Oct. 30, 1934. J. H. HAMMOND, JR 1,979,034

AMPLIFYING SYSTEM

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Fig. 1

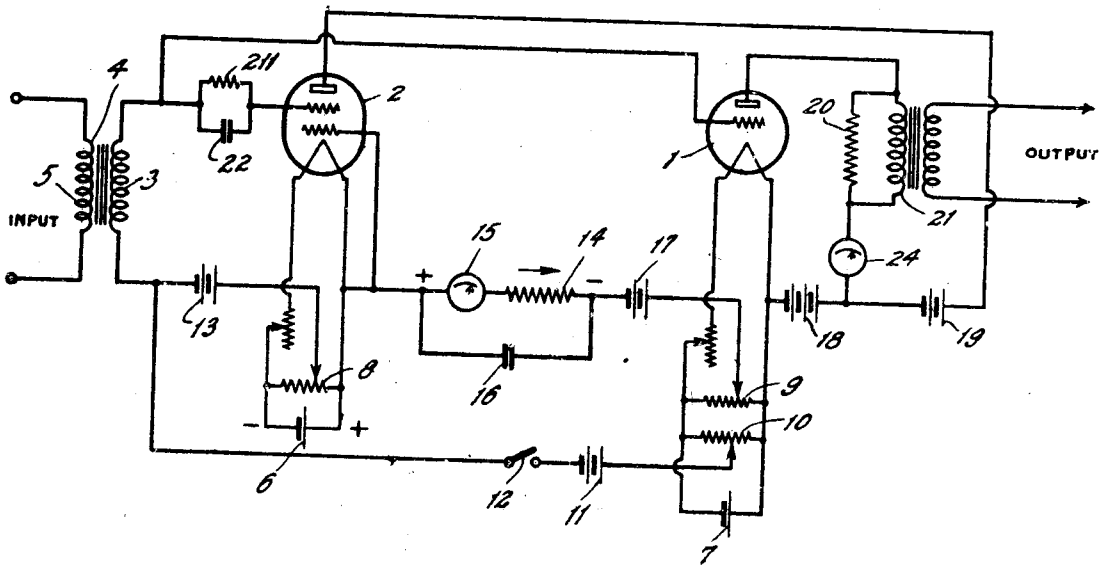

Fig. 2

