 127 are fed with energy derived from the secondary winding 128 of a transformer 129, the primary 130 of which is connected between one terminal of the transformer secondary 131 and ground. As an alternative, the primary 130 may be bridged across either all or part of the secondary 131, as shown in Fig. 5. Transformer 122, the primary of which is fed from the amplifier 134, supplies energy to the utilization circuit in addition to transformer 129. The other terminals of the rectifier 126 are connected in a circuit which includes the cathodes 117, the biasing battery 118 and the return leads to the grids 111. The cathodes 117 are also grounded.

The operation of the gain control device is as follows: When, in response to a high level signal, additional output energy is derived from the transformer secondary 131, an increase in alternating current potential occurs across the secondary winding 128 of the transformer 129. A potentiometer 132 preferably shunts the secondary and is provided with a movable contactor 133 in connection with one of the terminals 127 of the oxide rectifier. The purpose of this potentiometer is to permit adjustment of the energy supplied to the oxide rectifier in order to regulate the amount of automatic gain control action. The alternating current so derived is rectified and renders the grids 111 more negative with respect to ground, thereby reducing the gain in the amplifier. This reduction occurs rapidly. After a suitable time delay following the gain reduction, a normal gain is restored, assuming that the high level signalling peak has passed. The time constant in respect to this delay action is a function of the capacitance 119 and of the inherent leakage resistance of the rectifier 126.

Referring now to Fig. 4, I show typical curves of the frequency characteristics to be expected of certain of the embodiments of my invention herein described and illustrated typically in Figs. 1 and 2. The graphs of frequency response in the amplifier at low signal level, medium signal level and high signal level are coordinated to show the decibels of gain in the amplifier in relation to the frequency value of a given portion of the signal. It is assumed that the system is operated in the audio range, say, between 50 cycles and from 8,000 to 10,000 cycles. It will be noted that the frequency characteristic curve of low level signals has very steep slopes both at the low frequency end and at the high frequency end thereof. This indicates that the gain control device operates to suppress the noise level accompanying the useful signal, both as regards rumble and hiss. The curves tend to become levelled off at all audible frequencies when medium and high level signals are received and when the accompanying noise level would be less noticeable than otherwise.

A further feature to be noted in the diagram of

Fig. 4 is that the gain in the amplifier as measured in decibels is very much greater for a low level signal than for a high level signal. Thus the volume range is compressed within desirable limits for avoiding the overloading of equipment used subsequently to that of the amplifier.

It will be appreciated by those skilled in the art that many modifications of my invention may be made other than as herein shown without departing from the spirit and scope of my invention. The invention itself, therefore, is limited only as defined by the claims.

I claim:

1. In combination with a gain-controlled discharge tube amplifier system, a gain control device therefor comprising input energy diverting means, an electron discharge tube amplifier under control of said means, a double-diode rectifier, a transformer having a primary connected to the output side of the last said amplifier and a center-tapped secondary, the end terminals of which are connected respectively to the anodes of said rectifier, a grid biasing circuit extending between the cathodes and the control grids of the first said amplifier system, means including a capacitor and a non-linear resistive conglomerate substance composed of particles of conductive material imbedded in a non-conductive binder, both said capacitor and said resistive substance being in shunt between the cathode of said amplifier in the gain control device and the center-tap of said transformer secondary, for appreciably retarding the rate of gain recovery in said gain controlled amplifier system in relation to the time constant of the gain reduction therein, said capacitor being one of a plurality of selectable fixed capacitances having different values and each being provided with means for switching the same into shunting relation to the resistor of said grid biasing circuit.

2. In a gain control system for use with an amplifier having at least one electron discharge tube stage in which the amplification ratio is a function of the direct current grid bias potential applied thereto, means for diverting and rectifying a portion of the signalling energy from a source with which said amplifier is connected, means responsive to an increase in the rectified energy for suddenly increasing the negative grid bias applied to said amplifier stage, means comprising a capacitor in shunt with a non-linear resistive substance composed of finely comminuted particles imbedded in a non-conductive binder, said means being responsive to a decrease in the rectified energy for slowly decreasing said negative grid bias, and means for manually adjusting to a suitable value the time delay factor involved in the operation of the means for slowly decreasing said bias.

