Jan. 20, 1942. G. G. SMITH 2,270,789

METHOD AND APPARATUS FOR VOLUME CONTROL OF ELECTRONIC AMPLIFIERS

Filed April 13, 1940 2 Sheets-Sheet 1

FIG. 1

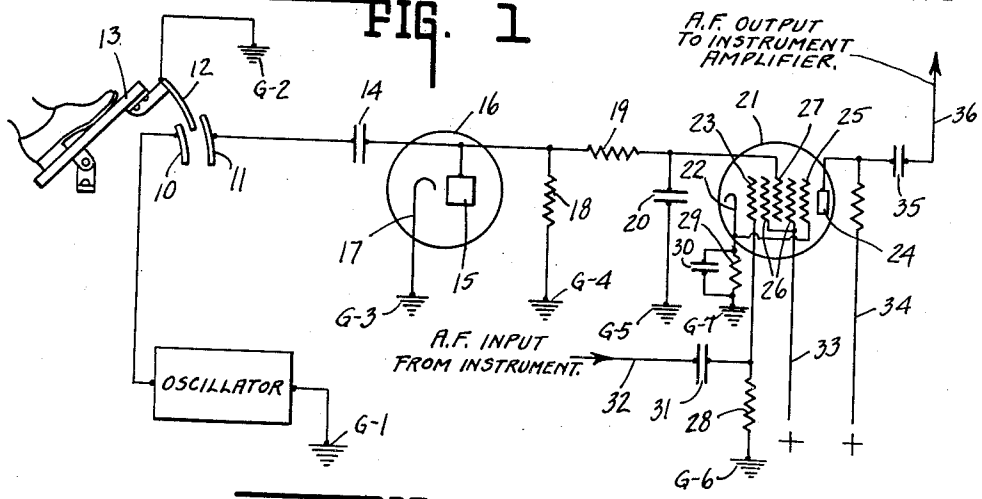


FIG. 2

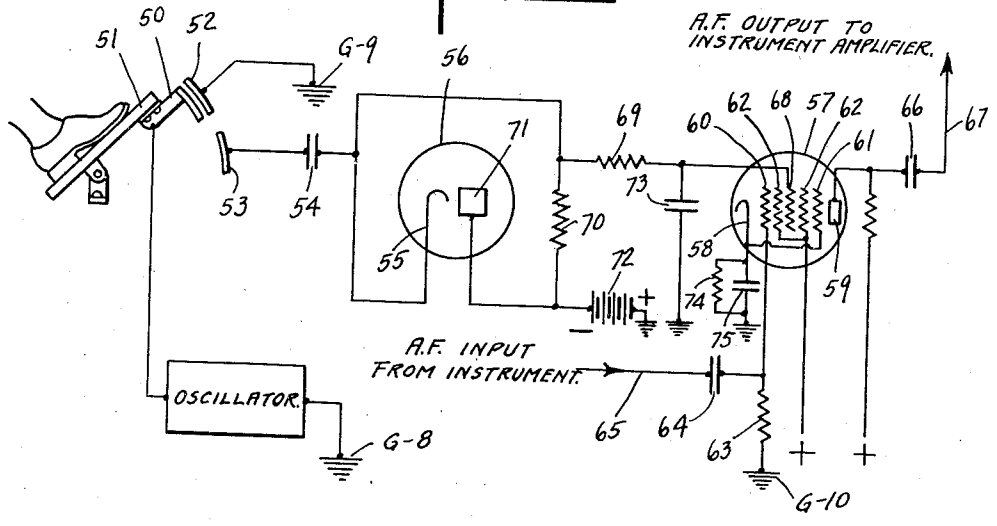
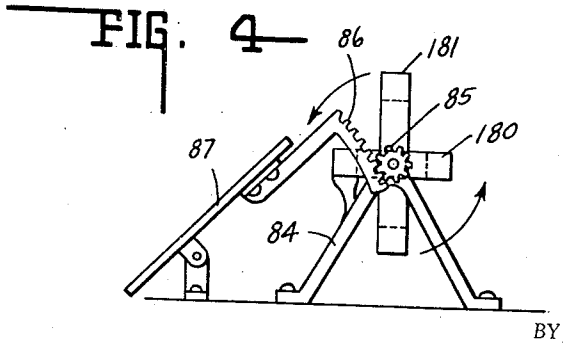


FIG. 4



INVENTOR.
GERALD G. SMITH.

BY Lockwood, Goldsmith & Galt.
ATTORNEYS.