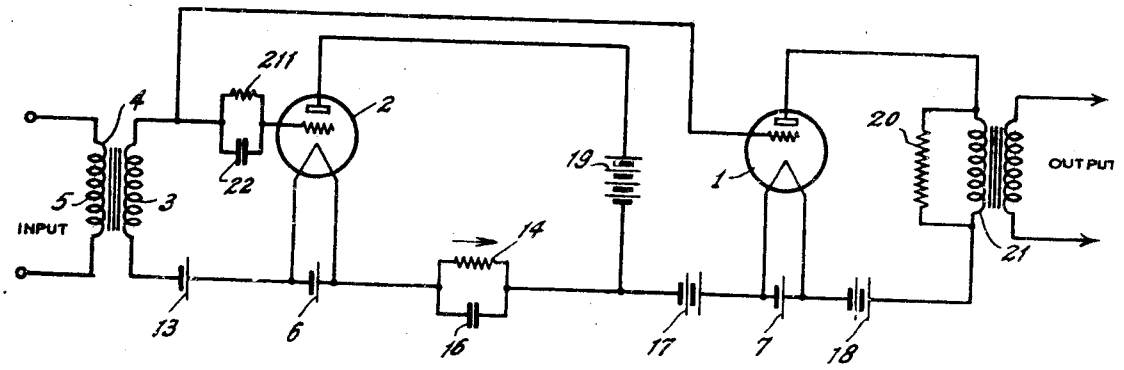

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Fig. 3

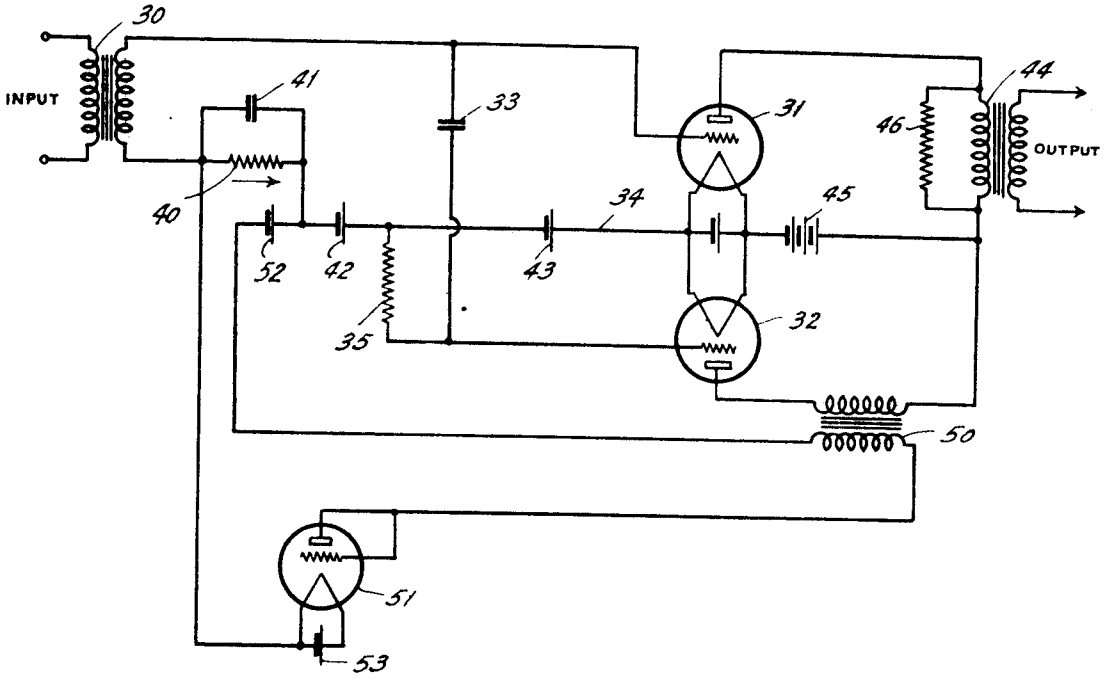
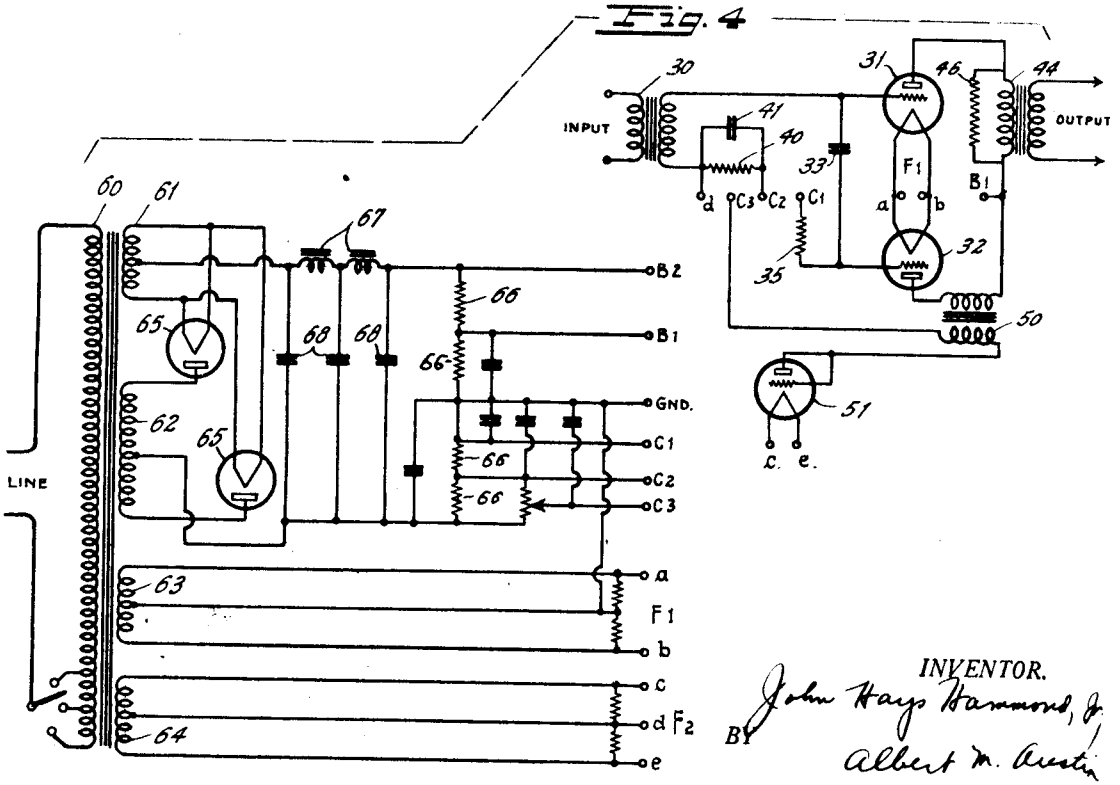