3. Apparatus connected with and operable to control the gain in an electron discharge tube stage of audio-frequency amplification, where said stage includes a grid biasing circuit, said apparatus comprising means including an absorption device bridging the source of input energy which is applied to said stage and operable under control of variations in the conductivity of the space path in said stage for diverting more or less of said input energy away from said stage, said apparatus also comprising a system of double diode rectification and amplification of another portion of the signalling energy diverted from said stage of audio-frequency amplification, said system including means connected to said grid

biasing circuit for quickly reducing the gain in said stage and for slowly increasing the gain therein, and means manually operable in accordance with the character of the program to be amplified for fixing at a suitable value the time constant pertaining to the rate of gain recovery to be permitted by said system.

4. The combination with a main amplifier system having at least one electron discharge tube stage and a circuit for varying the bias between the cathode and grid electrodes of said tube stage of a volume control device responsive to the volume of the undulatory energy impressed upon said amplifier system, said device comprising an electron discharge tube amplifier receptive of a portion of said undulatory energy, a transformer having its primary in the output circuit of the last said amplifier, an electron discharge tube having a double diode rectifier portion and an amplifier portion, the anodes of said rectifier portion being connected respectively to the secondary terminals of said transformer, a non-linear resistor composed of finely comminuted particles of conductive material imbedded in a non-conductive binder, said resistor being connected between a mid-tap on the secondary of said transformer and the cathode of the last said tube, the space path of said amplifier portion being disposed in and forming a part of said bias varying circuit, a fixed resistor in shunt with said space path and means including a capacitor in shunt with said non-linear resistor for introducing a time delay constant into the gain recovery action of said main amplifier following a sudden reduction therein of the gain incident to the reception of a high level signal.

5. The combination with a main amplifier system having at least one push-pull electron discharge tube stage, a transformer connected to the output circuit of said tube stage, and a circuit for varying the bias between the cathode and grid electrodes of said tube stage, of a volume control device responsive to the volume of the undulatory energy impressed by said amplifier system upon said transformer, said device comprising a full-wave dry plate rectifier forming a portion of said grid biasing circuit of the main amplifier, means including a capacitor in shunt with said rectifier for producing a rapid gain reduction while enabling said push-pull amplifier to cancel out the effects of sudden surges of rectified control potential, means connected to the alternating current terminals of said rectifier for deriving control energy which is impressed thereon according to the output level from said main amplifier, thereby to compress the range of amplitude variations in said output level, and means for controlling the output level of undulatory energy from said main amplifier, the last said means being slow-acting as compared with the action of the device for controlling the grid bias on said main amplifier.

6. The combination with a push-pull amplifier system having at least one electron discharge tube stage and a circuit for varying the bias between the cathode and grid electrodes of said tube stage of a volume control device responsive to the volume of the undulatory energy derived from said amplifier system, said device comprising a rectifier stage to which a portion of said undulatory energy is fed, means acting in response to an increase in the volume of said energy when rectified for suddenly increasing the grid bias in said push-pull amplifier system and in response to a decrease in the volume of

said energy when rectified for slowly decreasing the grid bias in said push-pull amplifier, and means including an absorption device coupled to the input circuit of said push-pull amplifier
5 for compressing the range of volume variations of the input energy to said push-pull amplifier while maintaining a relatively small difference between the rate of gain reduction and the rate of gain recovery, both said gain reduction and
10 said gain recovery being essentially slower than that which is produced by the first said volume control device.

7. The system as defined in claim 6 and having means adapted to compress the volume range to a greater extent in the intermediate portions of the audio frequency spectrum for which the system is usefully adapted than at the extremes of said spectrum.

8. In combination with an audio wave amplifying system of the type having a multi-electrode space discharge amplifier the gain in which

is controllable by varying the direct current potential between the cathode and the control grid electrodes thereof, a non-linear resistive substance composed of finely comminuted conductive particles imbedded in a non-conductive
5 binder and a shunt connected capacitor connected to a source of biasing potential between said cathode and control grid electrodes, a rectifying device for rectifying a portion of the audio-wave energy, means for impressing the
10 potential of the rectified current upon the control grid electrode of said amplifying system, means for simultaneously varying the charge upon said capacitor at a rapid rate in response to an increase in the amplitude of said rectified
15 current, said non-linear resistor constituting means for slowly discharging said capacitor at a rate such that the recovery of the gain is a direct function of the peak level of the input potential applied to said amplifying system. 20

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