Jan. 20, 1942. G. G. SMITH 2,270,789

METHOD AND APPARATUS FOR VOLUME CONTROL OF ELECTRONIC AMPLIFIERS

Filed April 13, 1940 2 Sheets-Sheet 2

FIG. 3

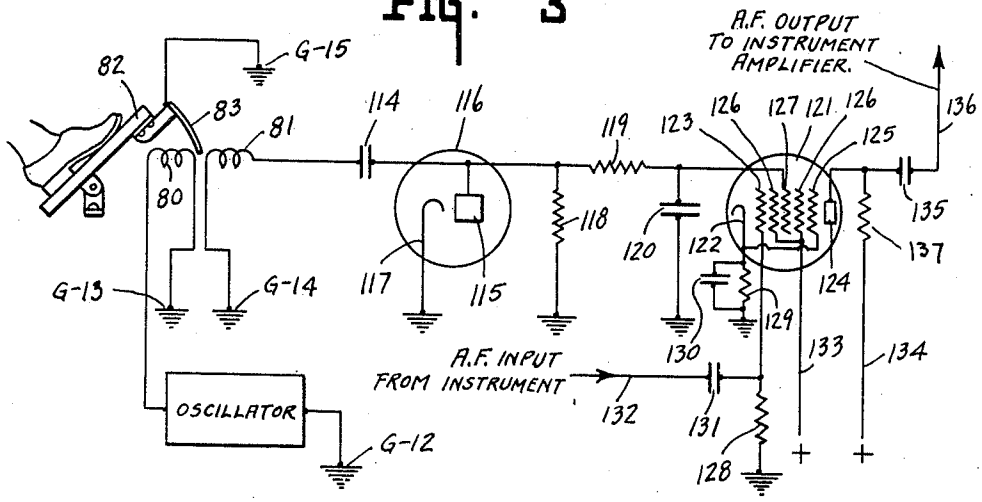


FIG. 5

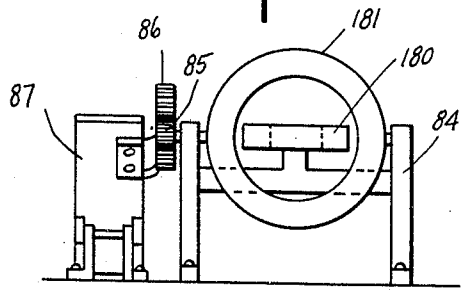


FIG. 6

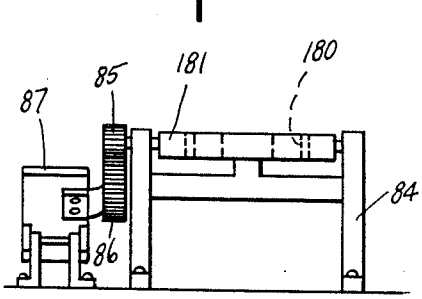
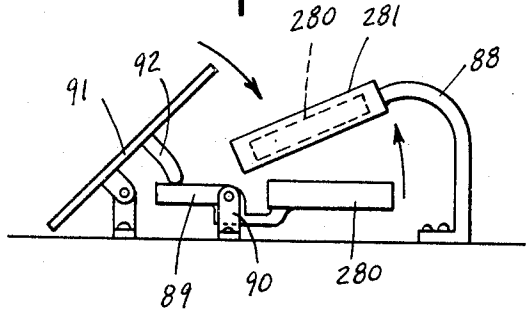


FIG. 7



INVENTOR.
GERALD G. SMITH.

BY Lockwood, Goldsmith & Galt.
ATTORNEYS.

Patented Jan. 20, 1942 2,270,789

UNITED STATES PATENT OFFICE

2,270,789

METHOD AND APPARATUS FOR VOLUME CONTROL OF ELECTRONIC AMPLIFIERS

Gerald G. Smith, Kenmore, N. Y., assignor to The Rudolph Wurlitzer Company, Cincinnati, Ohio, a corporation

Application April 13, 1940, Serial No. 329,437

2 Claims. (Cl. 179—171)

This invention relates to a method and apparatus for volume control of an electronic amplifier and is applicable to such amplifiers as are used in radio sets, phonographs, public address systems, electric organs or for amplifying sounds of other musical instruments.

Volume controls heretofore in use have almost invariably required the use of mechanically operated resistance units with frictionally engaged moving contacts. Such units are not well adapted to sensitive volume control such as is desired in the output of musical instruments and particularly electronic organs. The sliding contacts are points of wear requiring frequent attention and repair and the variations in output are necessarily of a step-by-step character as distinguished from smoothly continuous variations.