Fig. 4



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AMPLIFYING SYSTEM

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13 Claims. (Cl. 179—100.4)

This invention relates to amplifying systems, and more particularly, to an improved method of controlling the amount of amplification in accordance with the strength of the applied current.

The invention relates particularly to a system for use in recording and reproducing orchestral selections and provides for the reproduction of such selections in their original quality.

It has been found that for recording orchestral music which varies in intensity, the orchestra must make greater variations in intensity for recording purposes than for concert work. That is, with an intensity variation from "Piano" to "Forte", suitable for concert work, the variation must be from "Pianissimo" to "Fortissimo" so that the record will give the proper variation from "Piano" to "Forte" when reproduced by electrical means.

One of the purposes of this invention is to provide means for accentuating the intensity variations in the recording of orchestral selections, whereby the orchestra may be conducted for recording purposes in the same manner as for concert purposes. Another purpose of this invention is to accentuate the variation in reproducing records which may have been recorded without due regard to the proper method of recording.

This is accomplished in accordance with the present invention by the use of an amplifying system which is capable of producing a greater ratio of amplification or gain for impressed signals of high intensity than for impressed signals of low intensity. A gain, for example, of two to one may be obtained for weak signals whereas the gain for strong signals may be of the order of ten to one with intermediate intensities having corresponding gain ratios.

The invention also provides for avoiding distortion which is commonly due to a production of harmonics in the detector circuit. The gain in the amplifying system is determined by the applied potential and the system is such that the amplification is automatically controlled in accordance therewith.

The invention may be applied to the various recording or reproducing systems in which voltage amplification is desirable, for example, recording sound on records or films or reproducing the original signals therefrom.

The present invention provides for controlling the tube operating characteristics in accordance with the strength of the applied signal, so that the amplifying efficiency of the tube is greater for strong signals than for weak signals. Means is also provided for suitably altering the fidelity curve for strong and weak signals, so that the proper audible response is obtained at all times.

One simple method of control is by changing the bias on an amplifying tube in accordance with the intensity of the impressed signal. Amplifying tubes are usually biased so as to give maximum voltage gain, or in case of the last audio stages, so as to give maximum undistorted output. Preferably the control may be applied to a tube which during normal operation does not develop a very great proportion of its possible output power. If a variation of gain ratio of more than four or five to one is desired, the control may be applied to more than one amplifying tube giving a cascaded effect.

The invention also consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Fig. 1 illustrates diagrammatically one type of circuit for carrying out the present invention;

Fig. 2 is a schematic diagram of the circuit of Fig. 1;

Fig. 3 is a schematic diagram of a modified form of the invention; and

Fig. 4 is a diagram showing an arrangement of the system of Fig. 3 for use with a power pack.

Like reference characters denote like parts in the several figures of the drawings.