One object of the present invention is to provide volume control free from variable resistance units and their attendant moving contacts, in which the effort required to operate the control is negligibly small and one that is instantly and sensitively responsive and capable of expressing the most delicate musical nuances. This result is accomplished by the use of an amplifier tube in which the potential of a biasing electrode is determined by control of reactance in an electric network carrying alternating current energy of super audio frequency. Energy is supplied to this network by any suitable form of alternating current generator and energy flow is controlled by variable condensers or variable inductances, neither of which require sliding mechanical contacts and in each of which the variations may be smoothly continuous rather than by definite steps. The variable energy flow in the network is made to control through a rectifier current flow in a second circuit carrying only unidirectional current. Biasing potential for a control electrode of the amplifier tube or tubes is obtained from a point in the second circuit whose potential varies with current flow. Preferably the amplifier tube employed is one having a signal electrode and a separate biasing electrode. However, it is possible to provide connections by which a single electrode is used for both purposes. The variable reactances by which the volume is controlled may be operated by foot pedals, by manual means or automatically through such means as the perforated roll of a pneumatic player piano or by mechanical device actuated by phonograph mechanism as disclosed in copending application Serial No. 266,494 filed April 7, 1939, by Hokanson and Jones, now Patent No. 2,216,913, October 8, 1940, and application Serial No. 279,846, filed June 19, 1939 by Lannerd, now Patent No. 2,221,977, November 19, 1940.

Other objects and features of the invention will be understood from the accompanying drawings and the following description and claims:

Fig. 1 is a diagram of electrical connections of a preferred form of the invention controlled by operation of a foot pedal and particularly adapted for use with an electronic organ. In this form volume control is obtained by the use of a variable condenser. Fig. 2 is a similar diagram illustrating an alternative system of electrical connections for use with a variable condenser. Fig. 3 is a similar diagram showing a form of the invention in which volume control is obtained by the use of a variable inductance. Fig. 4 is a side view of a pedal operated variable inductance unit which may be used with the invention. Fig. 5 is an elevational end view of the same. Fig. 6 is a similar view with parts in a different position. Fig. 7 is an elevational side view of a different form of variable inductance unit.

In the form of the invention shown by way of illustration in Fig. 1, there is provided a source of alternating current potential preferably in the form of an oscillator of any well known type indicated in the drawing by the legend "Oscillator." The frequency of oscillation is adjusted considerably above the audio frequency band. One terminal of the oscillator is grounded at G1 and the opposite terminal is connected to a condenser plate 10 having a second condenser plate 11 in opposed relation thereto. A third condenser plate 12 is mounted on and insulated from a foot pedal 13 and may be moved by operation of said pedal between the plates 10 and 11. The plate 12 is grounded at G2. Plate 11 is connected through a blocking condenser 14 to the anode 15 of a rectifier tube 16, the cathode 17 of which is grounded at G3. By this means, as long as the condenser plate 12 is in the upraised position shown in the drawing, an alternating potential difference is created between the anode 15 and cathode 17 of the tube 16. As the foot pedal is pressed downwardly to bring the condenser plate 12 between the condenser plates 10 and 11, a portion of the area of the plate 11 is shielded from the plate 10 and a portion of the energy output of the oscillator is by-passed to ground through the ground connection G2. The amplitude of the potential difference impressed on the anode and cathode of tube 16 varies in accordance with the amount of such by-passed energy.

The anode 15 is connected to a ground connection G4 through a resistance 18 and to a ground connection G5 through a resistance 19 and condenser 20. These connections form a direct current circuit in which current flows during the half cycles of the alternating voltage in which the anode 15 is positive with respect to the cathode 17. The value of the resistances 18 and 19 and the condenser 20 are so chosen as to form a filter which translates the pulsating rectified electromotive force in this circuit into a fairly uniform direct potential. The magnitude of said potential is obviously responsive to the varying amplitude of the potential impressed on the plate 15 and this in turn is responsive to the position of the condenser plate 12.