In the following description and in the claims parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring more particularly to the drawings, Fig. 1 shows an amplifying tube 1 and a control tube 2. The control grids of both tubes may be operated in parallel from the secondary 3 of transformer 4, with primary 5 excited from a source of tone currents. Separate batteries 6 and 7 are used for the two tubes because a variable bias of one tube with respect to the other is required during operation. Potentiometers 8 and 9 are provided for manual adjustment of bias

to take care of variations in tubes as replacements are made, or for adjusting the ratio of amplification of tube 1 on high and on low signal strengths. Potentiometer 10 is provided so that in combination with bias battery 11 on closure of switch 12 a definite and invariable bias may be imposed on tube 1 so that the control mechanism may be rendered inoperative, for test and demonstration purposes.

Tube 2 may be conveniently a so-called high M tube, or a tetrode with one grid biased as for example to the positive end of the filament. This tube is biased by battery 13 in combination with the adjustment bias 8. It operates as a plate detector device in that increased signal strength increases the average D. C. value of the plate current. The output plate circuit of this tube includes the resistor 14 and meter 15, shunted by condenser 16, the bias battery 17, part of potentiometer 9, the plate battery 18 and if desired an additional battery 19. Normally potentiometer 8 is adjusted to produce little plate current as indicated by meter 15, and so that increased signal from transformer 4 increases the reading of the meter. The resistor and meter shunted by condenser 16 are so proportioned that variations of voltage across condenser 16 will be of lower frequency than the frequencies coming through transformer 4. The voltage across 16 is a bias voltage to tube 1, and is arranged that increased signal diminishes the bias, thereby lowering the impedance of the tube 1, and increasing the amplification ratio of tube and output transformer.

It is desirable to include a resistor 20 across the primary of output transformer 21 suitably chosen to prevent excessive changes in the fidelity of amplification as the control device operates. Further it is desirable to include a limiting means whereby the bias on tube 1 is not decreased too greatly, as for example, by a high resistance 211 with bypass condenser 22 in the grid lead to the control tube, which operates contrary to plate detection in definitely limiting the current through control resistance 14.

Resistor 211 and condenser 22 operate on grid rectification. When large voltages are impressed onto the grid from the transformer secondary 3, then the grid draws current as it becomes positive with respect to the filament during some portion of the cycle. This produces pulsating current which passes through resistance 211 and condenser 22 in parallel the D. C. part flowing through the resistance 211, and the A. C. part flowing chiefly through condenser 22 of low reactance. For example, with 211 of 5 megohms, and condenser 22 of .1 mf, then the reactance of 22 for 30 cycles is about 50,000 ohms so that practically all the audio currents pass through 22 without much voltage drop, compared with the D. C. drop due to the direct current through the resistance. The D. C. drop is in such a direction as to cause the tube to be further biased, cutting down the plate current.

Resistance 20 may be of the order of 10,000 ohms, for normal operation. If with maximum bias, the impedance of the tube 1 is 70,000 ohms, and with minimum bias it is 15,000 ohms, then the impedance of tube and resistor 20 in parallel varies between limits 8750 and 6000, while if resistance 20 is omitted (that is made infinite) the impedance across primary of the transformer would vary from 70,000 to 15,000. Thus a transformer designed for about 7000 ohms impedance would have the same transmission characteristics very closely although the tube impedance varies by a considerable factor. The principle involved is a ballast resistance suitably applied to maintain the transformer action substantially correct. Resistance 20 could be made to operate inversely as the tube impedance to keep the parallel value more constant if this is desired in a particular case.

The purpose of tube 2 is to insert D. C. grid voltage into the circuit of tube 1, and therefore the so-called rectification properties of tube 2 are utilized. In the plate circuit of tube 2 are alternating as well as direct currents. The amount of direct and alternating current depends upon the strength of input. The alternating current components are eliminated with respect to the D. C. components in the output circuit by making the output impedance low for alternating voltages, compared with the output impedance for direct currents. Thus 14 and 15 in series may be of the order 200,000 ohms for screen grid tube, or 20,000 for an ordinary tube. Condenser 16 may be of the order of 2 microfarads for a screen grid tube, or 20 microfarads for an ordinary tube.

Consider the ordinary tube circuit with 20,000 ohms D. C. impedance, and about 250 ohms for A. C. of 30 cycles. Now the A. C. current in the plate circuit may be of the same order of magnitude as the D. C. current. Assume for example, 1 milliampere A. C. and 1 milliampere D. C. to be flowing in the plate circuit of tube 2, and passing through 15 and 14 paralleled by condenser 16. Then the D. C. flows through 15 and 14, producing 20 volts D. C. in the grid tube, but the A. C. flowing chiefly through condenser 16 produces only .25 volt. That is from substantially equal A. C. and D. C. energies in the plate of tube 2, the A. C. voltage is about 1.25% of the D. C. voltage in the grid circuit of tube 1. Because of the high capacities required for satisfactory operation of grid circuit of tube 1, the screen grid tube is preferable to the ordinary tube, so as to permit the resistor 14 to be about a quarter megohm, and condenser 16 to be about 2 to 5 microfarads.

In operation, assume the equipment has been set up with a set of tubes not before used, then the bias on tube 2 is first adjusted by potentiometer 8 to give small reading of meter 15 compared with the reading with signal impressed. Then the bias of tube 1 is adjusted by potentiometer 9 so that the reading of meter 24 is small with no signal and a little less than rated value when the strongest signals are impressed. To care for different types of records, a hand volume control should be employed previous to the control stage shown. For records that require no change of amplification ratio, the switch 12 may be closed rendering the automatic control inoperative. For records which require large automatic variations in amplification ratio, the initial bias for no signal should be set to give low reading of meters 15 and 24. For records which require small automatic variations in amplification ratio, the initial bias for no signal may be set at intermediate bias values. As changes in initial bias are made there is need also for changes in volume control of signals as it enters the system, and arrangements may be made for adjusting the input hand volume control to different values depending on the adjustment of the bias for no signal.

The ratio of output voltage to input voltage of a control stage (as shown) may be called the gain ratio, and the curve showing amplification

ratio as dependent on the intensity of signal impressed on the control stage may be called the gain ratio curve. For normally adjusted amplifiers, this gain is independent of signal strength up to the power capacity of the tube. For amplifiers in accordance with this invention the general slope is upward, that is, for any intensity value an increase of intensity increases the gain ratio. Furthermore, there may be discriminations between frequencies, making different gain ratio curves for lower tones than intermediate value tones on high frequency tones. Thus for example, if the prominent tones are of low pitch there may be little variation of gain ratio, but considerable change in gain ratio if the prominent tones are of high pitch.

Referring to Fig. 3 the input current is applied through transformer 30 to the input circuit of tube 31. The input circuit of control tube 32 is connected in parallel to the input circuit of tube 31 through condenser 33 and the common filament lead 34. A high resistance 35 may be connected between the grid of control tube 32 and filament lead 34 to provide the necessary leakage path. Resistance 40 shunted by condenser 41 is connected in series with the batteries 42 and 43 in the common filament lead 34.

The output circuit of tube 31 comprises transformer 44 and a source of plate potential 45. Said transformer is shunted by high resistance 46 in order to obtain the proper fidelity curve. The output circuit of tube 32 includes the primary of transformer 50 and source 45. The secondary of transformer 50 is connected in series with a rectifying device 51 and battery 52 across resistance 40. Rectifying device 51 may be of any suitable type, as for example, a three electrode discharge device having a filament which may be energized by battery 53. Device 51 may take the form of a power rectifier or a dry disc rectifier if desired. A power rectifier which is capable of working into resistance 40 of some 40,000 ohms is particularly suitable.

In the operation of the system of Fig. 3, the amplifying characteristics of tube 31 are determined by the grid potential of that tube. This in turn is determined by batteries 42 and 43 and the voltage drop in resistance 40. The voltage drop of said resistance is governed by the amplitude of the impressed signals, which are applied to control tube 32 and determine the space current in that tube. The space current in tube 32 is passed through the primary of transformer 50 and incites a current in the secondary thereof, which is applied through rectifier 51 to resistance 40. A unidirectional current is thereby produced in resistance 40 which is proportional in value to the average amplitude of the impressed signal. This controls the amplification characteristics of tube 31 in a manner pointed out in connection with tube 1 of Fig. 1.