An amplifier tube 21 is provided with the usual cathode 22 which may be directly or indirectly heated, with the usual signal grid 23, anode 24, suppressor grid 25 and screen grids 26. Between the screen grids 26 there is interposed a second control electrode 27 connected to a point in the direct current network between the resistance 19 and condenser 20. The signal grid 23 is connected through a resistance 28 to ground connection G6. The cathode 22 is self-biased by means of resistance 29 and condenser 30 in a well known manner. The signal grid 23 is also coupled through a blocking condenser 31 to a conductor 32 receiving audio frequency input from an electronic organ, a phonograph pickup, a microphone or any other suitable source of signal energy. The screen grids 26 and anode 24 are connected by conductors 33 and 34 respectively to any suitable source of operating potential, the usual plate resistance 37 being inserted between the anode and conductor 34. The anode 24 is also connected through a condenser 35 to a condenser 36 leading to suitable units for further amplification or to a speaker unit as desired.

The tube 21 operates as an amplifier of the signal voltage impressed on control grid 23 in a well known manner. The amplification ratio or "gain" of the tube may, however, be increased or decreased by variation in the potential of the control electrode 27. If said potential is sufficiently negative the tube may be blocked entirely and no output signal results. The potential of control electrode 27 is determined by the potential of the point in the direct current network to which it is connected and this is in turn dependent upon the position of foot pedal 13 and plate 12 as previously described. Preferably the elements of the circuits are so proportioned that, when foot pedal 13 is in its uppermost position, the voltage of electrode 27 is sufficiently negative to prevent amplification. As the foot pedal is depressed the potential of electrode 27 is correspondingly varied to permit amplification through any desired range. Thus the volume output of the tube 21 is instantly responsive to operation of the foot pedal. No variable resistances are used and the volume variations may be smoothly continuous.

In Fig. 2 there is illustrated a different arrangement of electrical circuits by means of which the invention may be practiced. In this figure an oscillator, indicated by name, has one terminal connected to ground at G8 and its opposite terminal connected to a condenser plate 50 mounted on and insulated from a foot pedal 51. Said oscillator is a source of alternating current energy of super audio frequency. In its uppermost position the condenser plate 50 is opposed by a condenser plate 52 grounded at G9. In its lowermost position the condenser plate 50 is opposed by a condenser plate 53 connected through a blocking condenser 54 to the cathode 55 of a rectifier tube 56. In intermediate positions of the foot pedal 51, varying proportions of the high frequency energy from the oscillator are shunted to ground through plate 52 or to the rectifier 56. The amplitude of the high frequency potential variations impressed on the cathode 55 obviously vary with the position of said foot pedal.

An amplifier tube 57 of the same type as the tube 21 is provided with a cathode 58, anode 59, signal grid 60, suppressor grid 61 and screen grids 62 connected in a conventional manner. The signal grid 60 is connected to ground at G10 through a resistance 63 and is connected through a condenser 64 to a conductor 65 receiving signal energy from any suitable source. The anode 59 is connected through a condenser 66 to a conductor 67 leading to an instrument amplifier or to a speaker as desired. A control grid 68 is interposed between the screen grids 62 and is connected through resistances 69 and 70 to the anode 71 of the tube 56 and to the negative terminal of the battery 72. The positive terminal of said battery is connected to ground. The cathode 58 is self-biased in a well known manner by resistance 74 and condenser 75 connected to ground.

By the connections just described, the battery 72 may maintain the potential of the control electrode 68 sufficiently below that of the cathode 58 to prevent amplification in the tube 57 as long as the foot pedal 51 is in its upper position and no rectified energy is received from the tube 56. When the foot pedal 51 is pressed downwardly however, a portion of the high frequency energy of the oscillator is impressed on the cathode of tube 56 which is thus alternately above and below the potential of the anode 71. During the half cycles in which the cathode potential is less than that of the anode, a direct current flows from cathode 55 through resistance 70 to anode 71. The direction of this current through resistance 70 is such as to increase the potential of the upper terminal of said resistance (referring to the drawings) in opposition to the action of the battery 72. Thus the potential of control electrode 68 is also increased. The resistance 69 and condenser 73 act as a filter to impress on the electrode 68 a substantially uniform voltage in response to the pulsating direct current through the resistance 70.

The control of the potential of electrode 68 provides a volume control for the tube 57 which is instantly responsive from a complete blocking of the tube to full volume by operation of the pedal 51. Again, no variable resistances are used and the volume control is smoothly continuous.