It is obvious that increase in voltage across condenser 41 will depend on the voltage supplied by the transformer 50 and upon the value of the resistance 40. Decrease in voltage across the condenser 41, however, will depend solely upon the resistance 40, since the power rectifier 51 operates as an open circuit to the discharge of the condenser 41 as the rectifier is a one-way valve.

The triode 51 is connected as a diode power rectifier to give substantially linear voltage characteristics. This condition is possible when the biasing resistance 40 is very large compared to the internal resistance of the power rectifier 51 and therefore a relatively small current flows through the rectifier. Therefore, the change in the D. C. voltage drop across biasing resistance 40 is directly proportional to the alternating current voltage across the output of transformer 50. Since transformer 50 and amplifier 32 have linear characteristics, it follows that the change in bias on the main amplifier 31 is directly proportional to the change in the intensity of the input signal strength.

Referring to Fig. 4, a power pack of well known construction is disclosed which comprises a transformer 60 having a plurality of secondary windings 61, 62, 63 and 64. Winding 61 is used to light the filament of rectifier tubes 65 and winding 62 is used to obtain the necessary high voltage current across the resistances 66. The rectified current across said resistance is passed through a filter system comprising chokes 67 and condensers 68. Various potentials are obtained at output terminals B–1, B–2, C–1, C–2 and C–3 by suitably tapping resistances 66 at the required points.

Windings 63 and 64 may be utilized for lighting the filaments of tubes 31 and 32 and tube 53 respectively. By connecting the various terminals of the amplifying system to the correspondingly marked terminals of the power pack, the circuit illustrated in Fig. 3 may be produced. It is to be noted in connection therewith that the various sources of potential in Fig. 3 were referred to as batteries. Any suitable source such as the power pack arrangement illustrated in Fig. 4, may be utilized if desired.

It is to be noted that with the above system if a base note is struck with considerable force, all the notes being reproduced at that time will be amplified out of their true proportion. This can be overcome by suitably designing transformer 4 (Fig. 1) and transformer 30 (Fig. 3) so that these transformers discriminate against notes of lower frequencies. This may be accomplished in any well known manner by controlling the proportion between the windings and core of the transformer.

While certain novel features of the invention have been shown and described and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes in the forms and details of the device illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. In an amplifying system for reproducing sound from a sound record, a main amplifier, means for changing the gain ratio of said main amplifier including a control tube, means for impressing the same signal across said first amplifier and said control tube, a control resistance in the output circuit of said control tube for controlling the impedance of said main amplifier, means for operating said control tube with plate rectification to supply voltage to said control resistance, and means for operating said control tube with grid rectification opposing said plate rectification to limit the increase in gain ratio with increase in signal strength.

2. In an amplifying system for reproducing sound from a sound record, an amplifier including an amplifier tube, a transformer in the output of said amplifier tube, means for impressing an audio signal having different tone frequencies on said amplifier tube, means for varying the internal impedance of said amplifier tube in ac-

cordance with the changes in the average intensity of the audio signal, and a resistor across said transformer to limit variations in the gain ratio of the amplifier system with different tone frequencies of the same intensity.

3. In an amplifying system for reproducing sound from a sound record, a main amplifier, means for changing the gain ratio of said main amplifier including a control amplifier, means for impressing the same signal across said main amplifier and said control amplifier, a transformer in the output circuit of said control amplifier, a one-way rectifier in the output of said transformer circuit, a control resistance also in the output of said transformer circuit, a capacitance across said control resistance, said control resistance varying the gain ratio of said main amplifier.

4. In an amplifying system for reproducing sound from a sound record, a main amplifier, means for changing the gain ratio of said main amplifier including a control amplifier, means for impressing the same signal across said main amplifier and said control amplifier, a one-way rectifier in the output of said control amplifier, a control resistance in series with said rectifier and with the output of said control amplifier, said control resistance varying the gain ratio of said main amplifier.

5. In a sound reproducing system, a sound record, an electric pick-up device therefor and means for expanding the volume range, comprising an electric dynamic amplifier tube fed by said pick-up device, an electric sound propagating element fed by said amplifier, a control circuit fed from a point between said pick-up device and said amplifier tube, said control circuit having means for rectifying the variations picked up from said record, and means for increasing the gain ratio of the amplifier tube with increase in the intensity of said rectified variations.

6. In a sound reproducing system, a sound record, a pick-up device therefor, an amplifier fed by said pick-up device, a receiver fed by said amplifier, means controlled by energy also received from said pick-up device for varying the gain ratio of said amplifier over a wide range in accordance with the sound variations on said record and means including a resistance element for making the frequency characteristics of said amplifier substantially independent of the gain characteristics thereof.

7. In a sound reproducing system, a sound record, a pick-up device therefor, a dynamic amplifier fed by said pick-up device, a sound propagating device fed by said dynamic amplifier, a control circuit fed by said pick-up device having means governed by the energy obtained from said record for increasing the gain ratio of said amplifier with increase in average intensity of the energy picked up from the sound record, and adjustable means for predetermining the ratio between minimum and maximum gain ratios of said dynamic amplifier.

8. In a sound reproducing system, a sound record, a pick-up device for said record, a dynamic amplifier fed by said pick-up device, said dynamic amplifier comprising a vacuum tube having a control electrode, a biasing resistance in the circuit of said control electrode, a control circuit fed from a point between said pick-up device and said vacuum tube, said control circuit including a rectifier and feeding a varying D. C. current through said biasing resistance, a capacitance across said biasing resistance, and a sound propagating device fed by said dynamic amplifier.

9. The method of reproducing sound from a sound record which comprises translating the sound energy recorded on said record into corresponding electrical energy, feeding a part of said electrical energy into the input of an electron discharge amplifier, feeding a speaker from the output of said amplifier, feedin another part of said electrical energy from a point between said record and said amplifier input into a rectifier, smoothing out the rectified energy to obtain a sub-audio control current governing the bias on the control element of said amplifier, and fixing the initial bias on said amplifier with no signal and the ultimate bias on said amplifier with maximum signal so that substantially the entire volume range is expanded from the threshold of audibility to maximum volume.

10. The method of reproducing sound from a sound record which comprises translating the sound energy recorded on said record into corresponding electrical energy, feeding a part of said electrical energy into the input of an electron discharge amplifier, feeding a speaker from the output of said amplifier, feeding another part of said electrical energy from a point between said record and said amplifier input into a rectifier, smoothing out the rectified energy to obtain a sub-audio control current governing the bias on the control element of said amplifier.

11. In a sound reproducing system, a sound record, a pick-up device therefor, a dynamic expander fed by said pick-up device, a sound propagating device fed by said dynamic expander, a control arrangement fed by said pick-up device for controlling the gain of said dynamic expander, and a limiting device responsive to signal strength for automatically limiting the maximum gain of said expander sufficiently below the overload point of the expander to insure fidelity of reproduction.

12. In a sound reproducing system, a sound record, a pick-up device therefor, an amplifier fed by said pick-up device, a receiver fed by said amplifier, a control circuit fed by said pick-up device for governing the gain of said amplifier to expand the volume range of the signal, said control circuit comprising a linear rectifier for impressing a sub-audio bias on the control electrode of said amplifier to control the gain thereof, said bias varying in such manner that change in bias on said amplifier is directly proportional to change in average intensity of the signal on said record throughout the entire volume range of said record.

13. In a sound reproducing system, a sound record, a pick-up device therefor, a dynamic amplifier fed by said pick-up device for expanding the volume of the signal, a sound propagating device fed by said amplifier, a control circuit fed from a point between said pick-up device and said dynamic amplifier, said control circuit comprising a rectifier connected as a diode to provide a sub-audio control current to determine the bias on the control element of said amplifier, said bias varying in such manner that change in bias is directly proportional to change in average intensity of the signal on said record throughout the entire volume range of said record.

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