In Fig. 3 there is shown a third alternative form of the apparatus by means of which the invention may be practiced. In this form of the invention parts having reference numbers in the one hundred series have the same construction and functions as correspondingly numbered parts in the unit series in Fig. 1. An oscillator indicated by name has one terminal grounded at G12 and the opposite terminal connected to an induction coil 80, the opposite terminal of which is grounded at G13. A second induction coil 81 is inductively coupled to the coil 80 and has its terminals connected respectively to the condenser 114 and to ground at G14. A foot pedal 82 has

mounted thereon a plate 83 grounded at G15 and formed of magnetizable material adapted to change the inductive coupling of coils 80 and 81 as it is moved between said coils by operation of the pedal 82.

In the operation of this form of the apparatus, alternating current energy from the oscillator passes through the coil 80 and varying amounts of said energy are passed to the coil 81 and to the rectifier 116, depending upon the position of the foot pedal 82 and the plate 83. The remainder of the apparatus operates in the same manner as the apparatus of Fig. 1 to control the gain of the tube 121 in accordance with variations in energy received by the rectifier 116. In this case the control is accomplished by variations in inductive reactance as distinguished from capacitative reactance as shown in Fig. 1. In each case there are no variable resistances with sliding contacts.

In Figs. 4, 5 and 6 there is illustrated a variable inductance unit which may be substituted for the capacity unit 50—53 of Fig. 2. A pair of induction coils 180 and 181 are provided and may be connected to the oscillator and condenser 54 of Fig. 2 in the same manner that coils 80 and 81 are connected to the oscillator and condenser 114 of Fig. 3. One of said coils is mounted on a fixed support 84 and the second of said coils is mounted on suitable trunnions journaled on said support. A gear 85 mounted on one of said trunnions is engaged by a gear segment 86 mounted on a foot pedal 87 and serves to rotate the coil in the direction of the arrows in Fig. 4 as the foot pedal is depressed. When the foot pedal is in its upper position, the axes of the coils are at a right angle to each other as shown in Figs. 4 and 5 and the inductive coupling therebetween is a minimum. By operation of the foot pedal, the coils gradually approach a coaxial position shown in Fig. 6 and the magnetic coupling between them is increased. The variation in magnetic coupling is used to actuate the volume control apparatus of Fig. 2 in the same manner as the variation in coupling between the condenser plates 50 and 53.

Fig. 7 shows another variable induction unit which may be similarly used with the circuits of Fig. 2. In this arrangement a coil 281 is mounted on a fixed support 88 and a coil 280 is mounted on an arm 89 pivotally supported on a bracket 90. A foot pedal 91 is provided with a finger 92 engaging the arm 89. In this arrangement the inductive coupling between the coils 280 and 281 is a minimum when the parts are in the position of Fig. 7. Depression of the pedal 91 moves the coil 280 toward the coil 281 and increases the inductive coupling. Preferably the coil 280 is made sufficiently small so that it may assume a position within the coil 281, as shown by broken lines, when the pedal is fully depressed. In this position inductive coupling is a maximum. The coils 280 and 281 may be connected in the circuit of Fig. 2 in the same manner as described for the coils 180 and 181 and when so connected obviously operate in the same manner.

The method of practicing the invention has been described in connection with several forms of apparatus suitable for the purpose. Obviously, variations in the apparatus may be made without departing from the scope thereof as defined by the appended claims.

The invention claimed is:

1. Apparatus for volume control of an electron discharge tube amplifier including a generator of alternating electromotive force of super audio frequency, a rectifier operated by energy derived from said generator and producing a direct electromotive force, connections between said rectifier and a control electrode of said tube by means of which the potential of said electrode is varied in response to variations in said direct electromotive force, said potential variations controlling the gain of said tube, a three element capacitance unit having at least one movable element, a circuit including said generator, said rectifier and two of the elements of said capacitance unit, and a shunt circuit including the third element of said capacitance unit arranged to shunt more or less of the output of said generator around said rectifier as said movable element is moved, whereby said direct electromotive force is varied in response to movement of said movable element.

2. Apparatus for volume control of an electron discharge tube amplifier including a generator of alternating electromotive force of super audio frequency, a rectifier operated by energy derived from said generator and producing a direct electromotive force, connections between said rectifier and a control electrode of said tube by means of which the potential of said electrode is varied in response to variations in said direct electromotive force, said potential variations controlling the gain of said tube, a three element capacitance unit having a pair of fixed outer plates and a movable intermediate plate, a circuit including said generator, said rectifier and the outer plates of said capacitance unit, and a shunt circuit including the movable plate of said capacitance unit arranged to shunt more or less of the output of said generator around said rectifier as said movable plate is moved between said fixed plates, whereby said direct electromotive force is varied in response to movement of said movable plate.

GERALD G. SMITH.